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A STUDY OF HERBAGE AND SEED PRODUCTION
OF LUCERNE (MEDICAGO SATIVA L.) UNDER
DIFFERENT PLANT SPACING AND CUTTING
TREATMENTS

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ABSTRACT

The present study on lucerne cv. "Wairau" was carried out in two separate trials, - a herbage and seed production trial and a seed development trial. The purpose of the first part was to investigate the effect of cutting and spacing on herbage production and subsequently on seed yield. In the second part, changes in seed weight, moisture content, and viability during various stages of seed development were studied.

Results from the herbage study suggested that fresh and dry herbage yield were both affected more by plant spacing than by the height of cutting and the stage of plant development at the time of cutting. Close plant spacings resulted in higher yields of both dry matter per unit area and dry matter percentage than wide spacings. The study showed that lucerne plants in first year crops should be grown at a plant density higher than 44 plants per sq. metre and up to 100 plants per sq. metre to reach maximal herbage yield per unit area. Early cutting and high cutting gave a significantly lower herbage yield than when plants were cut late and cut at a low stubble height.

Cutting and spacing treatments had a profound influence on seed yield per unit area. Seed production in lucerne, unlike herbage production, depended mainly on seed yield per plant rather than on the number of plants per unit area. Both cutting and spacing treatments affected seed yield per plant by altering the number of reproductive shoots, number of flowers per plant and the percentage of seed set. Plants grown at wide spacings produced more branches and flowers per plant and also exhibited a higher percentage seed set, thereby producing high numbers of seeds per plant. To obtain high seed yield in this variety of lucerne, plants should be grown at a plant density of approximately

11-25 plants per sq. metre. Cutting lucerne plants prior to allowing them to seed resulted in a weakening of the plants, severely depressed reproductive potential, delayed flowering time and subsequently affected flower production and percentage seed set. Lucerne plants should therefore not be cut at all in the year of plant establishment if high seed yields are expected.

Seed development followed three distinct phases. The growth stage involved the period up to 22 days after pollination. At the end of the stage, 3% of seeds were germinable. The food reserve accumulation stage occupied the period from 23-40 days after pollination. Maximum seed dry weight was attained after 40 days at a seed moisture content of 58%. The ripening stage occupied the period from 41-75 days after pollination. At the end of this stage seed moisture content was approximately 14% and subsequently 6% of hard seed were found when seeds were tested immediately after harvest. Storage results in this trial indicated that immature seed tended to lose germination capacity more rapidly than mature seed. To ensure high seed quality in lucerne it was essential that seed be harvested after maturity.

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1. INTRODUCTION

Lucerne (Medicago sativa L.) is an important forage crop in many farming systems. As suggested by Ellison (1958) lucerne has a number of general merits in agriculture such as building and restoring soil fertility and as a high quality material for animal feeding. Other satisfactory aspects of lucerne, include its capability of producing higher (20-100%) dry matter yield than other pasture crops particularly under drought conditions; providing high quality hay at a critical time of the year (Janson 1974) and also richness of protein which is well recognized (Woodman et al 1933). This species is also known to outlast pasture and is economical irrespective of sowing costs (Janson 1974). It has also been reported by a number of workers (Keoghan 1967, Langer 1972) that good recovery after being cut or grazed is one of the outstanding characteristics of lucerne. All these characteristics render it suitable to fit well into the complete agricultural system where cutting or grazing is involved. One of the main problems facing lucerne growers is the continual supply of sufficient high quality seed for sowing. Seed production in this crop has always been thought of as relatively low and unreliable, varying from place to place and from season to season. Doull (1967) stated that while in many countries lucerne seed production yields in the range from 112-168 kg/ha. are common, exceptions occur in some areas with seed yields being as high as 2422 kg/ha. A great variation in lucerne seed yield may occur in different years as reported by Zaleski (1963). He quoted an example in Great Britain where seed yield of lucerne grown on the same site was recorded at 101 kg/ha. in one year, whereas it was 482 kg/ha. in the following year. These figures suggest that seed production in

lucerne varies greatly depending on environmental conditions. A lack of sufficient information about crop management could be another factor governing the success of growing lucerne for seed. Initial research into ways of increasing the seed yield of lucerne began as early as 1935, but there is still a great need for more study.

Plant spacing plays an important role in seed crop production since yield per unit area is a function of seed yield per plant and number of plants in a certain area. It is possible that different plant spacings could be one of the factors governing both lucerne herbage and seed yield. As knowledge of sowing patterns with lucerne is somewhat inconsistent and little guidance was obtained from previous work, it was decided to investigate the effect of square planting lucerne at different spacings to determine the effect of such treatments on seed yield.

Since lucerne is a perennial forage crop, plants can be grown either for forage or seed production. In normal practice it is common for farmers to cut lucerne for hay and then harvest for seed later in the same season. As the effect of previous cutting on the plant and on seed production is not clearly documented it was decided to investigate the effects of cutting on subsequent seed yield in the seeding year.

This study is presented in two sections; a herbage and seed production trial and a seed development trial. The purpose of the herbage and seed production trial was to investigate the effect of cutting lucerne plants at the young stage of plant development (bud stage, 12 weeks after sowing) and at a more mature stage (full flowering stage, 16 weeks after sowing) on herbage yield and seed production. In addition the

effect of height of cutting on herbage regrowth at different stages of plant development was also investigated. The effect of cutting on subsequent seed production was also studied using plants grown at ⁴ different plant density spacings. Various components which might be expected to have a bearing on seed production and yield were also examined.

In any seed crop production programme the quality of seed needs to be considered along with the amount of seed harvested. To assess this aspect a seed development trial was carried out to monitor changes in physiological components and seed quality in relation to seed age. The onset of hard seed formation and the effect of harvesting time and storage treatment on hard seed percentage was also studied.

2. MATERIALS AND METHODS

A. HERBAGE AND SEED PRODUCTION

1. Experimental Site and Land Preparation

Lucerne cv Wairau was used in this study. The seed was inoculated with certified lucerne rhizobium strain supplied by Wrightson NMA Ltd. immediately prior to sowing in order to ensure effective nodulation.

The 1000 sq. metres trial site was located at Massey University on Tokomaru silt loam. The previous crop grown in this area was fodder radish. The land was ploughed and rotary hoed in August 1976. Fertiliser (30% Pottassic Superphosphate) was broadcast at a rate of 251 kg/ha. before sowing.

2. Experimental Design

The layout of the experiment was a systematic design with 4 spacings, 5 cutting treatments and 4 replicates. It is necessary to explain why the systematic arrangement was used in this trial. As shown in Figure 1, the plot was parallel to the hill side and it became obvious that one side of the area was drier than the other. To minimize the moisture gradient effect, the spacing treatment was arranged across the field.

Each replicate of each spacing was divided into 5 subplots for cutting treatments. These cutting treatments involved an uncut control, two cutting times (bud stage and full bloom) and two cutting heights (7.5 cm. and 1.0 cm.). Again the systematic arrangement seemed to be most practical.

The size of the plots varied with different plant spacings, the object being to obtain similar total plants in each plot. Having each spacing in one block was therefore of great practical value.

FIGURE 1 EXPERIMENTAL LAY-OUT

PLOTS A, B, C, D - SEED DEVELOPMENT TRIAL

a, b, c, d - SPACINGS 10x10, 15x15, 20x20, 30x30 CM

1, 2, 3, 4 - REPLICATES

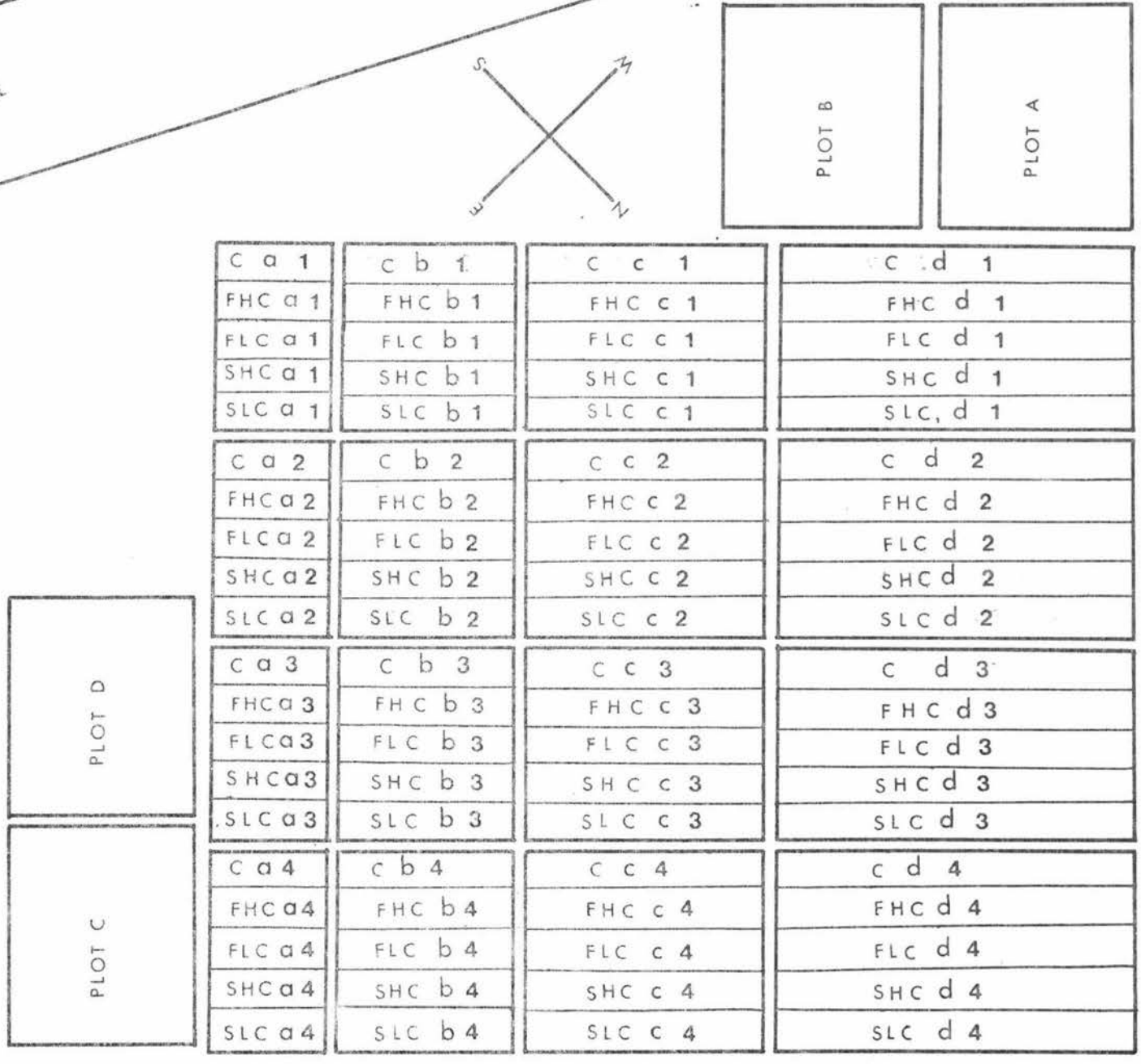
C - CONTROL (UNCUT)

FHC - CUT AT 7.5 CM ABOVE THE GROUND AT BUD STAGE

FLC - CUT AT GROUND LEVEL AT BUD STAGE

SHC - CUT AT 7.5 CM ABOVE THE GROUND AT FULL FLOWERING STAGE

SLC - CUT AT GROUND LEVEL AT FULL FLOWERING STAGE



In addition to this, the use of 4 replicates assisted in reducing environmental differences among subplots. Apart from the moisture effect, the trial area seemed to show uniformity when observing the growth of the previous crop in this area. Therefore the use of a systematic arrangement in this experiment was considered to be satisfactory especially in connection with the convenience of crop management.

3. Sowing Procedure

Square plantings 10x10 cm., 15x15 cm., 20x20 cm. and 30x30 cm. were employed in this study. These spacings resulted in approximately 100, 44, 25 and 11 plants per sq. metre respectively. Strings marked at the required spacing intervals were prepared as a sowing guide for different spacings. Seeds were sown by hand on September, 28, 1976, approximately 5 seeds per hold being sown at a depth of about 1 cm. Sowing was completed within 1 day by 7 planters. A thermohydrograph was used to record changes in temperature and relative humidity in the field during the growing season. (Plates 1 and 2).

PLATE 1.

SOWING THE SEED



PLATE 2.

A THERMOHYDROGRAPH FOR RECORDING AIR RELATIVE
HUMIDITY AND TEMPERATURE DURING THE GROWING SEASON



4. Seedling Emergence

Most seedlings emerged 8 days after sowing. The soil temperature recorded during seedling emergence ranged from 4°C - 19°C.

5. Thinning

In the study of population density effects the number of plants grown in a certain area is considered to be important. The lucerne seedlings emerged in each position were thinned to a single plant using a pair of sharp scissors to cut below the growing point of the stem. In the case of missing plants, these were replaced by transplanting seedlings of the same age from a small seedling nursery area nearby. Thinning and transplanting were completed within 8 weeks of sowing. During dry weather the area was irrigated for 3 hours prior to transplanting. In the 10x10 cm. plant spacing it was impossible to work within the plot without damaging the plants, and causing severe soil compaction. To overcome this problem a wooden board with short end supports was used for sitting on when doing the weeding, thinning and transplanting. (Plate 3).

6. Weeding

The predominant weeds present in the trial were: Hawkbit (Leontodon taraxacoides), Sowthistle (Sonchus oleraceus), White clover (Trifolium repens), Daisy (Bellis perennis), Toadrush (Juncus bufonius), and Californianthistle (Cirsium arvense).

Weeding was done twice, the first before thinning and the second after the first cut. There were two methods of weed

PLATE 3.

A WOODEN BOARD WITH SHORT END SUPPORTS USED FOR THINNING IN THE 15X15 CM. AND 10X10 CM. SPACING

PLATE 4.

THE STUBBLE OF LOW CUT AND HIGH CUT



control employed - hand hoeing and herbicide. The post emergence herbicide (24DB) was sprayed at a rate of 2.1 litres/ha. Unfortunately this herbicide while it did not affect the lucerne was found to be effective only for some of the weed species present. The rest were removed by hand hoeing.

7. Cutting

There were five cutting treatments involving a time of cutting and cutting height combination. Time of cutting occurred 12 weeks after sowing (first cut) or 16 weeks after sowing (second cut). The time of cutting was considered in relation to the stage of plant development, the first cut being timed to coincide with the appearance of green flowering buds and the second cut being delayed until the full bloom stage. At each time cuts were carried out at two different heights, i.e. ground level (low cut) and 7.5 cm. above the ground (high cut). (Plate 4). Therefore the five cutting treatments were: (1) uncut (control), (2) first high cut (FHC), (3) first low cut (FLC), (4) second high cut (SHC) and (5) second low cut (SLC).

A hand sickle was used to cut the plants from an area of 3.24 sq. metres, 4.84 sq. metres, 5.76 sq. metres and 9.99 sq. metres in the 10x10 cm., 15x15 cm., 20x20 cm. and 30x30 cm. spacings respectively. This allowed equal numbers of plants to be cut in each treatment. Two rows of plants were left at the edge of each subplot as guard rows. After cutting, plants in all subplots were allowed to run to seed.

8. Insecticide

Lorsban 40 EC¹ at a rate of 2.1 litres per hectare in 40 gallons of water was applied to control aphids and other

¹ Lorsban 40 EC - 400 gm./litre chlorpyrifos formulated as an emulsifiable concentrate.

harmful insects at the bud stage. At the flowering stage, Aldrex² was used at the same rate.

9. Beehive

Leaf cutter bees (Megachile sp.) were introduced to the trial site for use as pollinating agents. A shelter for the hive was made and placed at one central end of the field at the onset of blooming of the crop. (Plate 5).

10. Harvesting

Plants from each plot were hand harvested when most of the pods became black. The seed was at this stage at least 70 days after pollination. A hand sickle was used to cut five marked plants in each treatment at ground level. The cut portion from each plant was kept separately in a paper bag. After the five marked plants had been removed, the rest of the plants were bulk harvested for each subplot.

11. Laboratory Testing

a. Herbage yield. The green material from each cut of every treatment was weighed and then oven dried at 105°C for 24 hours. Fresh weight and dry weight were determined.

b. Seed yield components. The number of total shoots, reproductive shoots, clusters per plant, pods per cluster, seeds per pod and seeds per plant were determined from five marked single plants in each treatment. The seeds from each plant were threshed with a hand operated rubber thresher and then cleaned. Pure seeds were weighed, and used for the estimation of moisture content and germination at each harvesting time. Therefore the yield per plant was obtained from the average of seeds from five plants in each treatment.

2 Aldrex - 20% w/r (2 lbs/gallon) of aldrin.

PLATE 5.

A SHELTER FOR THE BEEHIVE



c. Seed yield per area. Clusters from bulk harvested plants were removed by hand and air dried in a glasshouse at a temperature of about 30° - 35° C for 1 week. Seeds were then hand threshed, cleaned, weighed and yield per hectare calculated. Seed moisture content and 1000 seed weight were also determined. The value of yield per unit area and seed weight from different moisture levels were converted for comparative purposes to a common value of moisture content (8%). Seeds from each treatment were stored separately in paper bags in the laboratory for a period of 3 months. The moisture content of each seed lot was determined by the air oven method at 103° C for 24 hours.

d. Germination test. Seeds from each treatment were tested for germination at intervals of 0, 6 and 12 weeks after harvest. Germination tests were carried out after different periods of storage because it was found that the germination percentage of freshly harvested seed was very low owing to the presence of hard seed. It was expected that the percentage of hard seed would decrease with increased storage period. Seeds obtained from each of the 5 cutting treatments were tested in the same way for the germination. Four replicates of 50 seeds were germinated on top of paper at a temperature of 20° C. Seeds were prechilled at 5° C for 3 days before the actual germination test to eliminate post harvest dormancy. The first count was made at 4 days and the final count at the end of the 10 day test period.

12. Statistical Analysis

Three way analysis was used for analysing the data. The least significant difference method was used to identify statistical differences among the results from different treatments and replicates.

B. SEED DEVELOPMENT EXPERIMENT

1. Experimental Site

The same seed line of lucerne was used in this experiment. The procedure of land preparation, sowing, weeding, thinning and transplanting was exactly the same for the herbage and seed production trial. (Section A). Plants were grown in four plots each of 6x5 sq. metres. A plant spacing of 30x30 cm. was used for this trial.

2. Pollination Cage Preparation

Four large nylon mesh nets each with dimensions of 5.35 x 2.75 x 0.65 m. were prepared to cover the plants before flowering. (Plate 6). Each net was designed to cover an area of 150 plants. Iron frames were used to support each net. Flower buds were tagged before putting the net over the plants. During this period it was necessary to check for the presence of bees in each cage as this was a critical period for excluding the bees. If any bees were found, all tagged flower heads were discarded from the trial, and a fresh crop of flower buds were tagged.

3. Pollination

Two different methods were employed for obtaining insect pollination. The first method tried involved putting about 60 honey bees into each cage and allowing them to pollinate the crop from 1030 hours until 1900 hours. As a result of this method only a very small number of flowers were pollinated since the bees became agitated at being confined in the cages and tended to attempt to escape rather than pollinate lucerne flowers. The other method, which was more successful for lucerne pollination was to remove the cage from 0930 hours until 2000 hours on a fine sunny day and when there were plenty

PLATE 6.

A POLLINATING CAGE USED IN SEED DEVELOPMENT
EXPERIMENT



of blooming flowers and allow normal insect activity to occur. The cage was then replaced on the plots.

Since there was insufficient seed set as a result of bee activity on any one day, the latter pollination procedure was repeated in each plot in order to obtain sufficient quantities of seed. The date of each day on which bees were allowed access to caged plants was recorded.

4. Harvesting

In the seed development study, seeds were hand harvested at various stages of maturity ranging from 10 days up to 75 days after pollination. Previous attempts had been made to harvest seed at 2 day intervals starting from 10 days after pollination through until seed ripeness. Unfortunately the seeds were not found to be mature until 40 days after pollination. At this stage, there were insufficient seeds left for sampling. Therefore the time interval was altered as follows: 10, 13, 16, 19, 22, 25, 28, 31, 34, 37, 40, 49, 55 and 75 days after pollination.

5. Laboratory Testing

At each harvest, pods were divided into two portions. One portion was immediately used for the estimation of fresh weight, dry weight, moisture content, total viability and seed germination while the other portion was stored in the laboratory for 3 months and then used to estimate the latter parameter. Seeds were removed from each portion of pods by hand to avoid any mechanical damage.

Two hundred seeds were used for the determination of fresh weight and dry weight. The air oven method (103°C for 24 hours) was employed to obtain the value of moisture content

of seeds at each harvest.

Four lots of fifty seeds were germinated on top of paper at 20°C. Seeds from each harvest were prechilled at 5°C for 3 days before the actual germination test. This was thought desirable to overcome post harvest dormancy. Seedlings were removed at intervals (4, 7, 14, 21 and 30 days) during the germination test period.

The tetrazolium test technique was employed to evaluate the total viability of 100 seeds of each seed age.

After storage in the laboratory for 3 months, seeds were removed from the pods by hand. Pure seeds were used to determine germinability by the same procedures previously used for freshly harvested seed.

3. HERBAGE YIELD AND SEED CROP PRODUCTION

INTRODUCTION

The lucerne plant has long been used for both herbage and seed production. Willard (1951) stated that it is common farming practice for the lucerne plant to be cut at least once up to several times for hay and then for seed production in the same year. Apart from cutting for hay, the lucerne plant can also be used for grazing. With grazing, the height of the stubble varies greatly with the type of animal. When using machines for cutting, the stubble height is determined by the construction and action of the moving machine (Ridgman 1960).

Since lucerne is a perennial forage legume, it is particularly important to maintain good development of the plant after each cut if a high seed yield is required later in the season. It is often said that lucerne is one of the best legume species in terms of good recovery after cutting. However, in some cases it has also been reported that the lucerne plant can be damaged by a severe cut. Most workers agree that any cutting system affects the subsequent regrowth of the lucerne plant by affecting the production of shoots from the crown, since the storage of food material in the root is depleted by removing the tops. Abu-Shakra et al (1977) noted that the number of stems per plant was greatly reduced when 3-4 forage harvests were practiced before starting the seed crop. This reduction was much less severe when only 1-2 forage crops were harvested. However, the findings by Willard et al (1934) as quoted by Willard (1951) oppose this view by saying that the height of cutting is not important in affecting recovery after cutting as the new growth of the lucerne plant originates from the crown buds at or below ground level.

Most plant species have the ability to change their size and form in response to changing environmental conditions such as changes in plant density. Such plant density differences can also influence both herbage and seed yield. There are a number of researchers attempting to investigate the optimum plant density necessary to give optimum herbage and seed yields for certain species or cultivars.

Principally, the amount and quality of herbage and seed removed under different cutting treatments and at different plant densities should be considered along with the subsequent recovery potential of the plant. The following chapter involves a review of literature, results and discussion on the effects of time of cutting, height of cutting and plant density on herbage production (Section A) and on subsequent seed yield and seed yield components (Section B).

A. HERBAGE YIELD

LITERATURE REVIEW

1. Nature of Plant Growth and the Effect of Cutting on Herbage yield

To manage the lucerne crop successfully, it is necessary that its growth pattern be well understood. Janson (1974) suggests that the growing point of the lucerne plant, which is responsible for the growth of new stems and shoots, is normally found at the shoot apex which develops from the crown region. According to Leach (1968) the word "crown" includes the extreme bases (less than 0.5 cm. in length) of the discrete stems, and "stubble" refers to the basal 5 cm. of the discrete stems. He also suggests that the rate of growing point growth declines as the plant starts flowering. As a compensation for

this new crown buds occur. He stresses that the growing point needs to be physiologically mature before the development of basal shoots can take place. So lucerne plants will produce no top growth during the dormant stage. Cowett and Sprague (1962) showed that the development of new buds and shoots at the crown of the lucerne plant depends on both environmental and plant management factors such as; soil moisture, light intensity, air temperature, mineral nutrient, cutting height, plant maturity and stand density. Furthermore it is suggested by Willard (1951) that favourable conditions which result in high levels of carbohydrate or high root reserves are responsible for crown bud initiation and development. Investigation by Singh and Minch (1974) also contributes to this aspect. They studied the morphological development of the regrowth in lucerne plants and indicated that the regrowth patterns of uncut and cut lucerne were different. The stems of uncut lucerne arise from the base of the stem that formed the first growth. In the cut plant the regrowth stems are produced from the stubble of the most recently harvested stems. In addition to this, Smith and Soberalske (1975) examined the regrowth of lucerne after cutting and reported that about 26.6% of the new shoots were produced from the region of 5-12 cm. stubble stems.

It is widely accepted amongst workers that both leaf quantity and quality contribute to a large extent to growth rate and subsequent crop yields. The understanding of leaf efficiency could be used as a guide to maximise crop yield. Theoretically any cut of sufficient height to retain an appropriate LAI would result in higher growth rate. A clear statement is given by Brown et al (1966) that in forage production, particularly where grazing or cutting is involved,

the stubble achieving optimum light interception should be considered along with the beneficial or parasitic value of the remaining leaves. Therefore leaf age and efficiency are of prime importance in increasing forage yield. In relation to this Leach (1968) showed that differences in herbage yield at different cutting intensities involving retaining or removing the stubble was due to differences in leaf area. Thus the maintenance of a reasonable top growth necessary to keep the lucerne plant in good condition is the primary fact to be considered in farm practice.

A variation of stubble height ranging from ground level up to 30 cm. is normally found in many cutting experiments. Cowett and Sprague (1962) found that leaving a stubble height of 7.5 cm. gave a significantly higher herbage yield of regrowth material than cutting at 2.5 cm. They further explained that the higher stubble height contributed greatly to the increased production of buds and stems of the second crop.

Ridgman (1960) claimed that cutting at ground level or leaving a stubble too high were disadvantageous to herbage yield. As a result of cutting too low, some plants were even killed, and others were affected by greatly reduced yield capacity. When leaving the stubble too high, low yield was presumably due to less material being removed from the plant (at the time of cutting). In addition, work by Hildebrand and Harrison (1939) indicated that there was a reduction in yield when leaving a stubble height of 30 cm. due to plant maturity and slow growth of the tops below the cutting level. These results suggest there might be an optimum height of stubble to give a maximum yield depending on the regrowth period between cuts. For instance Ridgman (1960) showed that when lucerne

plants were left for regrowth after cutting for 7 months, cutting at 5 cm. and 10 cm. and the uncut control, gave a higher yield than cutting at ground level. But in the situation where lucerne plants were cut more often, leaving a sufficient stubble height favoured herbage production. Hildebrand and Harrison (1939) studied the regrowth of lucerne after cutting at heights of 2.5 cm., 7.5 cm., 15 cm. and 22.5 cm., each treatment being cut weekly, biweekly, or monthly. Their results indicated that cuts at the 2.5 cm. level gave significantly lower yield than the other treatments and also suggested that the optimum height for good recovery of the plant under this situation was 15 cm.

It is of interest that cutting height may or may not influence herbage yield, depending on the height of the plant at the time of cutting. Birch et al (1976) found that a cutting height of 0-8 cm. above the ground level gave a similar herbage yield as a cut at 24 cm. height. On the otherhand, herbage yield was increased when the stubble height was cut at 12 cm. This might be due to the fact that recovery of the young plant (12 cm.) is poorer than that of older plants (24 cm.) when cutting at a very low level. However, in reviewing the effect of cutting height on herbage yield of lucerne Keoghan (1967), reached the conclusion that height of cutting seemed to be unimportant from a practical point of view except when frequent cutting was involved.

Herbage yield is a result of the accumulation of growth material on the plant. Consequently, the yield of dry matter depends largely on the stage of plant development (Willard 1951). A number of workers have conducted experiments by cutting lucerne at different stages of plant maturity namely; vegetative stage,

bud stage, early flowering, full flowering and past bloom stages. Unfortunately, the results obtained by various workers are inconsistent. Cowett and Sprague (1962) and Leach (1963) have agreed that cutting more mature plants (late flowering and past bloom stage) results in a higher dry weight and higher numbers of stems than cutting at the early bud stage or early bloom stage. This might be due to the fact that mature plants contain a higher storage level of nutritive tissue which is available for successive growth. Work by Petrovski (1974) is supporting evidence. He reported that an average herbage yield of lucerne of 11.35 ton/ha. was achieved when cutting was carried out at the early flowering stage whereas the lowest yield of 8.27 ton/ha. was obtained when cutting at the bud formation stage. The finding of Birch et al (1976) agrees with this result. In contrast to this Grigoryan et al (1977) found that the highest yield of hay was obtained when cutting occurred before bud formation. However, Cokoljic et al (1977) did not find any difference in herbage yield when cutting was carried out at the vegetative and bud stages. Since the maximum herbage yield of lucerne grown in different regions (determined by different workers) is obtained by cutting plants at varying stages of maturity it is reasonable to assume that environmental conditions lead to different rates of growth.

As the digestibility of the lucerne plants plays an important role in feeding quality, it is necessary when cutting lucerne for hay that the quality should be considered simultaneously with the quantity gained from each cut. Most workers (Woodman et al (1933), Crowder et al (1960), Weir et al (1960), Birch et al (1976) and Grigoryan et al (1977)) agree

that the percentage of crude protein decreases while the crude fibre and dry matter increases as the plant progresses to maturity. Grigoryan et al (1977) reported that CP contents of 20.75%, 18.3% and 16.3% were obtained when lucerne plants were cut before the bud stage, during the bud stage and at the early flowering stage respectively. Also interesting in this respect is work by Weir et al (1960) who considered the average annual yield of lucerne together with digestible protein and total digestible nutrients. They found that the highest yield of total digestible nutrients was obtained by cutting at the 1/10 bloom stage and that the highest yield of digestible protein was obtained in cuts made at the bloom stage. Nevertheless, Winch et al (1970) indicated that the highest dry matter in conjunction with high levels of in vitro DM digestibility and crude protein were obtained when lucerne was cut at the medium bud stage of development compared to cutting at the early bloom stage. These results suggest that cutting lucerne plants for hay during the bud stage and early bloom stage should be ideal for farm practice

2. Effect of Plant Density on Herbage Yield

The terms "crop yield" or "herbage yield" are used to refer to either yield per plant or yield per unit area. From an agronomic stand point, it is preferable to achieve maximum crop yield per unit area rather than yield per plant. Generally, yield per unit area depends largely on plant population which is determined by the number of plants in that area and the average yield of each plant. Consequently, a decrease in either the number of plants or yield per plant will be reflected in a lower crop yield. Cowett and Sprague (1962) pointed out that changes in stand density alter the

microenvironment in terms of moisture, light temperature and nutrient availability resulting in different yields. Likewise low stand density contributed to less yield per unit area but a greater number of stems per plant.

In the investigation of vegetative growth of plants there is agreement in work by Donald (1951) on subterranean clover, Aspinall and Milthorpe (1959) on barley and white persicaria and Holliday (1960) on fodder beet and kale that the dry matter of these crops increases with increasing populations but remains constant at an extremely high population density. In other words there is no reduction in dry matter per unit area even when the plant density is extremely high. As a result of this an asymptotic curve is proposed for vegetative growth by Holliday (1960).

In previous studies carried out by various workers it has been suggested that a dense population is favourable for maximum herbage yield. The early work by Garner and Sanders (1940) showed that dry matter herbage yield of lucerne was 202 kg/ha. higher when sown in narrow rows (9-18 cm.) than in wide rows (24-35 cm.). A similar conclusion has been reached by Cowett and Sprague (1962) who found that in lucerne a plant density of 80 plants per sq. metre gave a significantly higher yield (6400 kg/ha.) than herbage from 10 plants per sq. metre (2600 kg/ha.). However, when plant densities were in a range of 46-240 plants per sq. metre Palmer (1971) did not note any significant difference in lucerne herbage yield. A careful study of the effect of lucerne growth on crop yield at different plant densities by Jarvis (1962) contributes to this aspect. He grew lucerne plants under a square planting system with 8 different spacings. He found that herbage yield was increased with increasing plant

population up to a level of 75 plants per sq. metre. He also noted that there was only a small increase in yield when plant population was increased beyond this point. However, his results did not suggest there was an optimum plant density for maximum herbage yield in lucerne.

An understanding of plant behaviour is important when studying the effects of plant density on crop yield. In relation to this Donald (1951) states that competition between plants of a single species or between different species normally occurs in a plant community. Aspinall and Milthorpe (1959) defined the word "competition" as restriction of plant growth arising from association with other plants. Competition occurs when one individual is sufficiently close to another to modify its environment (either soil or atmospheric) and finally decreases the rate of growth. In addition Donald (1951) classified competition into two groups, inter-plant competition and intra-plant competition. Inter-plant competition occurs between plants, normally at higher population densities. Intra-plant competition always exists among the plant parts of individuals when grown as widely spaced plants or as single plants.

When plant population is expressed in terms of seed sowing rate, differences in herbage yield were not detected when lucerne was sown at various rates from 1.1 to 40 kg/ha. and harvested at the seedling stage or at the 10% flowering stage (Sims (1975), Palmer (1971) and Ballatore et al (1977)). These results imply that maximum herbage yield of lucerne can be obtained under a wide range of population densities. A possible explanation may lie in the fact that, firstly the varieties used might be different as all were unknown except

for the 'Wairau' variety used by Palmer (1971). A second explanation might be that competition amongst plants resulted in high plant mortality. Irrespective of this effect Palmer (1971) observed that the death rate of plants was higher in a dense population than in a sparse population. It is likely that despite initial plant density differences, the number of plants present at harvest tends to have been adjusted by competition to reach a similar plant population density.

Particular interest should be paid to the relationship between plant age and stand density in regard to herbage yield. Palmer (1971) indicated that when lucerne plants were grown at different spacings, equivalent to seeding rates of 0.28 - 4.48 kg/ha., a seeding rate of 0.28 kg/ha. resulted in a significantly lower herbage yield than the other 3 seeding rates (1.12, 2.24 and 4.48 kg/ha.) in the first year. However in the second year herbage yield from all seeding rates was similar. This was possibly due to either increased plant size in the widest spacing or to poor plant development and even plant mortality occurring in close spacing populations.

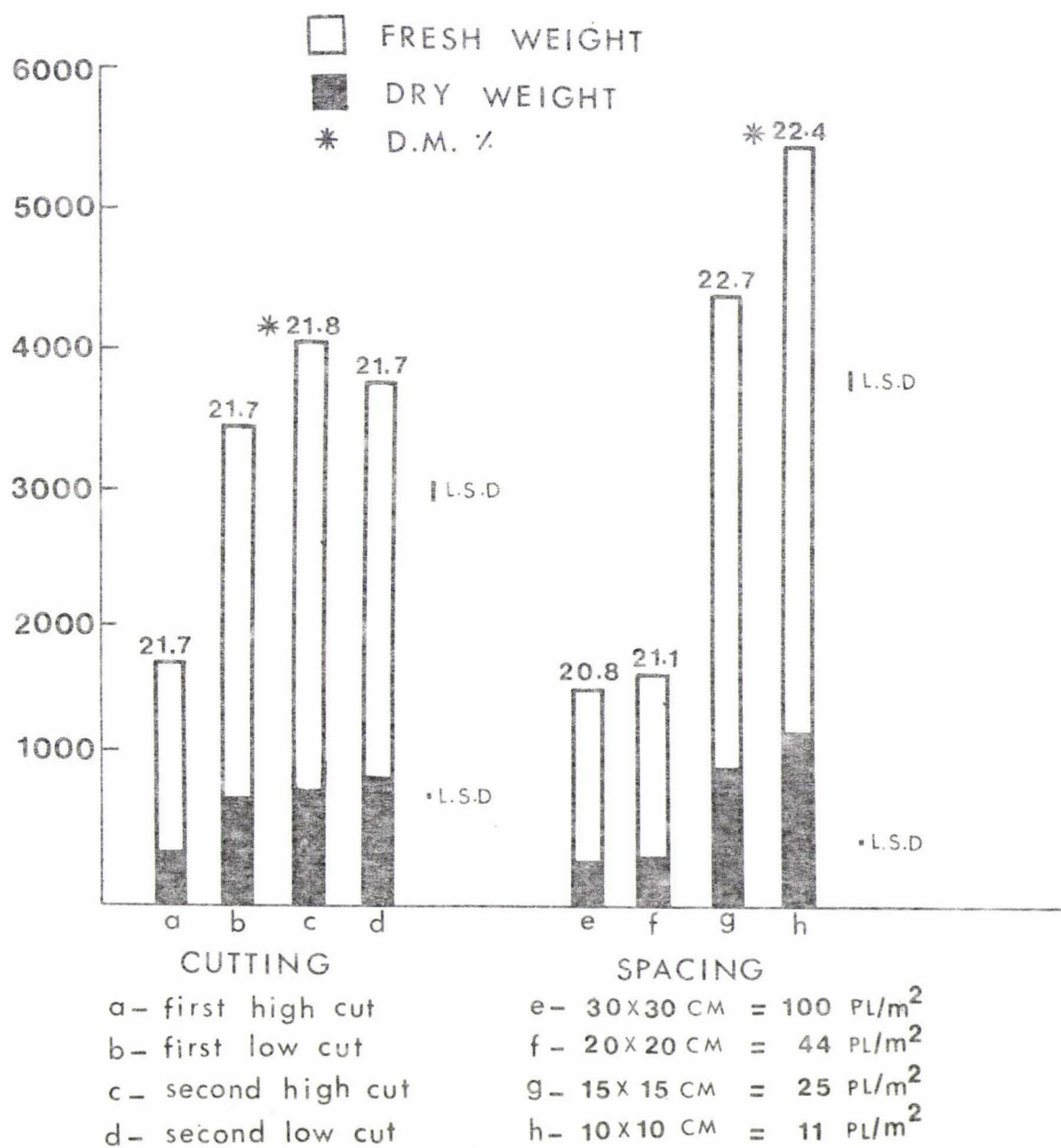
RESULTS

Mean results of plant spacing and cutting effects on fresh weight (FW) and dry weight (DW) of herbage are shown in Figure 2 (individual treatments in Appendices 1 and 2)

1. Fresh Weight (FW)

Statistical analysis indicates that both spacing treatments and cutting treatments had a significant effect on the fresh weight of herbage yield. It is likely that there was a higher fresh weight variation due to spacing treatments than due to cutting treatments. Consequently, yields of fresh weight in the range of 1562-5437 kg/ha. and 1714-4084 kg/ha.

FIGURE 2 EFFECT OF CUTTING AND SPACING TREATMENTS ON FRESH WEIGHT AND DRY WEIGHT OF HERBAGE YIELD



were recorded for spacing and cutting treatments respectively.

In cutting treatments, low cutting or late cutting gave a significantly higher FW of herbage than early or high cutting treatments. The highest FW of herbage yield of 4084 kg/ha. was obtained from the second low cut (cut at full flowering stage and at 1 cm. above the ground) while the lowest herbage yield of 171⁴ kg/ha. was obtained from the first high cut (cut at flowering bud stage and at 7.5 cm. above the ground).

Irrespective of the spacing treatment, the graphs in Figure 2 illustrate that maximum fresh weight yield (5437 kg/ha.) was reached when plants were grown at a spacing of 10x10 cm. (100 plants per sq. metre). Conversely lowest herbage yield (1561 kg/ha.) was obtained from the widest spacing of 30x30 cm. (11 plants per sq. metre). It was observed that when plants spacing was decreased from 30x30 cm. to 15x15 cm., fresh herbage yield of lucerne was more than doubled.

2. Dry Weight (Dw)

The relationship between cutting and spacing effects and dry weight is essentially similar to that obtained with fresh weight results (Figure 2). The results indicate that plant spacing plays a more important role in affecting herbage dry weight than cutting height and the stage of plant development.

With regard to cutting treatments, the highest yield of 910 kg/ha. (means of 4 spacings) was obtained when lucerne was cut at the flowering stage and at the ground level (second low cut). The mean lowest yield (383 kg/ha.) was obtained when plants were cut at the bud stage and at a height of 7.5 cm. (first high cut). The other interesting point to emerge from these results is that irrespective of the stage of plant

development at the time of cutting, cutting to ground level gave a significantly higher dry matter yield than when plants were cut at 7.5 cm. height at a comparable stage of plant development.

In relation to spacing effect, the dry matter herbage yield obtained from each spacing was significantly different. Results ranged from a dry matter yield of only 325 kg/ha. at the widest spacing (30x30 cm.) up to 1215 kg/ha. at 10x10 cm. spacing. Dry matter herbage yield was therefore inversely proportional to plant spacing.

3. Dry Matter Percentage

Plant spacing had a significant effect on the percentage of dry matter in the herbage whereas the effect of cutting treatments were not significantly different. The results show that plants grown at a close spacing produced herbage containing a significantly higher DM percentage than those grown at a wide spacing. Consequently, dry matter percentages of 22.4% and 22.7% were recorded at the 10x10 cm. and the 15x15 cm. spacings respectively compared with values of 20.8% and 21.1% from plant spacings of 30x30 cm. and 20x20 cm. respectively.

DISCUSSION

1. Effect of Cutting Treatments on Herbage Yield

In terms of herbage yield and time and height of cutting, results show a similar trend for both FW and DW. Cutting at the bud stage (12 weeks after sowing) gave a significantly lower herbage yield (both of FW and DW) than when cutting was delayed until plants had reached the full flowering stage (16 weeks after sowing). These results agree with those of Cowett and Sprague (1962), Leach (1968), Petrovski (1974)

and Birch et al (1976) who found that cutting lucerne at a more mature stage (early flowering to past bloom stage) resulted in higher dry matter herbage yield than cutting at a younger stage (vegetative and bud stage). These differences may be due to variation in plant size and the number of shoots and branches which had developed before cutting. In the present study, observations indicated that the size and number of shoots and branches increased as plants approached maturity. The size of plants at 16 weeks was much greater than at 12 weeks. The size and number of shoots and branches greatly influence herbage yield per unit area (Cowett and Sprague (1962) and Leach (1968)).

The number of years that a lucerne stand has been established might be positively correlated with plant development and herbage yield. In the present study, plants at the full flowering stage in the seeding year were not fully grown even though there was a big increase in plant size during the period from bud formation to the full flowering stage. This could explain the large differences in herbage yield obtained in this experiment.

Many workers have reported that more mature plants contain a higher percentage of fibre than younger plants (Woodman et al (1933), Crowder et al (1960), Weir et al (1960), Birch et al (1976) and Grigoryan et al (1977)). Although a higher herbage yield (dry weight) was observed when lucerne in the present study was cut at the full flowering stage, the dry matter percentage results did not show any significant increase or difference between herbage of different ages. However, it is also important to bear in mind that high feeding quality in connection with high levels of digestible protein is more

likely to be obtained when plants are cut early (at bud stage) as reported by Woodman et al (1933), Crowder et al (1960), Weir et al (1960), Birch et al (1976) and Grigoryan et al (1977).

2. Effect of Plant Density on Herbage Yield

Close spacing favours high herbage yield (both FW and DW) whereas lower herbage yield occurs as plant population per unit area is reduced. This result supports the work of Cowett and Sprague (1962) who reported that herbage yield of lucerne obtained from a plant density of 80 plants per sq. metre was significantly higher than that obtained from a plant density of 10 plants per sq. metre. It also supports work by Palmer (1971) that in the first year, a seeding rate of 0.28 kg/ha. gave a significantly lower herbage yield than higher seeding rates (1.12 - 4.48 kg/ha.). A possible explanation for low herbage yield at low plant density particularly in first year stands may lie in the fact that there may have been insufficient time for an increase in individual plant size to compensate for a decrease in plant number per unit area. Therefore, under such situations, herbage yield per unit area is more likely to be determined by the number of plants per unit area rather than by yield per plant. It is interesting also to note that in studies of plant density effects on herbage yield, Palmer (1971) found the significant difference of herbage yield obtained from different plant densities in a seeding year. However, he did not find any difference in herbage yield in a second year harvest taken from the same area. Therefore, in studying the effect of plant density on herbage yield the plant age effect may need to be taken into account.

The results of this experiment show there was an increase in herbage yield with an increase of plant density

which reached a maximum at a plant population of 100 plants per sq. metre (10x10 cm. spacing). It is of particular interest that the increase of herbage yield was more gradual when plant density was increased from 44 to 100 plants per sq. metre (15x15 cm. and 10x10 cm. spacings) than when the plant density was increased from 25 to 44 plants per sq. metre (20x20 cm. and 15x15 cm. spacings). It is possible however that maximum herbage yield of lucerne per unit area might be reached at a population density of less than 100 plants per sq. metre. If this is so, the asymptotic curve of vegetative growth previously proposed by Holliday (1960) and also found by Donald (1951) and Aspinall and Milthorpe (1959) could be applied to the vegetative growth curve of lucerne in the seeding year of this study.

Differences in the dry matter percentage of herbage found at different plant spacings was probably due to differences in the population of plant parts present. Although the partition of leaves and stems was not determined separately, observations indicated that plants grown at the closest spacing (10x10 cm.) tended to produce more stalks with few side branches and fewer and smaller leaves. Individual plants grown at the wider spacings (20x20 cm. and 30x30 cm.) developed more extensive and expansive branches and leaves. Such observations stress the influence of spacing on plant development, and may help to explain differences in the percentage dry matter of plants from different population densities recorded in the present study.

CONCLUSION

In a first year lucerne crop early cutting (bud stage) results in less herbage yield than when cutting is delayed until the crop has reached the flowering stage.

Severe late cutting, although it results in high herbage yield should be avoided since it causes the removal of the terminal portions of developing basal shoots. If late cutting is carried out a high residual stubble should be left. Such a cutting regime still allows high herbage yields but at the same time avoids damage to the crown shoots.

Plant spacing has a more pronounced effect on herbage yield than the height of cutting and the stage of plant development at the time of cutting. Close spacing favours increases in both fresh weight and dry weight yields per unit area as well as dry matter percentage. Herbage yield per unit area seems to depend more on the number of plants per unit area than on yield per plant. To obtain maximum herbage yield per unit area in a first year lucerne crop plants should be grown at a population density higher than 1/3 plants per sq. metre and up to 100 plants per sq. metre.

B. SEED CROP PRODUCTION

LITERATURE REVIEW

1. The Effect of Cutting on Seed Yield and Yield Components

The seeding year of lucerne is commonly known as the year of plant establishment (development of both root and top growth). Hadfield (1952) considered that this was a critical period of lucerne growth especially during the first summer and winter and cutting should be strictly avoided except where weeds were predominant. The suitable time for cutting lucerne plants for both herbage and seed yield varies from place to place and from year to year since seed production depends largely on environmental conditions or geographic area and is favoured under more sunny days irrespective of bee activity (Abu-Shakra et al 1977). According to Hadfield (1952) New Zealand farmers, after the seeding year cut lucerne in November for herbage and then leave the regrowth to produce a seed crop. He stressed that a lucerne crop should not be cut at all during the winter if it is required for a subsequent seed crop. However, in relation to the suitable cutting time for seed production, some farmers in the Blenheim district have observed that in some years the highest seed yield of lucerne is obtained when plants are cut in December, but in other years it is achieved following cutting of plants for hay in January.

Unfortunately there has been a limited amount of work carried out on this aspect previously. Nevertheless, work by Abu-Shakra et al (1977) in Lebanon on the effects of cutting lucerne for forage purposes on subsequent seed yield, tends to contribute a great deal in this aspect. Their results showed that seed yield was greatly reduced when 3 or 4 forage harvests were taken before the crop was allowed to seed compared to the

situation when plants were allowed to run to seed following only 1 or 2 forage harvests. Seed crop taken following 1 or 2 forage harvests resulted in 4 times more seed per unit area than the yield from crop taken following 3 or 4 forage harvests. Similarly Melton (1973) reported that the highest seed yield of lucerne was obtained from a plot in which one harvest for fodder was taken before harvesting for seed. It is unfortunate that in these experiments the researchers did not appear to have an uncut control to compare the seed yield of cut and uncut treatments. However, their results still show the deleterious effect of cutting on subsequent seed yield particularly where a high number of cuts are practiced before the seed crop is taken. Abu-Shakra et al (1977) also explain that the seed yield reduction, where 3 or 4 forage crops were taken before setting seed, could possibly be due to the depletion of root reserves resulting in low plant vigour. They further suggested that the number of cuttings for forage taken before seeding markedly reduced the number of pods per raceme. They did not record any significant difference in the number of seeds per pod due to forage harvesting in first year crops but there was a significant effect in the second seed crop. Therefore the number of seeds per pod is unlikely to be a sensitive component of seed yield except when plant vigour has been reduced in second year crops following extensive cutting for forage. In addition, Rincker et al (1977) investigated the effect of clipping 3 red clover cultivars on seed production. They indicated that removing a hay crop in all cultivars resulted in a subsequent seed yield reduction. Clipping also reduced 1000 seed weight of two cultivars and decreased the number of seeds per head in one cultivar.

2. Effect of Spacing on Seed Yield and Yield Components

Generally, the relationship between reproductive yield and plant density is a parabolic curve in most of the species studied. In the investigations by Donald (1954), it has been shown that subterranean clover and wimmera grass both showed the same response irrespective of seed production. Eventually high seed production is gained at moderate plant densities and declines thereafter. Grimes and Musick (1960) stated that in a reasonably dense stand of sorghum, the individual plant may increase in size to make use of growth materials. Sparse plants are unable to expand sufficiently to fill the gaps between plants and cannot fully utilize growth factors, resulting in a lower overall yield.

Some confusion appears in the literature about whether wide spacings favour high seed production per unit area in lucerne. Beran (1966) found that highest seed yield of lucerne was achieved when plants were grown in double rows (12.5 cm. between rows) 45 cm. apart compared to plants grown at closer spacings in single rows 12.5 cm. apart. Similarly, work by Mozhaev and Luzko (1975) in the U.S.S.R. has shown that the average 4 year lucerne seed production was 620 kg/ha. when plants were grown in rows 60 cm. apart compared with only 420 kg/ha. when plants were grown in rows 15 cm. apart. Conversely however, when lucerne plants were grown at wide spacings, it has been reported by some workers that seed yield reduction occurs. For instance, Antoniani (1971), grew lucerne for seed with 30, 45, 60 and 100 cm. between rows, and densities of 10, 6.2 and 4.8 plants per sq. metre. Seed yield was increased with increased distance between the rows from 30-60 cm. but decreased with both increases in plant density and when the distance

between rows was greater than 60 cm. The same trend was observed by Ibraimov (1973). In addition, Abu-Shakra et al (1969) suggested that a square planting of 50x50 cm. gave a higher seed yield than other spacings (50x25 cm. and 50x75 cm.). From the work available it is likely that the optimum row spacing, to give maximum seed yield in lucerne is approximately 45-60 cm. depending on the variety and the environmental conditions occurring where the plants are grown.

It is commonly found by researchers that different species or varieties have a different growth habit. Consequently it might be expected that there are varietal differences in seed yield components irrespective of plant density. This statement has been applied to some varieties of soybeans (Lehman and Lambert (1960), Vicia faba (Hodgson and Blackman (1956) and lucerne (Zambrana (1973)). In this connection Hinson and Hanson (1962) suggested that late varieties of soybean are more successful at wide spacings, increases in height, pods per plant and branches per plant enabling them to utilize available growth materials more efficiently than early varieties. In addition, it was suggested by Roberts and Kenney (1912) as cited by Widstrom (1969), that a thick planting was more beneficial for small varieties while a thin planting was preferable for large varieties. In the case of lucerne, Zambrana (1973) reported that to achieve maximum seed yield the variety Galilee needs to be grown at a spacing of 60x60 cm., while the Gilboa variety requires to be grown at 30x30 cm. Hodgson and Blackman (1956) found that the optimum density to give maximum seed yield was 35-45 plants per sq. metre for the spring type of Vicia faba. Apart from the varietal effect, it was also found that optimum plant densities

varied from season to season due to climatic conditions.

It is assumed that a high degree of competition exists when plant density is too high. As a result of this, a high rate of plant mortality is found (Palmer (1971) and Wynn-Williams and Palmer (1974)). Besides plant mortality, stalk barrenness also occurs. It was reported by Donald (1954) that at a very high population density of wimmera grass (22783 plants per sq. metre) the percentage of sterile tillers increased to 66%, while at the low and moderate densities (12-195 plants per sq. metre) all the tillers produced heads. Similar results were found in corn by Center and Camper (1970). Giesbrech (1969) reported that the effect of plant density on the percentage of barren plants in corn became more pronounced when the growth material was limited. Robinson et al (1964) suggested that other disadvantages of a very high population density are the cost of extra seeds required and an increase in lodging percentage.

Plant population should be defined not only in terms of the number of plants per unit area but also by the arrangement of these plants on the ground (spatial or plant rectangularity) (Willey and Heath 1969). The arrangement of plants and planting patterns in the field may influence the degree of competition between adjacent plants. Hoff and Mederski (1960) suggest that an equidistant planting may reduce competition between the roots of adjacent plants for water and nutrients and therefore should increase crop yield. Equidistance may also provide a vegetative canopy which results in good conservation of soil moisture and high efficiency in the utilization of solar energy. Work by Robinson et al (1964) with corn and Koldaev and Abduvalier (1974) with lucerne indicates the

important role of plant arrangement on seed crop yields even though it is unfortunate that only a small amount of research work is currently available on this aspect.

Rossister (1959) showed that competition of subterranean clover plants for water grown as single plants or in swards was the major factor responsible for seed yield reduction. He noted that when there was a soil moisture stress during the flowering period of single plants then flowering was delayed by 1 month compared with situations where plants were grown in swards. Zambrana (1973) reported that the flowering time of lucerne plants was delayed when they were grown at a high plant density of 15x15 cm. Hodgson and Blackman (1956) suggested that flower production in Vicia faba was less sensitive to change in plant density than pod production. In other words, the intra-plant competition amongst flowers during seed setting is more critical than in the period of flower initiation. Since this species is self-pollinating, variation in percentage of seed set should be mainly due to internal factors. In an extremely dense stand the competition at the time of floral primodial formation is so intense that, there is a reduction in the number of inflorescences per plant and the florets per inflorescence is reduced in the case of wimmera ryegrass (Donald 1954).

It is often found by researchers that at wide spacings, individual plants have the greatest number of flowers, pods and seeds. This statement holds true for Lolium and Trifolium species (Donald 1963), Lupin (Withers et al 1974 and Withers 1975), Vicia faba (Hodgson and Blackman 1956), beans (Bennett et al 1977) and lucerne (Beran 1966). The data of Bennett et al (1977) on dry bean (Phaseolus vulgaris L.) gives a very clear picture

of this aspect. Their results revealed that the number of pods/plant was reduced from 17.7 to 6.6 when plant densities increased from 17 plants to 63 plants per sq. metre. Similarly, Stickler and Wearden (1965) found in sorghum that the number of heads per plant varied from 0.87 to 4.50 at plant densities ranging from 25.8 to 3.3 plants per sq. metre.

Apart from the three yield components already mentioned there are other yield components which influence seed yield. Beran (1966) found in lucerne plants that at the widest spacing of 45 cm. between rows, plants produced more branches and had a greater number of pods and seeds per branch, than plants grown at a close spacing. This suggests that plants compensate for low density of plants by increased development. A similar finding was reported with soybean plants by Lehman and Lambert (1960).

Whether or not seed weight is altered by plant density depends on the plant species. It has been reported by Reiss and Sherwood (1965) that seed weight of soybean was affected by plant density. They found that the heaviest seed was obtained at widest spacings of 100 cm. and 80 cm. row widths or at a seeding rate of 53.5 kg/ha. while lightest seed was obtained from plants grown in 20 and 40 cm. row widths. However, according to their results seed weight did not seem to have a major effect on overall seed yield since the row width of 100 cm. produced the heaviest seed but did not give the highest seed yield per unit area. Similar effects with soybean have been shown by Lehman and Lambert (1960). However, Stickler and Wearden (1965) noted only a minor increase in seed weight of sorghum as stand density decreased. In contrast to this, Donald (1963) stated that seeds of Lolium and Trifolium species

were smaller when grown at wide spacings. This was possibly due to high intra-plant competition during seed development as there were a great number of inflorescences per plant. Nevertheless, changes in seed size of Vicia faba were not noted when plants were grown under different spacings (Hodgson and Blackman (1956)).

Number of seeds per pod appears to be an unimportant yield component in many species and/or varieties at different plant densities. Unfortunately, the current literature on this aspect of lucerne was not found. However, Hodgson and Blackman (1956) reported that there was no change in the number of seeds per pod in Vicia faba when plants were grown at different spacings.

When considering all seed yield components on grain yield of sorghum per unit area there seems to be a compensation between components such as number of fertile inflorescences per unit area and number of seeds per head. This compensation results in a constancy of seed yield despite changes in plant densities (Stickler and Wearden 1965).

3. Pollination

It has been reported by Umaerus and Akerberg (1959) in Sweden, Pedersen (1962), Gladstone (1970) and Johnston (1970) in U.S.A. and Palmer-Jones (1966) in New Zealand that lucerne seed production is generally relatively low and uncertain, failure of seed production being often attributed to problems of ineffective pollination. It is estimated that only about 10% of lucerne flowers grown in the major seed production districts of New Zealand are pollinated even under conditions of high density bee populations (Palmer-Jones and Forster (1965) and Cook (1974)).

Lucerne in the field may either be self-fertilized or

cross-fertilized. Hadfield and Calder (1936) believe that there are zones in which either self-fertilization or cross-fertilization is dominant. They have shown that in the Palmerston North district, 56% of pod set resulted from self-fertilization under open-pollinated conditions. In contrast to this, Knowles (1943) reports an average of 94.2% cross-pollination in a lucerne field in Saskatoon. There is agreement among workers that self-fertility in lucerne plants is an undesirable characteristic. Since it generally results in reduced seed production (Hadfield and Calder (1936), Knowles (1943) and Umaerus and Akerberg (1959)) and to a lesser degree in reduced vegetative vigour (Hadfield and Calder (1936), Tysdal (1940), Busbice (1968), and Free (1970)). This concept has been proved by investigation by Knowles (1943) that self-fertilization in lucerne plants resulted in 1.65 seeds per flower while cross-pollination gave 4.60 seeds per flower. Cooper et al (1937) claimed that failure to set selfed seed in lucerne might be caused by lack of fertilization or by abortion of the proembryo. An average of 9.3 ovules per flower is normally found in lucerne. Among these, seed setting ranged from only 2.1 to 3.1 ovules per flower (Cooper et al 1937).

Honey bees (Apis sp.) are of great importance in pollinating legumes (Bohart and Todd 1961). However, they are more valuable in lucerne seed production when they collect pollen rather than when they collect nectar (Pedersen 1953). Most workers (Vansell and Todd (1946), Bohart and Todd (1961), Palmer-Jones and Forster (1965), Nye (1970) and Cook (1974)) agree that honey bees are known to visit lucerne mainly for nectar often without touching the tripping mechanism. By doing so, the flowers are rarely tripped although there may still be

some chance of cross-pollination where honey bee numbers are abundant (Hadfield 1952).

The alfalfa leaf cutter bee (Megachile sp.) is considered to be a very reliable pollinator of lucerne. As the leaf cutter bee has a habit of working during earlier periods of the day and at lower temperatures than honey bees, there seems more likelihood of success from their introduction into lucerne fields under low summer temperatures in New Zealand than with other species (Knowles 1943). Farmers in the Blenheim district depend greatly on leaf cutter bee populations to obtain high yields of lucerne seed. This type of bee does not live in a colony but tends to live in close proximity to its neighbour. It is an advantage that the leaf cutter bee is able to be housed in a man-made dwelling. The transport of egg cells from place to place by man is also convenient. Only the female bee is effective in pollination, the male bee always takes nectar without tripping the flower. The female leaf cutter bee is very hard working collecting small leaf pieces and petals to make cells for the larvae as she lacks glands to produce wax (Hobbs 1973).

Hadfield and Calder (1936) have also suggested that the bumble bee (Bombus terrestris) is also a most efficient pollinating agent for lucerne. Unfortunately low population numbers often limit lucerne seed production. Consistent tripping and pollinating is always a feature of the activity of this species. However, it is unlikely that seed yields can be increased by keeping bumble bees since their colonies generally consist of less than 100 individuals (Bohart and Todd 1961).

RESULTS

1. Influence of Cutting on Plant Recovery and Seed Yield

Effect of cutting on seed yield per unit area. The results of mean values for all cutting treatments are presented graphically in Figure 3. It has been shown that cutting has a significant effect on seed production. Cutting lucerne plants after they had commenced reproductive development in a first year crop always depleted seed yield. The data collected shows a highest mean seed yield of 83.8 kg/ha. from the control (uncut) plot and a lowest mean yield of only 4.5 kg/ha. from the second low cut (plants cut at ground level 16 weeks after sowing) (Appendix 4).

Time of cutting and stubble height were both responsible for seed yield reduction. Of these two factors time of cutting tended to have the greatest effect on seed yield. The data revealed that seed yield was reduced by 3 - 5 times when plants were cut at the bud stage (12 weeks after sowing) whereas the reduction was as much as 12 - 19 times compared with the uncut control when plants were cut at the full flowering stage (16 weeks after sowing). Therefore the latest cut resulted in the lowest seed yield. Yield reduction due to the time of cutting is also obvious when comparisons are made between the yields of the first high cut and the second high cut (4.4 times) and between the first low cut and the second low cut (3.5 times).

The results further show that seed yield from the first high cut was twice as high as from the first low cut. In contrast to this, less obvious differences due to height of cutting were detected at the second cut. This implies that when plants are cut at the bud stage, leaving a stubble height of 7.5 cm. is preferable to cutting at ground level.

FIGURE 3 EFFECT OF CUTTING ON SEED YIELD PER UNIT AREA

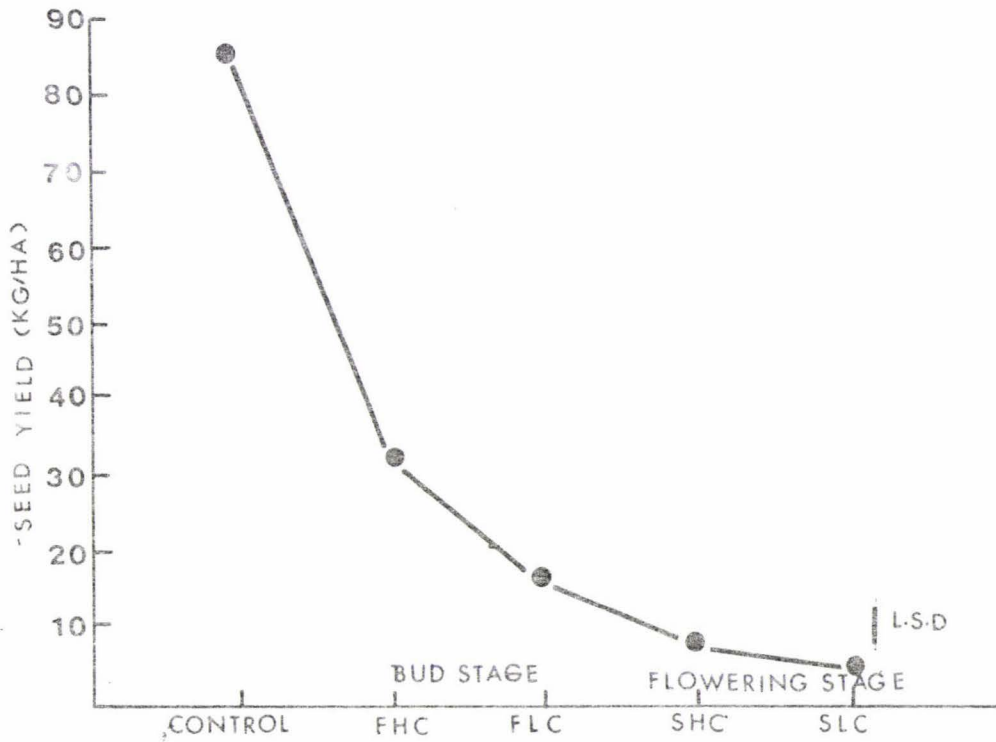
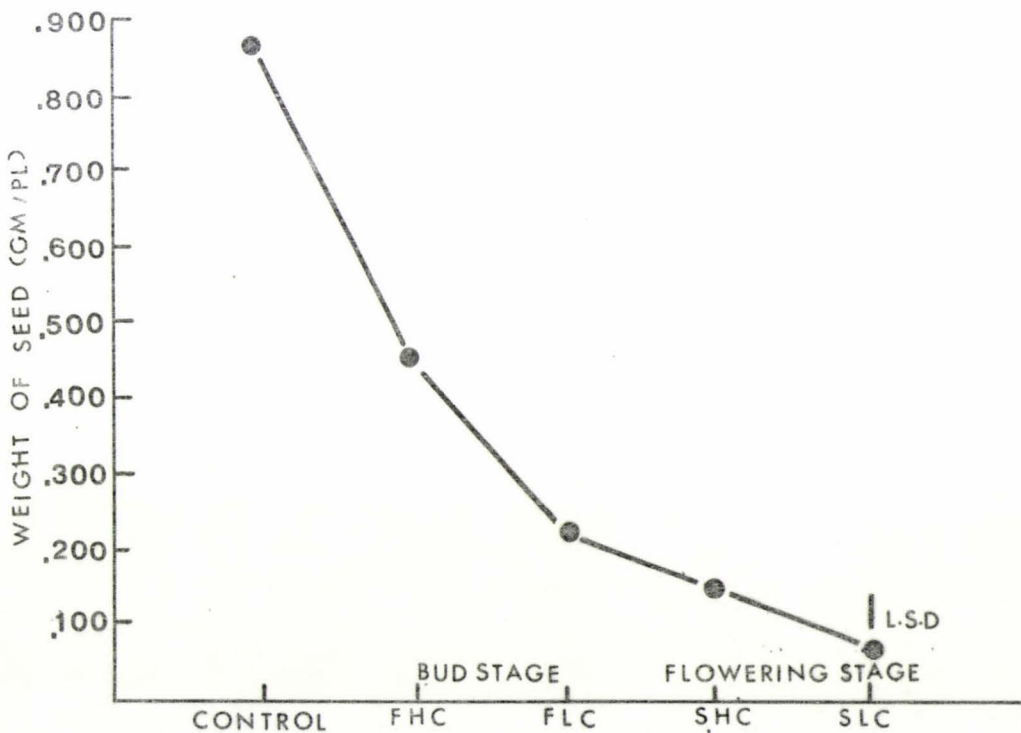


FIGURE 4 EFFECT OF CUTTING ON SEED YIELD PER PLANT



Effect of cutting on seed yield per plant. The mean values of yield per plant obtained from various cutting treatments are presented graphically in Figure 4. The results show that the effect of cutting on seed yield per plant was essentially similar to that on seed yield per unit area. Figure 4 shows that plants from the uncut control plot gave the highest seed yield of .851 gm. per plant. There was a considerable decline in seed yield per plant from the control to the first high cut and the first low cut. The reduction became more gradual between the second high cut and the second low cut. Nevertheless cutting at a height of 7.5 cm. seemed to result in less seed yield depression than cutting plants to ground level at a similar stage of plant development.

The relationship between cutting treatment and seed yield components. Since cutting had an extremely depressing effect on both seed yield per plant and per unit area, it was imperative to further investigate the various components which govern seed production. In this experiment 11 components of seed yield were examined. It was found that some components had a major effect on seed yield, some a minor effect and others had no effect at all. Hence greater emphasis should be given to those which had the more pronounced effect on the seed yield production. Mean values of each component are presented in Table 1.

TABLE 1.

A SUMMARY OF MEAN EFFECT OF CUTTING ON SEED
YIELD COMPONENTS (RAW DATA APPENDICES 6-16)

YIELD COMPONENTS	CUTTING TREATMENTS					L.S.D.
	CONTROL	FHC	FLC	SHC	SLC	5%
1. SEED NUMBER PER PLANT	366 * a	224 b	116 c	88 d	44 e	28.9
2. POD NUMBER PER PLANT	166.4 a	84.3 b	43.9 c	36.3 c	20.3 d	10.5
3. NUMBER OF CLUSTERS PER PLANT	36.4 a	16.3 b	9.1 c	8.0 c	4.8 d	1.5
4. MAXIMUM FLOWERS PER PLANT	13.1 a	3.6 c	5.2 b	4.7 bc	4.1 bc	1.4
5. % OF SHOOTS PRODUCED SEED	23.5 a	16.7 b	12.6 c	12.4 c	7.9 d	2.1
6. REPRODUCTIVE SHOOTS PER PLANT	5.7 a	4.6 b	3.1 c	3.4 c	2.2 d	0.5
7. TOTAL SHOOTS PER PLANT	24.1 b	27.9 ab	25.2 b	25.8 b	28.8 a	2.8
8. 1000 SEED WEIGHT	2.26 a	1.93 b	1.85 c	1.67 d	1.60 e	0.05
9. NUMBER OF FLORETS PER FLOWER	11.0 a	8.6 c	10.0 b	10.8 ab	10.3 ab	0.8
10. NUMBER OF SEED PER POD	2.35 b	2.81 a	2.65 ab	2.94 a	2.27 b	0.43
11. NUMBER OF PODS PER CLUSTER	3.95 a	4.31 a	4.34 a	4.28 a	3.95 a	0.45

* Figure in any column followed by the same letter do not differ significantly at 5% level.

It appears from the results that cutting (time of cutting and cutting height) had a depressing effect on all seed yield components except number of pods per cluster and to a lesser extent on the number of seeds per pod and total shoots per plant. Plants from the uncut control gave the highest number of seeds per plant (366) whereas plants cut at the second low cut (cut late and at ground level) yielded only 44 seeds per plant. This reduction in the number of seeds per plant was caused by both time of cutting and cutting height. In Table 1. seed numbers per plant fell from 224 in the first high cut to 88 in the second high cut (a reduction to one third) but a significant reduction occurred between the first high cut (224) and the first low cut (116) (a reduction to nearly half).

Like the number of seeds per plant, it is to be noted that the number of pods, clusters and maximum number of flowers per plant were drastically reduced by cutting. (Table 1.).

Normally the number of flowering shoots are considered to be a fundamental factor affecting overall seed yield, since this factor affects the potential of a crop for the subsequent development of flowers, pods and seeds per plant. There was a definite relationship between cutting treatments and both the percentage of shoots that produced seed and the number of reproductive shoots which formed. Both of these parameters were significantly higher in the uncut control than in any of the cutting treatments because of the depression in reproductive shoot growth and subsequent development caused by the physical removal of herbage. This effect became more pronounced with later cutting treatments.

Significant differences in both the number of total shoots and reproductive shoots were found when plants were cut for

herbage before seed production. The total number of shoots formed per plant was slightly increased following cutting. On the other hand cutting caused a great depression in the number of reproductive shoots per plant. Generally, the effect of early (bud stage) and high (7.5 cm.) cutting was not as severe as the effect of late (flowering) and low (ground level) cutting. Apparently the first high cut removed only some of the reproductive shoots whereas the first low cut removed twice as much. When cutting was delayed until the flowering stage (second cut), nearly all the reproductive shoots were removed particularly in the case of low cutting. (Plate 7).

PLATE 7

DIAGRAM OF CUTTING DAMAGE TO THE PLANT



It is of particular interest to note that cutting not only reduced the number of reproductive shoots but also restricted the percentage of total shoots which subsequently produced seed. In other words cutting seemed to stimulate the growth of vegetative shoots and to depress reproductive shoot development. This effect was more pronounced in the SLC where only 7.9% of total shoots were able to produce seed heads compared with 23.5% from the uncut control (Appendix 12).

1000 seed weight was found to be reduced with both the time and severity in cutting (Appendix 13). Control plots gave heavier and larger seeds when compared with seeds from cut plots particularly at the latest cut. However this seed weight effect seemed to contribute less to seed yield reduction, greater effects being attributable to greater numbers of seeds per plant rather than increases or decreases in individual seed weight.

Treatment effects on the number of florets per flower and the number of seeds per pod showed only a minor influence on seed yield. These values were less consistently influenced by cutting (Appendix 14).

One of the parameters found not to be important in seed yield was the number of pods per cluster, which was almost the same in every cutting treatment (Appendix 16). This was the only seed yield component which was not affected by management.

Pod set

TABLE 2.

EFFECT OF CUTTING ON PERCENT POD SET

	CONTROL	FHC	FLC	SHC	SLC
MEAN TOTAL FLOWERS PER PLANT	47.8	22.9	13.5	20.1	9.3
MEAN TOTAL CLUSTERS PER PLANT	36.4	16.3	9.1	8.0	4.8
PERCENT POD SET	76.2	71.1	67.5	39.8	51.6

A comparison between the total number of flowers per plant and the number of clusters per plant provides information about the percentage of pods setting seed. Data in Table 2 suggests that the percentage of flowers that set pods was high (76.2%) in the uncut control plot and that this percentage decreased when plants were cut for forage before being allowed to run to seed. Lowest percentage of pod set (39.8%) was found in the SHC. When a comparison of this value was made between the early cut and late cut, results suggest that percentage of pod set is consistently lower following late cuts than early cuts.

2. Influence of Spacing on Plant Behaviour and Seed Yield

Effect of spacing on seed yield per unit area. Within the range of plant densities used in this experiment (11 - 100 plants per sq. metre), the results suggested that spacing had a tremendous effect on seed yield. To compare the spacing effects the data was pooled over all cutting treatments (Figure 5). The plant spacing of 30x30 cm. produced an average seed yield of 45 kg/ha., 20x20 cm. was slightly reduced at 43 kg/ha. Seed yield was sharply reduced at 15x15 cm. (16 kg/ha.) and 10x10 cm. plant spacings, (10 kg/ha). The data therefore shows that seed yield per unit area was reduced as the distance between plants became smaller (Appendix 4).

The interrelationship between spacing and seed yield per plant.

Significant differences in seed yield per plant were detected between plants grown in different spacings. A reduction in seed yield per plant was noted when spacings were reduced. Average seed yield per plant for all spacing treatments are shown in Figure 6. Plants from the widest spacing of 30x30 cm. produced

FIGURE 5 DIFFERENCES IN SEED YIELD PER UNIT AREA (KG/HA) CAUSED BY DIFFERENT SPACING

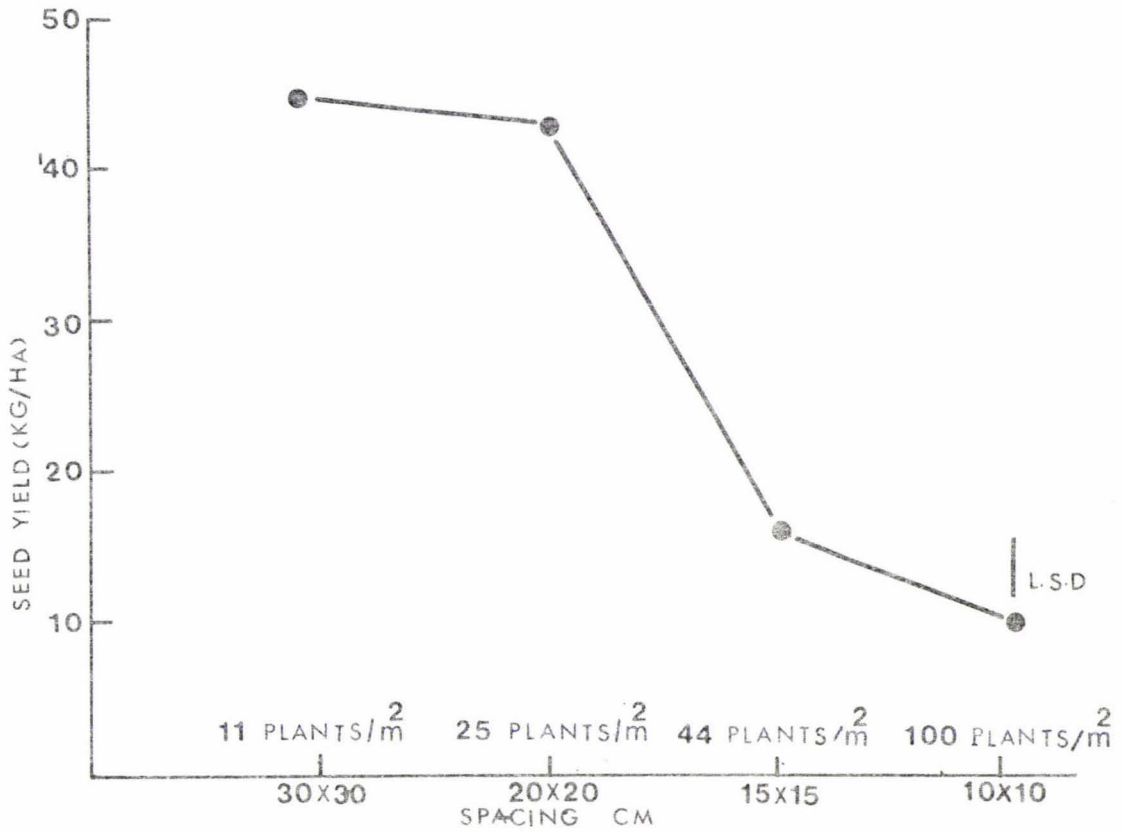
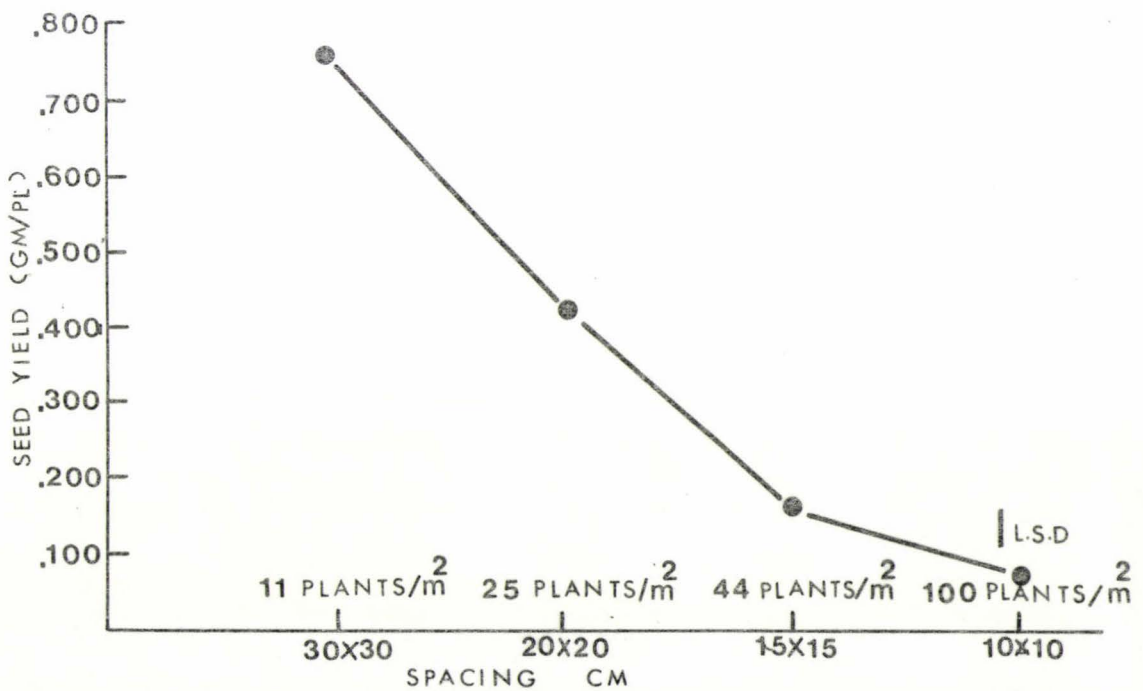


FIGURE 6 EFFECTS OF DIFFERENT SPACING ON SEED YIELD PER PLANT



a yield of .741 gm. per plant (Appendix 5). This seed yield was reduced 2, 5 and 11 times when plant spacings were reduced from 30x30 cm. to 20x20 cm., 15x15 cm. and 10x10 cm. respectively. Observation indicated that the size of plants grown at a 20x20 cm. spacing was slightly smaller and had a slightly lower number of stems when compared to those grown in 30x30 cm. However this reduction in plant size was more pronounced at spacings of 15x15 cm. and 10x10 cm. Particularly at the highest population density (10x10 cm. spacing) individual plants were relatively small and tended to have a large number of barren (non-flowering) stems. The overall results suggest that seed yield per plant was extremely low when the plant density reached or exceeded 44 plants per sq. metre (Plate 8).

PLATE 8.

EFFECT OF SPACING ON PLANT SIZE AND SEED YIELD



PLANTS PER				
SQ. METRE	11	25	44	100
PLANT	30X30	20X20	15X15	10X10
SPACING CM.				

The effect of spacing on seed yield components. Since differences in both seed yield per unit area and per plant were noted as a result of different spacings, further investigations were carried out to determine the direct effect of spacing on those seed yield components which mainly govern seed production. There seemed to be many factors involved, some contributing to a greater extent than others. The mean values of each component are presented in Table 3. (raw data Appendices 6-16).

TABLE 3.

A SUMMARY OF MEAN EFFECT OF SPACING ON SEED YIELD COMPONENTS

YIELD COMPONENTS	SPACINGS				L.S.D. 5%
	30X30 CM.	20X20 CM.	15X15 CM.	10X10 CM.	
1. POD NUMBER PER PLANT	150.9 * a	82.1 b	35.7 c	12.3 d	9.4
2. SEED NUMBER PER PLANT	350 a	205 b	78 c	38 d	25.8
3. NUMBER OF CLUSTERS PER PLANT	27.7 a	18.1 b	9.8 c	4.3 d	1.3
4. MAXIMUM FLOWERS PER PLANT	8.4 a	7.6 a	5.6 b	2.9 c	1.3
5. REPRODUCTIVE SHOOTS PER PLANT	5.3 a	4.3 b	3.3 c	2.1 d	0.4
6. TOTAL SHOOTS PER PLANT	36.1 a	30.2 b	24.3 c	15.0 d	2.5
7. NUMBER OF PODS PER CLUSTER	5.3 a	4.7 b	3.6 c	3.1 d	0.4
8. NUMBER OF FLORETS PER FLOWER	10.3 b	11.2 a	10.1 b	8.9 c	0.7
9. 1000 SEED WEIGHT (GM.)	1.98 a	1.91 b	1.82 c	1.76 d	0.05
10. NUMBER OF SEEDS PER POD	2.34 b	2.47 b	2.37 b	3.22 a	0.4
11. % OF SHOOTS PRODUCED SEED	15.7 a	14.2 a	14.0 a	14.5 a	1.9

* Figures in any column followed by the same letter do not differ significantly at 5% level.

The number of pods per plant was found to be the most sensitive yield component altered by plant spacing.

An examination of the number of pods per plant showed that there was a major relationship between this seed yield component and plant spacings. There was a decline in the number of pods per plant as plant spacing was decreased. This value fell drastically from 151 pods per plant in the widest spacing to only 12 pods per plant at the closest spacing. Therefore this yield component was reduced more than 12 times simply as a result of alteration in plant population numbers per unit area.

Seed numbers per plant also appeared to be an extremely important component of seed yield affected by varying plant spacings. The widest spacing (30x30 cm.) again gave the highest number of seeds per plant. The mean value of this component (Table 3.) indicates there was a marked decrease from 350 seeds per plant at the widest spacing to only 38 seeds per plant at the closest spacing. The rate of reduction in seed numbers per plant due to the decrease in plant spacing follows a similar pattern to that obtained for the number of pods per plant.

Clusters of pods per plant was also considerably reduced as plant density became more intensive. This component ranged from 27.7 in the widest spacing down to 4.3 in the closest spacing, (a reduction of over 600%).

It was also observed that plant density had a significant effect on the maximum number of flowers per plant. The results suggest that plants grown at wide spacings tended to produce more flowers than those grown at close spacings. Flower numbers per plant gradually fell as plant population per unit area increased, this reduction being particularly marked at the 10x10

cm. spacing. Similarly the number of both total and reproductive shoots per plant was also highest at the widest spacing and gradually reduced as plant spacings decreased. At all plant spacings the consistent percentage of the shoots that became reproductive was within the range of 14% - 16%. The number of reproductive stems was well correlated with spacing, ranging from 2 to 5 per plant in the closest and widest spacings respectively.

The number of pods per cluster and 1000 seed weight were also decreased with increases in plant population. However they were shown to have a generally smaller effect on seed yield production than some other components. The number of seeds per pod was similar in the wide spacings of 30x30 cm., 20x20 cm. and 15x15 cm. but this component of total yield tended to be higher at the highest population of 100 plants per sq. metre (10x10 cm. spacing).

The number of florets per flower found in this experiment varied from 8.9 to 11.2 depending on the spacing between plants. This component was higher at the 20x20 cm. spacing than at 30x30 cm., 15x15 cm. and 10x10 cm. spacings. The lowest number of florets per flower (8.9) occurred at the closest spacing (10x10 cm.).

Pod set

TABLE 4.

EFFECT OF SPACING ON PERCENT POD SET

	30X30 CM.	20X20 CM.	15X15 CM.	10X10 CM.
MEANS OF TOTAL FLOWERS PER PLANT	46.8	34.2	22.9	9.7
MEANS OF TOTAL CLUSTERS PER PLANT	27.8	18.1	9.7	4.3
% POD SET PER PLANT	59.4	52.9	42.3	44.3

Mean values of percent pod set per plant are presented in Table 4. The results indicate that plants grown at wide spacings (30x30 cm. and 20x20 cm.) tend to result in higher values of pod set (59.4% and 52.9% respectively). At close plant spacings (15x15 cm. and 10x10 cm.) a lower percentage of flowers subsequently setting pods (42.3% and 44.3%) was noted.

3. Combined Influence of Cutting and Spacing on Seed Yield

The effects of cutting and spacing on seed yield production have already been investigated separately in the above section. However the expression of seed yield due to these two factors could not be completely achieved without considering their combined effects.

Total seed yield per unit area. The results of individual treatments are shown in Figure 7. Considerable variation in seed yield both within and between treatments occurred. Seed yield per hectare varied from 1.7 kg. in the treatment of the second low cut combined with a plant spacing of 10x10 cm. up to 137.4 kg/ha. in the control (uncut) plot at a plant spacing of 20x20 cm. It is interesting to note that in the control plot, seed yield per unit area at a spacing of 20x20 cm. outyielded plants grown at a 30x30 cm. spacing by 10 percent. When a comparison was made between the effects of cutting and spacing, cutting treatments employed in this experiment tended to cause a greater depression in seed yield than the spacing effect. A close investigation of the data revealed that at the 30x30 cm. spacing seed yield reduction due to cutting was very critical falling from 124.7 kg/ha. in the uncut plot to 6.2 kg/ha. in the second low cut treatment. This general effect also occurred at the other 3 plant spacings. An important feature was that plants in the uncut control plot reacted differently to the

FIGURE 7 COMBINED EFFECT OF PLANT SPACING AND CUTTING TREATMENTS ON SEED YIELD PER UNIT AREA (KG/HA)

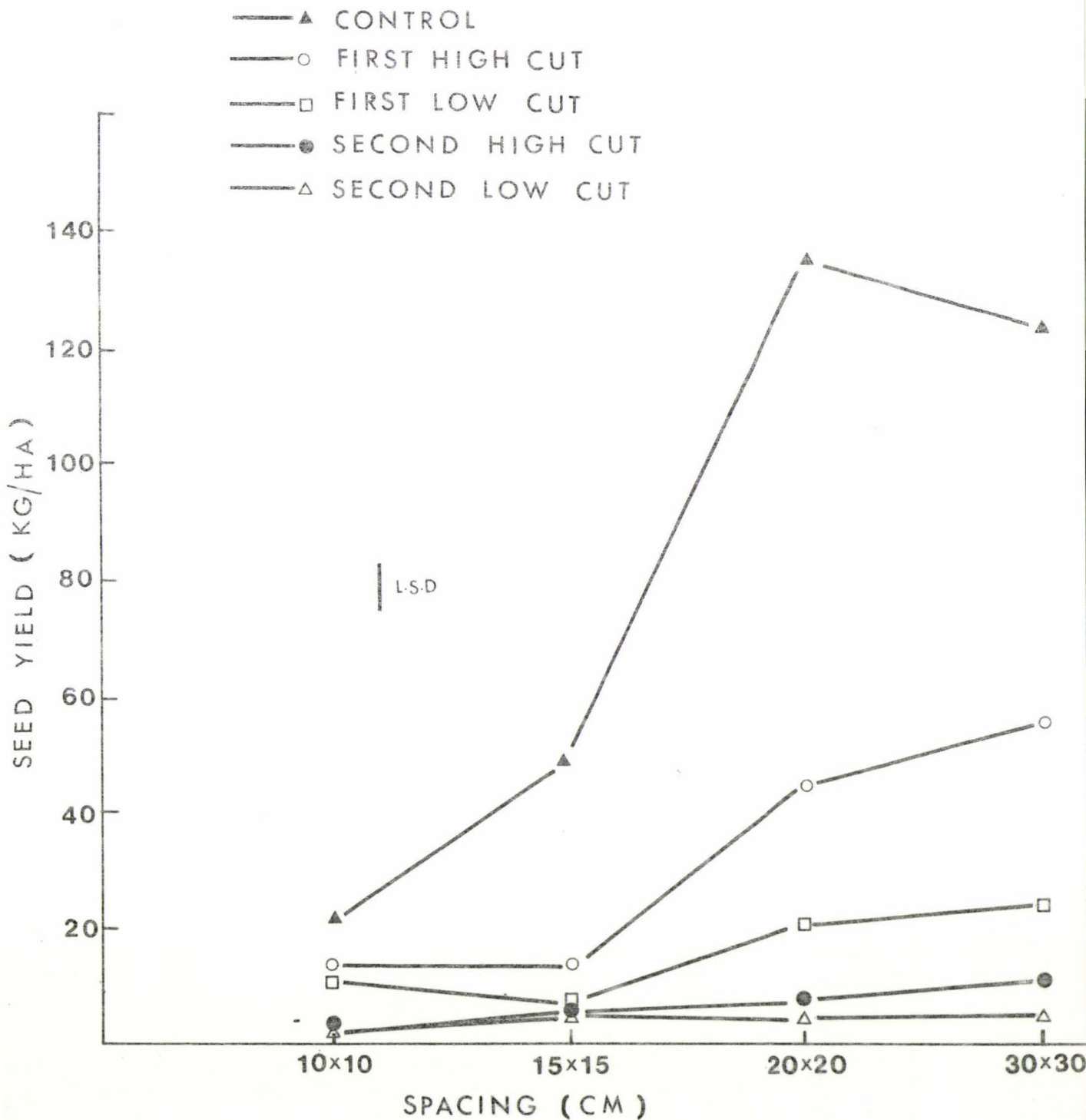
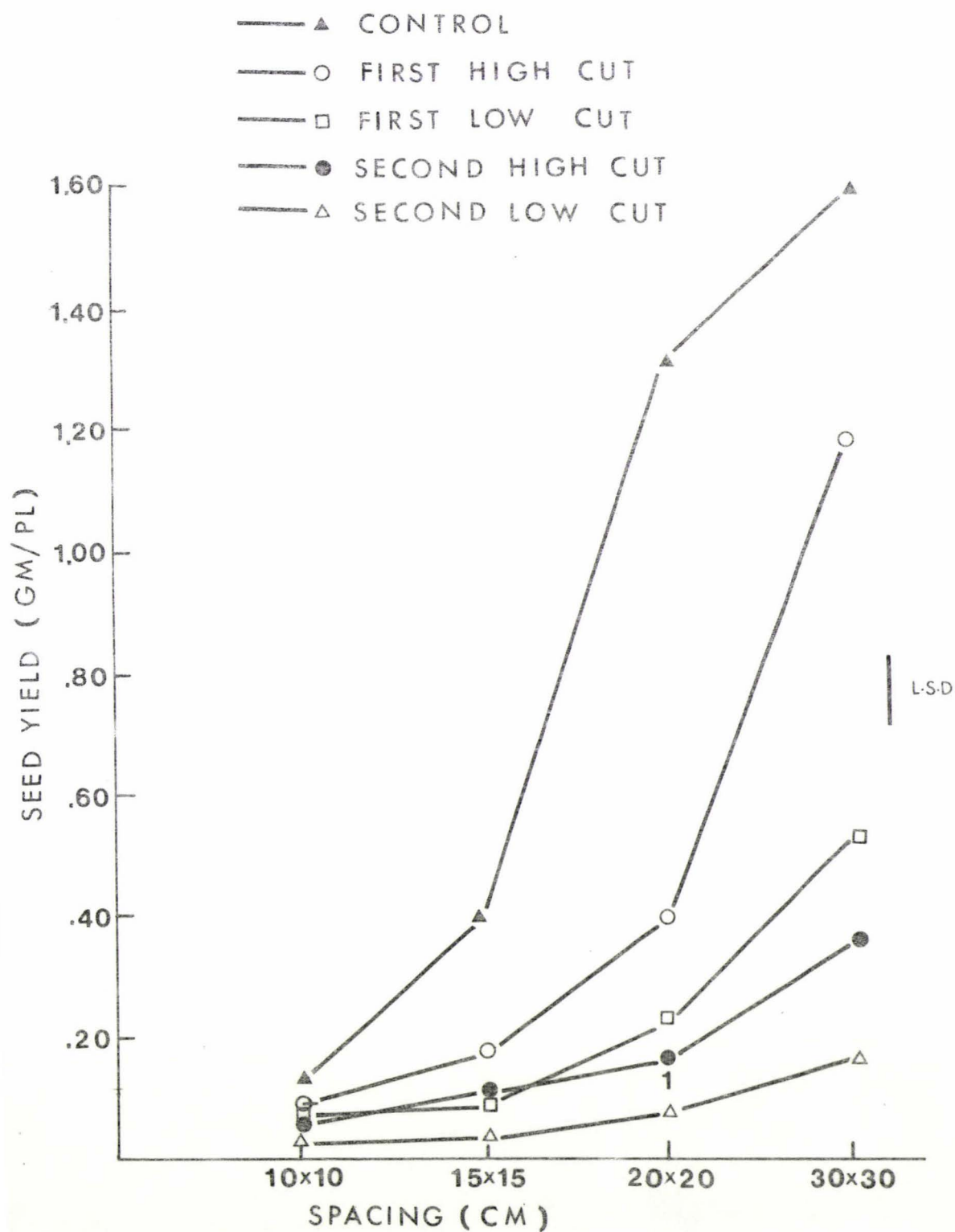


FIGURE 8 COMBINED EFFECT OF PLANT SPACING AND CUTTING TREATMENTS ON SEED YIELD PER PLANT



interrelationship between seed yield reduction and spacing compared with the cut plots. In the uncut control plot the seed yield per hectare obtained from the 30x30 cm. spacing was slightly higher than those from 20x20 cm. spacing but seed yield sharply dropped to 49 and 23 kg. when plants were grown at 15x15 cm. and 10x10 cm. spacings respectively. This showed that the highest yielding treatment outyielded the poorest one by 5 times in the control plot purely as a result of altering plant density per unit area. In the other 4 cutting treatments it appeared that the rate of seed yield reduction affected by spacing was quite similar and that the difference between the highest and the lowest yielding treatments was about 3 times. Therefore it seems that the effect of spacing on seed yield was more pronounced in the uncut plot than in any of the cut treatments.

Seed yield per plant. Yield per plant varied greatly depending on both plant spacing and cutting effects. Highest seed yield of 1.58 gm. per plant was obtained from the uncut control plot at a plant spacing of 30x30 cm., lowest seed yield of .20 gm. per plant was obtained from the closest spacing and the second low cut (latest cut, at ground level). Yield per plant again was found to be different between the uncut and cut plots in relation to the spacing effect.

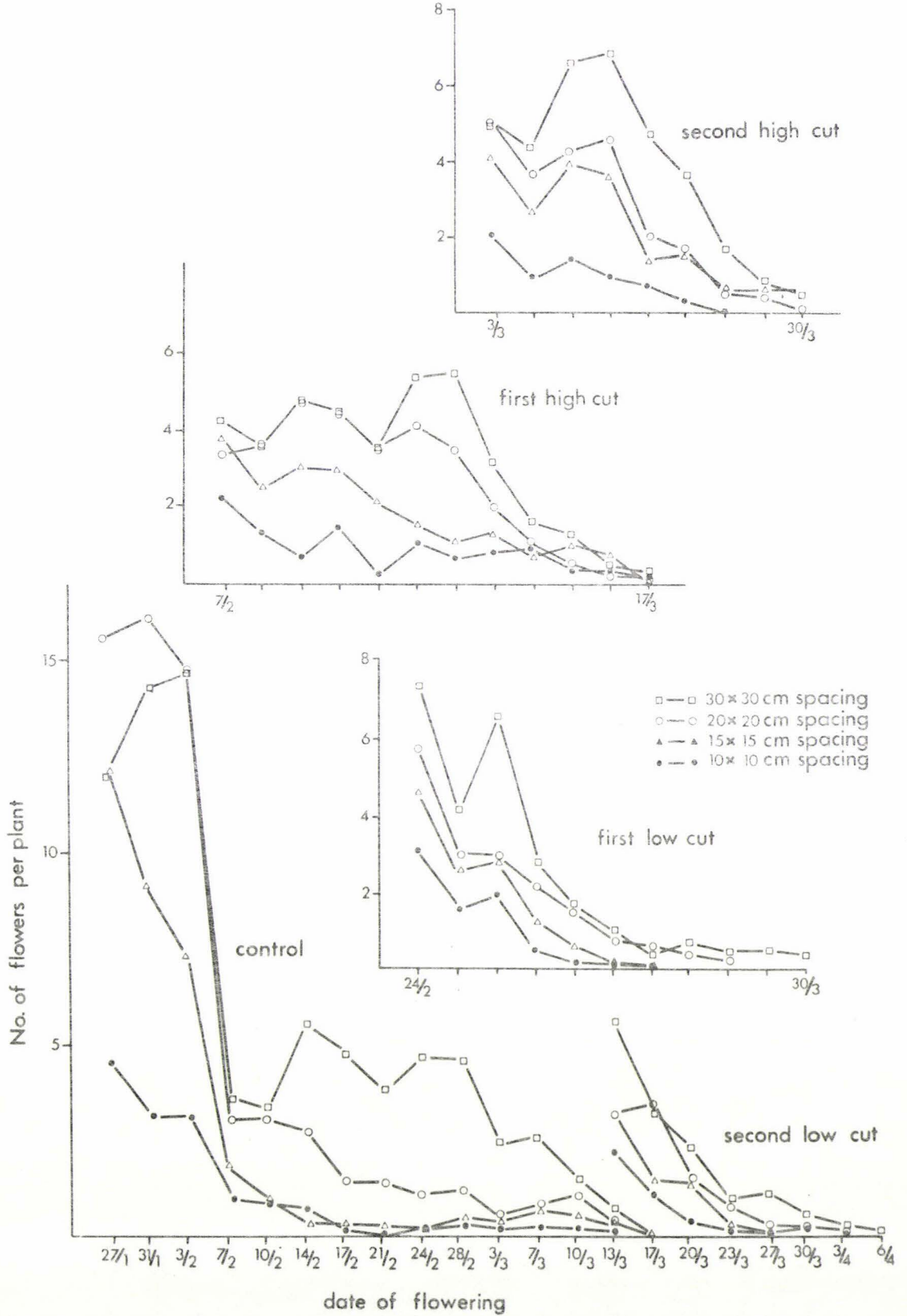
In the control (uncut) plot, yield per plant increased with increasing spacing (Figure 8.). The rate of increase in seed yield was gradual from 10x10 cm. spacing to 15x15 cm. spacing, rose sharply when plant spacing was increased from 15x15 cm. to 20x20 cm. and increased again when the interplant spacing was increased from 20x20 cm. to 30x30 cm. In all cases cutting reduced seed yield per plant, later cuts showing a greater seed yield depression than earlier cuts. Reduction in seed yield

was also affected by the amount of residual stubble remaining after cutting, high cuts depressing seed yield per plant less than low cuts.

Flowering pattern. Numbers of flowers per plant in each treatment were recorded beginning when sufficient number of flowers occurred. Results indicate that cutting had a profound bearing on the time of onset of flowering and on flowering intensity as shown in Figure 9. Both delays in cutting and lower cutting (at ground level) resulted in later flowering of the crop e.g. the highest number of flowers recorded from the second low cut treatment (cut late and at ground level) was during the second week of March while a similar point was reached as early as late January in the uncut control plot. It is likely that the depressing effect of cutting on flowering intensity seemed to be more pronounced in late rather than early cut treatments and in the low cut rather than the high cut. As shown in Figure 9., the number of flowers per plant at each observation was lower in the cut plots than in the uncut control plot. Results also indicate that later dates of flowering shortened the duration of flowering. As a result of a lower number of flowers recorded at each observation and a shorter flowering period in the cut plots, the mean number of total flowers per plant were 47.8, 22.9, 13.5, 20.1 and 9.3 in the control, FHC, FLC, SHC and SLC respectively (Appendix 17).

Regarding the spacing effect on flowering pattern, the results show that plants grown at the widest spacing (30x30 cm.) which had more reproductive shoots and branches produced the greatest number of flowers per plant. In contrast to this, the lowest number of flowers per plant occurred at the closest spacing (10x10 cm.), due to a small plant size with lower numbers

FIGURE 9 DIFFERENCES IN THE PATTERN, TIME OF ONSET AND DURATION OF FLOWERING DUE TO CUTTING AND SPACING TREATMENTS



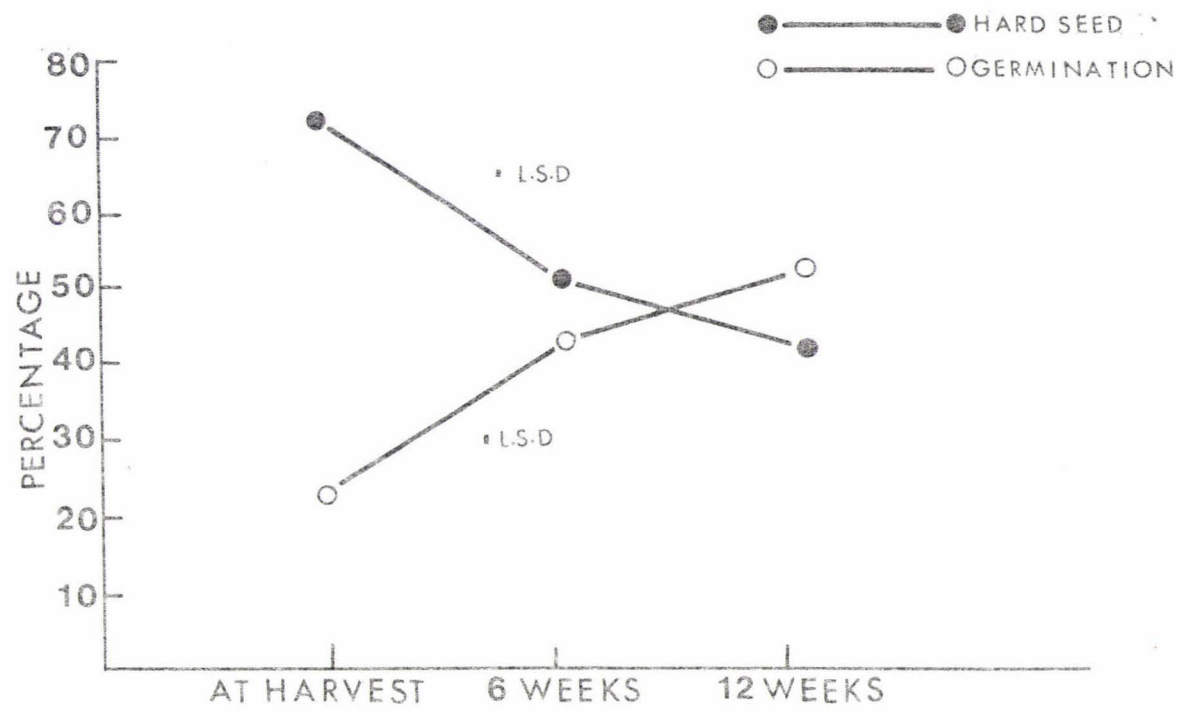
of reproductive shoots. The mean number of total flowers per plant obtained from plant spacings of 30x30 cm., 20x20 cm., 15x15 cm. and 10x10 cm. were 46.8, 34.2, 22.9 and 9.7 respectively (Appendix 17).

Due to the delayed flowering period occurring in the cut plots, seeds in different cutting treatments were subjected to different climatic conditions during seed ripening. Plants in the control plot ripened during hot and dry weather (maximum: minimum daily temperatures within the range $42^{\circ}\text{C}:7^{\circ}\text{C}$ respectively) (Appendices 23 and 25). Conversely seeds from late cut treatments (e.g. the second low cut) were ripening during cool and wet weather (maximum:minimum daily temperatures within the range $25^{\circ}\text{C}:2^{\circ}\text{C}$ respectively). These different environmental conditions during the seed ripening period resulted in differences in the amount of hard seed formed in seed harvested from different treatments. For example a high percentage of hard seed (87%) was found in the uncut control plot while lower percentages (56%-79%) were obtained when seeds from the cut plots were tested immediately after harvest.

4. Mean Germination and Hard Seed Results from Storage Treatments

Apart from the study of the effects of cutting and spacing on seed yield, additional tests were made on the effects of seed storage period on the level of hard seed content. The germination results obtained from seed samples harvested from different spacings of the same cutting treatment were similar. To analyse the data, the mean results of the 4 spacings were used. Results showing the mean values of seed germination and hard seed percentage obtained following different storage periods are shown graphically in Figure 10 (individual treatments in Appendices 19 and 20). Results indicate that a storage

FIGURE 10 THE EFFECT OF STORAGE ON GERMINATION AND HARD SEED RESULTS



period of up to 3 months under ambient temperature and relative humidity conditions had a significant effect on the reduction of hard seed content. Apparently there was an increase in the germination percentage as storage period increased. Mean germination results were 24%, 42% and 51% when seeds were tested at 0 weeks, 6 weeks and 12 weeks respectively. In contrast to this, the percentage of hard seed while initially high (mean value 71%) decreased as the storage period increased. The data shows a fall in the mean hard seed content to 43% when seeds were tested after 12 weeks storage.

DISCUSSION

1. Effect of Cutting on Seed Production

A forage cut before allowing a lucerne crop to run to seed greatly reduced both seed yield per plant and per unit area. The deleterious effect of cutting on subsequent seed yield observed in this study was similar to that previously reported by Melton (1973). It also agrees with the findings of Abu-Shakra et al (1977) even though plants in the present study were only cut once i.e. at bud stage or at flowering stage. Results also support Hadfield's opinion (1952) that in the seedling year (year of plant establishment of both root and top growth), lucerne plants should not be cut if a subsequent seed crop is contemplated in the same year.

Irrespective of cutting treatment, seed yield in the cut plots was mainly a product of reproductive shoots produced as regrowth of new buds and shoots arising from the crown. The time of cutting had a more pronounced effect on seed yield than cutting height. This may be due to the effect of environmental conditions. Time of cutting determined both the flowering time and flowering duration which in turn influenced the degree of

successful pollination. A reduction of seed yield of 50% in the second cut compared with the first cut indicates the reduced yield potential of lucerne plants when cut at the full flowering stage. Plants in the cut plots particularly under late cutting were subjected to unfavourable climatic conditions for both flower production and pollination. The low production of flowers in the late cut treatment was possibly due to a photoperiod effect. The lucerne plant is classified as a long day plant which normally flowers during a long day period as suggested by Thomas (1967) e.g. lucerne plant requires a 14 hour day to flower successfully (Massengale and Medlar 1958). In this experiment it was noted that the number of days taken from cutting to flowering following a late herbage cut was approximately 4-17 days less than for the flowering following an early cut and depending on cutting height. The reproductive growth may not have had sufficient time to reach its full potential. Subsequently there were fewer flowers produced per plant.

Cutting lucerne depressed seed yield by reducing reproductive shoots per plant, percentage of shoots producing seed, number of flowers, clusters, pods and seeds per plant and 1000 seed weight.

Cutting seemed to stimulate the production of vegetative shoots by removal of reproductive shoots and hence the reproductive stimulus, throwing the plant back into vegetative shoot production. The small variation of reproductive shoots and a marked difference in seed yield found between the control plot and the cut treatments indicated that cutting may have weakened the plant or depressed the yield capacity of each shoot. Even though the number of seeds or flowers per shoot was not

recorded, the stems of plants in the uncut control plot carried more branches and flowers when compared with those in cut plots.

Generally the percentage of flowers setting seed found in this experiment was rather high (37-76%) when compared to the results of Palmer-Jones and Forster (1965) who reported average pollination results of lucerne crops grown in New Zealand (North Canterbury, North Otago, Central Otago and the Blenheim district) as approximately 10%. Pollination did not seem to be a big problem in the production of seed in this experiment, the number of visiting honey bees from the 12 hives located within 400 metres being sufficient for such a small lucerne planting area. It was expected that the leaf cutter bee (Megachile sp.) would be the most successful pollinator of lucerne and one bee hive consisting of approximately 2500 cells was placed in the field prior to the blooming stage of the crop. Observations during this stage suggested that the majority of visiting bees were honey bees (Apis sp.), both bumble bees (Bombus terrestris) and leaf cutter bees being far less frequently observed to be working the crop. It soon became evident that leaf cutter bees favoured lotus flowers to lucerne flowers as they preferentially visited volunteer lotus plants growing adjacent to the experimental area in large numbers. Therefore it is unlikely that leaf cutter bees were responsible for successfully pollinating many of the lucerne flowers in the trial area. One other reason for this suggestion is that heavy concentrations of honey bees may have resulted in competitive exclusion of leaf cutter bees from the experimental area. Such an effect has been previously suggested by Bohart et al (1955), cited by Free (1970). This suggests that if it is desirable to ensure that leaf cutter bees work efficiently

in lucerne fields, it could be advantageous if the planting area is located some considerable distance from honey bee hives. Reducing the extent of competing blooms in areas adjacent to the lucerne field during blooming period is another way of increasing lucerne pollination efficiency as suggested by Vansell and Todd (1946), Bohart (1957), Todd and Crawford (1962) and Free (1970).

Low seed yield in late cut plots was caused by both a low percentage of seed set and lower numbers of flowers making plants less attractive to bee visitation. Also the cold and moist weather during flowering may have influenced the flying hours of bees as previously suggested by Tysdal (1940). Therefore a suitable time for cutting irrespective of flower production and pollination results needs to be considered if a high seed production is required. The percentage of flowers setting seed was quite high in the control plot where flowering occurred in January. Results suggest the hot and dry climatic conditions in the month of January in 1978 were favourable for bee activity in the Manawatu area. This effect seems to agree with statements of farmers in the Blenheim area, that in some years seed yields of lucerne is high when plants were cut in December.

The differences in seed yield between plots cut high or low at the bud stage of development and subsequently allowed to run to seed indicates the influence of stubble height on subsequent seed yield. The seed yield potential from low cut plots was more depressed than the high cut. There seem to be two possible factors involved. The first is the potential amount of reproductive shoots already present at cutting. The other is potential for subsequent regrowth of new buds and

shoots. The size and number of buds and shoots occurring at the crown of the plant before flowering suggests that with cutting at a height of 7.5 cm. at the bud stage, the material removed consists mainly of mature vegetative and reproductive shoots. By contrast cutting to ground level at this stage also removes some of the new basal shoots, with resultant reduction in recovery potential.

Apart from the effect of reduction in yield potential removed at the time of cutting, observation indicates that plants in the high cut plots resumed growth faster than those in low cut plots. This was shown by the fact that flowering in the first high cut plot commenced 2 weeks earlier than the flowering of regrowth from the corresponding low cut plots. Rate of plant growth was more vigorous when a stubble height of 7.5 cm. was left rather than when cutting height was reduced to 1 cm. from the ground. Leaving a high stubble height at cutting seems to be of advantage in connection with the amount of residual leaf or leaf area index. This enables plants to resume growth faster than when all leaves are removed by cutting as reported by Cowett and Sprague (1962). The other advantage of leaving a high stubble is that it provides more available sites for the initiation of reproductive shoots and hence large number of flowers per plant. This is in agreement with the work of Cowett and Sprague (1962) and the findings of Shakenov (1970) that reproductive shoots were produced mainly from the axillary buds. However, no appreciable difference in seed yield between the second low cut and second high cut may be due to the relatively low yielding recovery potential of plants as a result of being cut late and then subjected to unfavourable environmental conditions for growth.

A reduction in the number of pods, clusters and seeds per plant due to a decrease in the number of flowers per plant and a low percentage seed set was the major deleterious influence of cutting on subsequent seed yield. This supports the results of Melton (1973) and Abu-Shakra et al (1977) that cutting reduces the number of pods and seeds per plant.

The reduction in 1000 seed weight as a result of cutting observed in this experiment agrees with the results of Rincker et al (1977) with red clover. However, seed weight does not seem to be such an important factor governing seed yield as seed numbers per plant.

The consistency in the number of pods per cluster found in this experiment does not agree with work by Melton (1973) who recorded a reduction in this yield component when plants were subjected to 3-4 forage cuts before running to seed. The differing results may be due to the plant weakening effect of forage cutting which results in lower numbers of florets per flower and possibly a lower percentage seed set. This effect is unlikely to be so important in the situation where the lucerne crop is cut for forage only once before a seed crop.

In the present study the number of seeds per pod was not affected by cutting treatments. This agrees with the results of Melton (1973).

2. Effect of Spacing on Seed Yield

It is generally accepted that seed yield per unit area is a function of the production of seed yield per plant and the number of plants in that area. Plant density has been shown to have a marked influence on plant behaviour and finally seed yield per plant. When studying the effect of plant density on seed yield, the understanding of plant competition is of prime

importance. The micro-environment around each plant is known to be altered when there is a change in plant density as reported by Donald (1963).

Results from this study indicate that wide spacing favours high seed yield per plant. The results are therefore in agreement with those of Withers (1975) on lupin. When lucerne plants were grown individually at a 30x30 cm. spacing it is likely that no inter-competition occurred after sowing. As a result plants were taller and expanded in size by developing more branches, shoots flowers and seeds. In contrast to this, plants grown in a more dense population or close spacing (particularly at the spacing of 10x10 cm.) were subjected to intense interplant competition immediately after sowing. At the 10x10 cm. spacing plants were so close together that each individual plant did not have enough space to fully develop its plant parts successfully. In such situations plants were relatively small, spindly and were quickly exhibiting signs of low vigour due to inter-plant competition.

With regard to seed production per unit area, it is of particular interest that plants in cut plots and the uncut (control) plot responded differently to changes in plant densities. In the control plot where cutting was not imposed, plants grown at a spacing of 20x20 cm. gave the highest yield per unit area whereas in the cut plots, a spacing of 30x30 cm. between plants resulted in highest seed yield. Results indicate that there was a slight decrease in seed yield per plant when lucerne plants were grown at a 20x20 cm. spacing compared to those grown at a 30x30 cm. spacing. However the differences in the number of plants per sq. metre between these two spacings was great. Therefore, the lower seed yield per unit area obtained from a 30x30 cm.

plant spacing was mainly due to a lower plant density effect. The results found in this study, therefore suggest that an increase in seed yield per plant from widely spaced plants (30x30 cm.) was insufficient to compensate for the decrease in low numbers of plants in unit area. The same relationship between seed yield per unit area and plant density has been previously observed in subterranean clover and wimmera ryegrass by Donald (1954), in sorghum by Grime and Musick (1960); in corn by Prime and Schroder (1964); and in lucerne by Abu-Shakra et al (1969), Antoniani (1971) and Ibraimov (1973). At high plant densities (44-100 plants per sq. metre), the increase in plant number per unit area was insufficient to compensate for the reduction of seed yield produced by poor individual plants. Apart from low seed yield per plant, stalk barrenness (non-flowering stems) was a main characteristic and a disadvantage of the dense population. This latter aspect supports the results of Donald (1954) on wimmera ryegrass, Giesbrech (1969) and Center and Camper (1970) on corn.

The optimum plant spacing to give optimum seed yield in this trial, particularly when lucerne plants had not been cut before producing seed crop, seems to be closer than those found by many researchers (Beran (1966), Abu-Shakra et al (1969), Antoniani (1971), Ibraimov (1973) and Mozhaev and Luzko (1975)), who recorded an optimum row spacing of 45-60 cm. apart. The difference between these results might lie in the fact that in this trial the seed yield data was obtained in the first year following sowing. Lucerne seed producers generally state that old lucerne stands often yield more seed than new stands. This may be partly due to insufficient time for full plant development in the sowing year. It may also be a reflection of reduced plant

density in stands used for seed production in subsequent years.

It is also likely that different cultivars of lucerne need to be grown at different spacings to give maximum seed yield. Zambrana (1973) reported that the optimum spacing to give maximum seed yield of cv. Gilboa and cv. Galilee were 30x30 cm. and 20x20 cm. respectively. The the present experiment lucerne cv. "airau gave a maximum seed yield per unit area when grown at a spacing of 20x20 cm. in the seeding year provided plants were not cut for herbage before producing a seed crop.

As discussed in the previous section, plant density has a great influence on plant behaviour. Consequently many researchers have found that seed yield components of certain species vary with changes in plant density. Generally, it might be expected in the legume family that the number of flowers, pods and seeds per plant are the most important yield components contributing to seed yield. However, it should also be borne in mind that the number of flowers are determined by the number of reproductive shoots. These are influenced by stand density and also by climatic and management factors, many of which are not fully understood.

The result of the relationship between the number of shoots and plant density found in this experiment supports the findings of Abu-Shakra et al (1969) and Dovrat et al (1975) that plants grown in wide spacings produced more shoots and branches than those grown at closer spacings. The most important point to emerge from the plant spacing effect was that spacing caused effects unlike cutting which had no influence on the percentage of shoots which became reproductive. It was evident that plants in each spacing produced the same ratio of vegetative and reproductive stems although the total shoot numbers per

plant was reduced by plant spacing. The important feature of the close spacing was to depress both the total number of vegetative and reproductive shoots. This characteristic has been regarded as a main disadvantage of high plant density.

It has been suggested by Thomas (1967) that seed yield capacity of the lucerne plant is dependent on the initiation and development of flower primordia, satisfactory pollination mechanisms and agents, fertilization and seed development. The result of the current study agrees closely with this statement. Apparently, besides the number of reproductive shoots produced, the number of flowers per plant and percentage of flowers setting seed seems to be fundamental factors governing seed yield.

In relation to flower production Donald (1954) claimed that the sparse plant of wimmera ryegrass grown at a wide spacing produced more flowers per plant. A similar result with lucerne was observed in this study. Plants in all spacings of the same treatment commenced flowering at the same time. This indicates that flowering time of lucerne grown in this trial was not affected by spacing treatment unlike the finding of Zambrana (1973) that flowering time in lucerne was delayed when plants were grown at a high population density.

With respect to the percentage of flowers setting pods, there was a trend that plants in the widest spacing had a higher percentage of pod set than those grown at close spacings. These results are in close agreement with Zaleski (1963) and Pedersen and McAllister (1955) as quoted by Wynn-Williams and Palmer (1974). One explanation for this might be that plants growing at wide spacings are more attractive to bees perhaps because such plants produced flowers with more nectar and high

sugar concentration.

Cooper et al (1937) reported that an average 9.3 ovules per flower are normally found in lucerne. The percentage of seed set reported by Knowles (1943) is approximately 1.65 and 4.60 seeds per pod for self-pollinated and crossed-pollinated lucerne respectively while Dovrat et al (1960) reported that the number of seeds per pod in lucerne ranged from 4.4 - 6.3 depending on growing season. In the present experiment, although the number of ovules per flower was not determined, the number of seeds formed per pod recorded at harvest ranged from 1.9 - 4.4. The higher numbers of seeds per pod found in the close spacing in the present trial was possibly due to the fact that plants in the close spacing produced fewer flowers and a lower percentage of pod set. As a result of few pods per plant and few pods per cluster, intra-pod competition should be reduced, allowing the production of higher number of seeds per pod. This result however does not agree with the findings of Hodgson and Blackman (1956) in beans. Nevertheless, the number of seeds per pod is not regarded as a important seed yield component governing ultimate seed yield in lucerne.

Individual plants from wide spacings produced higher numbers of pods and seeds than plants from close spacings. This agrees with the result of Beran (1966) on lucerne and is apparently true for other species such as subterranean clover (Donald 1954), lupin (Withers 1975), Vicia faba (Bennett et al 1977) and also with members of the grass family such as Lolium (Donald 1954), and sorghum (Stickler and Wearden 1965). It is also interesting to note that variations in the number of pods per plant in this experiment has been shown to be almost entirely due to the effect of different plant spacings.

Plants in the wide spacings resulted in heavier seed than those grown at close spacings. The same trend has previously been observed in soybean by Reiss and Sherwood (1965) and Lehman and Lambert (1960). Nevertheless, the findings in this experiment contrasts markedly with Donald's (1963) work where he reported that *Lolium* and *Trifolium* seeds became smaller when grown at wider plant spacings. Donald suggested that the possible explanation may be that, this is a result of intra-seed competition during seed development. This situation is unlikely to occur in the case of lucerne since pollination is still a limiting factor to the amount of seed produced. These results however do not agree with work reported by Hodgson and Blackman (1956) in which they did not find any changes in seed weight in Vicia faba grown at different plant spacings.

Following consideration of all seed yield components, it appears that little compensation between seed yield components such as number of pods or seeds per unit area and number of pods per plant, exists in this species where there is a change in plant density. However there is a variation in seed yield per unit area with changes in plant population.

It was also noted in the present study that a plant spacing of 20x20 cm. was the minimum spacing suitable when work such as thinning, weeding and harvesting were done by hand. The wide spacing of 30x30 cm. seems to be conducive to greater weed infestation than when plants are grown at a closer spacing.

3. Effect of Harvesting Time on Germination and Hard Seed Percentage

Both time and height of cutting altered the time and duration of flowering in lucerne. Plants in each treatment

(control, FHC, FLC SHC and SLC) were pollinated at different times and were thereby subjected to different environmental conditions during seed development. Results show that time of harvesting had a significant effect on both germination and hard seed percentage. The control (uncut) plot gave the highest percentage of hard seed (87%). A decrease in the hard seed percentage occurred in all other treatments. Differences in the percentage of hard seed seem to be due to an environmental effect. The ripening of seeds from the control plot occurred during the period from 10 March to 15 April, when weather conditions were hot and dry. The delayed flowering imposed by cutting treatments resulted in plants flowering under progressively cooler and moister environmental conditions. Such conditions resulted in protracted seed development. Such situations stress the need to grow lucerne for seed production in areas which have reliably warm and dry weather extending into the autumn, particularly if lucerne seed production occurs under a cutting and seeding type of management system. Under the cool and wet conditions occurring during later stages of seed development and ripening some sprouting of seed in the pod was commonly observed. This result agrees with the findings of Hyde (1954), Abu-Shakra (1969), Pacuta (1976) and Win Pe (pers. comm. 1967) that dry conditions during seed development (ripening stage) result in a high percentage of hard seededness, while cool, wet conditions not only reduce the level of hard seededness but may also result in seed sprouting prior to harvest.

4. Effect of Storage Period on Germination and Hard Seed Percentage

Mean germination results of hand harvested lucerne seed

significantly increased after storage for 6 weeks and 12 weeks respectively. Hard seed percentage dropped from 71% at the time of harvest to 43% after storage for 12 weeks. This decrease of hard seed content is of significance, indicating the marked effect of temperature and relative humidity (in the range of 11°-24°C and 43%-72% RH respectively) on the softening of the seed with time. These results appear similar to previous findings with subterranean clover, that the daily temperature cycle (Quinlivan 1965) and fluctuations in soil temperature (Hagon 1971) are important in the breakdown of hard-seededness in legume seeds. Hagon (1971) further suggested with subterranean clover that under natural conditions fluctuations in soil temperature cause expansion and contraction of the seed coat causing softening due to fracturing of the testa at the strophiole site. Possibly a similar effect occurs with lucerne. It is probable that under field conditions when seeds are buried in soil, the role of relative humidity and moisture is involved along with soil temperature in assisting the softening of hard seed. It is reasonable to assume that fluctuations in both relative humidity and temperatures accelerate the rate of expansion and contraction and finally fracturing of the seedcoat. Satisfactory laboratory germination results (over 95%) when lucerne seeds were tested following mechanical scarification (up to 15 psi for 1 minute) implies that the hard seed condition in this variety of lucerne is a shallow type, which is easily removed. Results also suggest that the seeds of lucerne used in this study do not have a prolonged period of dormancy.

CONCLUSION

The capacity of lucerne plants to produce maximal seed yield is directly associated with the number of reproductive

shoots, branches, flowers per plant and percentage seed set resulting in high numbers of pods and seeds per plant. These components of seed yield are greatly affected by cutting and spacing treatments. To obtain high seed yield of lucerne, the proper spacing and cutting management is of prime importance.

Wide plant spacings favour high seed yield. Seed yield per unit area depends mainly on seed yield per plant but is also affected by the number of plants per unit area. To produce seed successfully lucerne plants must be grown at wide spacings to obtain vigorous plants. Such plants tend to develop more reproductive shoots, flowers, pods, seeds and heavier seeds and also appear to be amenable to higher levels of pollination. There is apparently nothing to be gained in the production of lucerne seed by using sowing rates which lead to high densities (44-100 plants per sq. metre), since close spacing results in large number of small plants with a low seed yield potential and also many barren (non-flowering) plants. To maximise seed production in the lucerne cultivar "Wairau" plants should be grown at a wide spacing of approximately 11-25 plants per sq. metre.

Cutting weakens the plant and severely depresses reproductive stimulus particularly in the case of low cuts (1 cm. above the ground). This is reflected in the development of fewer reproductive shoots, pods and seeds per plant. The results of cutting treatments suggest that lucerne plants in the seedling year should not be cut at all if maximum seed yields are required. In a situation where hay production is necessary prior to seed production results indicate that cutting lucerne early (at or before the bud stage) and at a height of 7.5 cm. causes less depression on plant recovery and ultimate

seed yield. Cutting delays flowering and plants may be therefore subjected to less favourable environmental conditions during pollination and seed development. Cutting lucerne at the right time to allow flowering to occur during a time of the year when hot, dry weather is most likely, should be one of the aims to produce high seed yields.

To obtain a better understanding of the effect of spacing and cutting on lucerne seed yield, further experiments should be carried out on established lucerne stands after the seeding year. It would be expected that optimum spacings for maximum seed yield might well differ from those found in the present study in the year of establishment.

4. SEED DEVELOPMENT

INTRODUCTION

Most researchers agree that seed development is concerned with those processes and stages occurring during the period from pollination until the seed is fully formed and ready for harvest. This development is accompanied by physiological changes in seed moisture content, seed weight, germination capacity and chemical changes in biochemical substances. The most important aspects of seed development which contribute a great deal to yield at the time of harvesting are seed maturity and ripeness. Several studies have been undertaken to determine the stage of maturity and ripeness of different crops in order to guide seed growers in deciding when crops are at the correct stage for harvest and therefore to obtain maximum quality and quantity seed crops (Hyde (1950), Shaw and Loomis (1950), Anderson (1954), Hyde et al (1959), Stoddart (1964a and 1964b) and Hill (1971)). However, less is known about seed development of lucerne. Apparently little published data has been reported on the length of time required from pollination until seed maturity or ripeness under field conditions in this species. The objective of the present investigation was to study changes in moisture content, fresh weight and dry weight of lucerne during seed development. In addition the relationship between stages of seed development and seed quality including germination capacity and the percentage of hard seed was also investigated.

LITERATURE REVIEW

It is necessary to clarify the terms "maturity" and "ripeness" since they are considered an important feature in seed development studies. The point at which maximum dry weight is first obtained is defined as "morphological maturity"

(Anderson 1954) or as "physiological maturity" (Shaw and Loomis 1950). Commonly however, researchers simply use the word "maturity" to describe the point at which maximum dry weight is first obtained. The ripening stage refers to a stage occurring from seed maturity until the seed has dried to a moisture content in equilibrium with ambient relative humidity (Hyde et al 1959) or to a moisture content that is suitable for harvesting (Hill 1971).

Careful studies on seed development of white clover, red clover and perennial ryegrass (Hyde 1950, Hyde et al 1959) have provided a very good guide for later researchers. These studies have shown that both grass and legume species follow the same pattern in three major stages of seed development. The first or growth stage occupies the first 10 days after flowering during which time the rate of growth is rapid (determined by cell division in the embryo and seedcoat) and the moisture content is high (75-80% of wet weight). The food reserve accumulation stage follows during which the rate of growth is determined by the rate at which food materials are transferred from the parent plant for accumulation in the developing seed. During this stage seed weight increases, reaching a maximum by the end of the stage which lasts for 10-14 days. Moisture content decreases to approximately 40%. The ripening stage normally lasts for 3-7 days. This final stage involves a fall in moisture content from about 40% to equilibrium with the surrounding atmosphere. It is expected that the same pattern of seed development could be applied to most species but the duration of time occupied by each stage may vary with both the species and seasonal conditions.

Changes in moisture content, seed weight, biochemical

substances, pod or seed colour and germination capacity during seed development of some agricultural species are of particular importance. Previous work often shows a close relationship between seed maturity and changes in these parameters.

1. Moisture Content

A good relationship between stages of seed development and seed moisture content has been reported by a number of investigators (Hyde (1950), Grabe (1956), Griffith et al (1967) and Hill (1971)). Generally, high moisture content (70-80%) is a characteristic of young seed in the early stages of seed development. This decreases as seeds go into an advanced or ripening stage of development. The convenience of assessment of moisture content renders it a desirable and widely used method among farmers for determining seed maturity and correct harvesting time of crops. For instance, bromegrass has been reported to be mature at a moisture content of 47% (Grabe 1956); and white clover at 63% (Hyde 1950). However, when using moisture content as a guide for maturity or harvesting Griffith et al (1967) and Hill (1971) agree that there are two aspects which farmers should be aware of - the relationship between moisture content and the percentage of seed viability may vary with growing season and also precipitation may alter the values obtained.

2. Seed Weight

The fresh weight of individual seeds increases with an increase in seed age (number of days after pollination) reaching a maximum at the time of seed maturity. After this point seed fresh weight decreases as the seed loses moisture until it reaches equilibrium with the ambient air relative humidity. However, the dry weight of individual seeds seems to be widely used among researchers to monitor seed development. For example,

an investigation by Chow and Crowder (1974) on Desmodium species shows that a maximum seed weight (maturity) is gained in this species about 28 days after flowering. Since there is often a good correlation between seed weight and the number of days after pollination, some researchers determine seed maturity and harvesting time in terms of this criterion. Al-Tikirty et al (1974) reported that the mean number of days required from pollination to seed maturity in crownvetch (Coronilla varia) ranged from 59.3 days for plants pollinated on July 15, 1969, but only 45.7 days for those pollinated on August, 1970. They explained that this difference of 14 days in the seed development period was due to differing environmental conditions, particularly rainfall and low temperatures.

3. Biochemical Changes

The chemical constituents of seeds are mainly genetically controlled but may also vary with environmental conditions. Besides the normal constituents which are commonly found in ordinary plant tissues, there are storage materials which are mostly found in seed. Carbohydrates, lipids and proteins are the three major seed constituents. Carbohydrates are mainly starch and hemicellulose, legume seeds generally containing more of the former than the latter. Lipids in seed can be in the form of either fats or oils. Protein in seed is different from other seed constituents because it is characterized by a high nitrogen content and most proteins are metabolically active (Mayer and Poljakoff-Maber 1975).

During food reserve accumulation, a large quantity of carbohydrate, free sugar and amino acids are translocated to the seed. In grass species the level of both total soluble sugars and amino acids rises sharply during the first phase of

seed development, decreasing gradually thereafter and becoming stable at the point of harvesting. Therefore stable levels of these compounds can provide a good indication of physiological ripeness (Stoddart 1964a and 1964b, Griffifth et al 1967).

4. Colour Changes

There is a good correlation between the stage of seed development and colour changes in the pod, seedcoat, pericarp and glumes (Hyde et al (1959), Griffifth et al (1967) and Hill 1971). More studies on this aspect have been carried out for grass species, less being known about such changes in legumes, particularly in the case of lucerne. According to Griffifth et al (1967) colour changes in perennial ryegrass during seed development is mainly due to variations in chlorophyll and anthocyanin content. Hyde et al (1959) suggested that the onset of colour changes starts at the second stage of seed development before seed is mature and hence is a sign of approaching maturity. Young red clover seeds are light green in colour and become yellow or coloured with red or purple pigments when they are well developed (Hyde et al (1959)). In this species they found that colour changes begin about 18 days after flowering and are completed about 24 days after flowering. However, the evidence found by Hyde et al (1959) and Stoddart (1964c) that in some years seedcoat of grass seed was still green at maturity suggests that colour changes alone cannot always be used as a reliable indicator for seed maturity. The more recent findings of Hill (1971) that changes in seed colour are affected by environmental conditions during seed development i.e. loss of greenness in grass seed was quicker under hot conditions than under humid conditions, lends strong support to the above statement.

5. Viability of Seed

According to Hyde et al (1959), seeds of most species have the ability to germinate at the beginning of the food reserve accumulation stage. They reported that white clover seed was first found to be viable 12 days after pollination. Subsequently there was a rapid increase in viability and 100% of the seeds were viable when harvested 14 days after pollination. One of the characteristics of legume seeds to be noted is the development of hard seed. It has been reported that hard seed formation first appears in red clover and white clover 14 days after pollination (Hyde et al 1959), and 17 days after pollination for Desmodium (Chow and Crowder 1974). The number of hard seeds formed increases with seed age, rising to a maximum 25 days after pollination for white clover (Hyde 1950) and 24 days after pollination for Desmodium (Chow and Crowder 1974).

6. Effect of Seed Age on Seedling Performance

The most valuable property of agricultural seed is the ability to maintain a high germination capacity during storage and to produce vigorous seedlings in the field. Studies on seed development of most plant species show that maximum viability of seed can be obtained before maturity. However if seeds have to be stored for any length of time before sowing or to ensure the production of vigorous seedlings, it is necessary that seeds be harvested after maturity. Mature seed contains more food reserves than immature seed, hence it can retain germination capacity for a longer period. In relation to this, Hyde (1950) reported that white clover seed 13 and 24 days old showed germination percentages of 5% and 79% respectively after storage under unfavourable conditions at 99°F and 70% RH for

one month. Irrespective of seedling vigour he also noted that immature white clover seeds produced smaller seedlings than mature seeds. When seeds were sown at a depth of 4 cm. he reported that 37% of seedlings (from 2⁴ day old seeds) penetrated through this depth while none of the seed removed from plants 12 or 14 days after pollination were unable to emerge from this depth.

7. Hard Seed

According to Hyde (1954) the word "hard seed" refers to seed which fails to imbibe water within a standard testing period. Mayer and Shain (1974) suggested that the hard seedcoat affects germination by providing an impermeable layer to water, interfering with various processes such as gaseous exchange and obstructing the diffusion of endogenous germination inhibitors. The inability of seed to germinate seems to have more disadvantages in farm practice than advantages, particularly when it causes uneven germination and subsequent seed crop contamination. The condition of hard-seededness is a characteristic of the ripe seed of the majority of leguminous species, especially the small seeded legumes, and also occurs in some other plant families e.g. Malvaceae, Connaceae, Geraniaceae, Chenopodiaceae, Convallariaceae, Convolvulaceae, and Solanaceae (Crocker and Barton (1953)).

Hard-seededness has been shown in some instances to be a genetic factor but the effect of environmental conditions on the plant during seed development also influences the level of hard seed content in seed lots (Nutile and Nutile (1947), Moorley (1958) and Mayer and Shain (1974)). The extent to which hard seed occurs varies with species, site of plantation and growing season. Abu-Shakra et al (1969) and Pacuta (1976)

reported that higher percentages of hard seed in lucerne are found in seeds developed under dry conditions than wet conditions. The occurrence of hard seed content in commercially harvested seed lots in lucerne may vary within the range 5-65% compared with 20-100% for hand threshed seed (Bolton 1962).

The findings of Hyde (1954) throws considerable light on the mechanism of hard seed development. They indicated that the onset of hard-seededness in some Papilionaceae begins during the ripening stage. As the seed dries, nearly 90% of the moisture in the seed passes out through the palisade epidermis and its cavity cuticle. Permeability decreases when the seed moisture content is approximately 25% and the seedcoat becomes impermeable at 14% moisture content. Further loss of water is through the hilum which is a one way valve, opening or closing according to differences in moisture tension between the counter palisade and the epidermis cells. There was some confusion in the past about the causes of seedcoat impermeability. It has long been known that the malpighian or palisade layers obstruct the inward passage of water (Hamley (1932) and Martin and Watt (1944)). Recent work by Ballard (1973) however has also shown that the suberized regions of malpighian cells persist well below the light line to deep levels and are the main barrier to water entry.

The condition of hard-seededness can be removed by several means, thereby enabling normal germination to occur. Under field conditions the daily temperature cycle is a causative agent in softening impermeable seed (Quinlivan (1965) and Hagon (1971)). The same role of temperature in reducing hard-seededness might be expected to operate under storage conditions since the air relative humidity during storage also

plays an important role on breaking hard-seededness. Nutile and Nutile (1947) and Owen (1956) agree that hard seed in certain species can be rendered permeable at will by increasing the seed moisture content by storage under high relative humidity conditions.

RESULTS

Mean values of changes in the physiological components fresh weight (FW), dry weight (DW), weight of moisture (M) and moisture percentage at different seed ages are graphically shown in Figure 11.

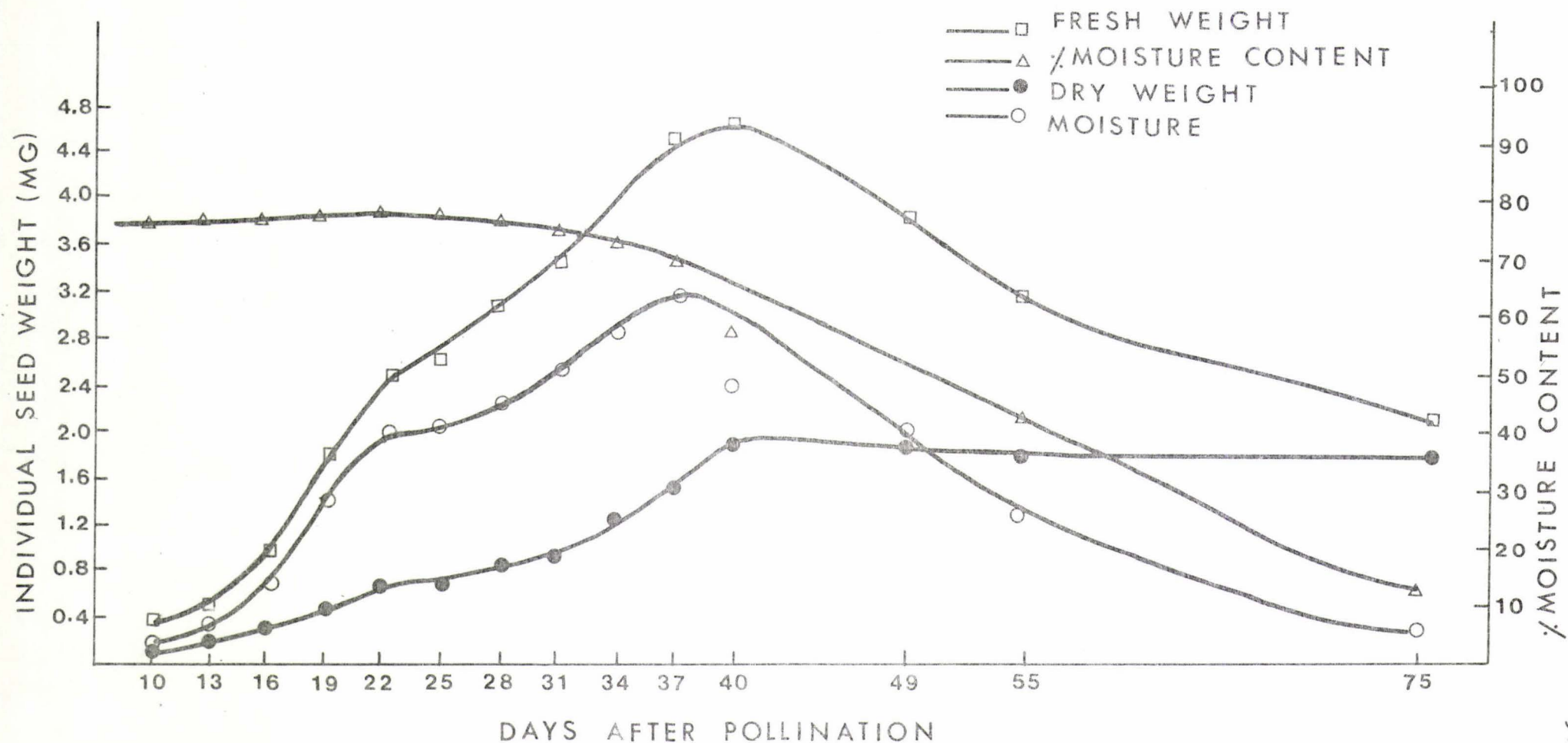
1. Fresh Weight (FW)

Ten days after pollination, FW of individual seeds was as low as .23 mg. (8% of final value). From this point, seed weight increased markedly during the period 10-22 days after pollination. FW of individual seeds was .43 gm. when harvested 13 days after pollination and .91 mg. 16 days after pollination. At the 22nd day, FW had reached 2.79 mg. (Appendix 21). From the period of 23-40 days after pollination, there was a more gradual increase when compared to the period up to 22 days. Maximum individual seed fresh weight of 4.5 mg. was attained 40 days after pollination. Following this peak, FW was found to decrease owing to a loss in moisture. In this experiment the period of moisture loss occurred from 41 days up to 75 days after pollination, the final FW of individual seeds being recorded at 2.22 mg.

2. Dry Weight (DW)

Mean seed dry weight was 0.09 mg. when harvested 10 days after pollination. Changes in seed dry weight with time (seed age) shows essentially the same pattern as changes in fresh

FIGURE 11 CHANGES IN PHYSIOLOGICAL COMPONENTS



weight during the period up to 40 days after pollination. It has been shown in Figure 11 that maximum mean dry weight of individual seeds (1.89 mg.) was obtained 40 days after pollination. Following this point, the value of seed dry weight remained relatively constant. Therefore lucerne seed is considered to be physiologically mature at 40 days after flowering.

3. Moisture Content of the Seed

In this section, moisture content of the seed is expressed as both the actual weight of moisture present in the seed and moisture content percentage (wet basis). Changes in seed moisture content can be described as a rapid increase from about 0.17 mg. on the 10th day after pollination to 1.92 mg. per seed by the 22nd day. It is interesting to note that the highest seed moisture content was reached 37 days after pollination (a few days before maturity). Subsequently there was a decrease in moisture content as the seed entered the drying or ripening stage.

When considering the seed moisture content in terms of percentage (wet weight basis), it is generally found to be relatively high (70-75%) during the period between 10-37 days after pollination. The highest value of 78% was recorded 19 days after pollination. After this point there was a decrease in % m.c. At maturity (the point of maximum dry weight) the seed moisture content was approximately 58%. Seeds seemed to dry out very slowly, the time taken for moisture content to fall from 70% to 14% was up to 38 days. The daily temperatures recorded during the first few days after maturity were high. The weather then became cooler, minimum temperatures ranging from 2^o-12^oC and maximums between 16^o and 27^oC. Maximum

relative humidity ranged from 93-100%, with minimum values between 34-82%. There were also 15 days when rainfall was more than 1.00 mm. during this stage (Appendices 23, 24 and 25).

4. Changes in the Appearance of Seed and Pod

A careful examination of pods and seeds showed that during the period from 10-19 days after pollination, pods were relatively small and green in colour and contained small green seeds which were very soft. Between 23 and 31 days after pollination both pods and seeds enlarged although the pods were still green.

Pod colour began to change from green to yellow 34 days after pollination. At this stage the seedcoat was quite firm. At seed maturity (40 days after pollination), it was noted that approximately 50% of the pods harvested were yellow, the remainder green and the seeds were relatively large. Seedcoat colour was equally distributed between yellowish-green and greenish-yellow categories.

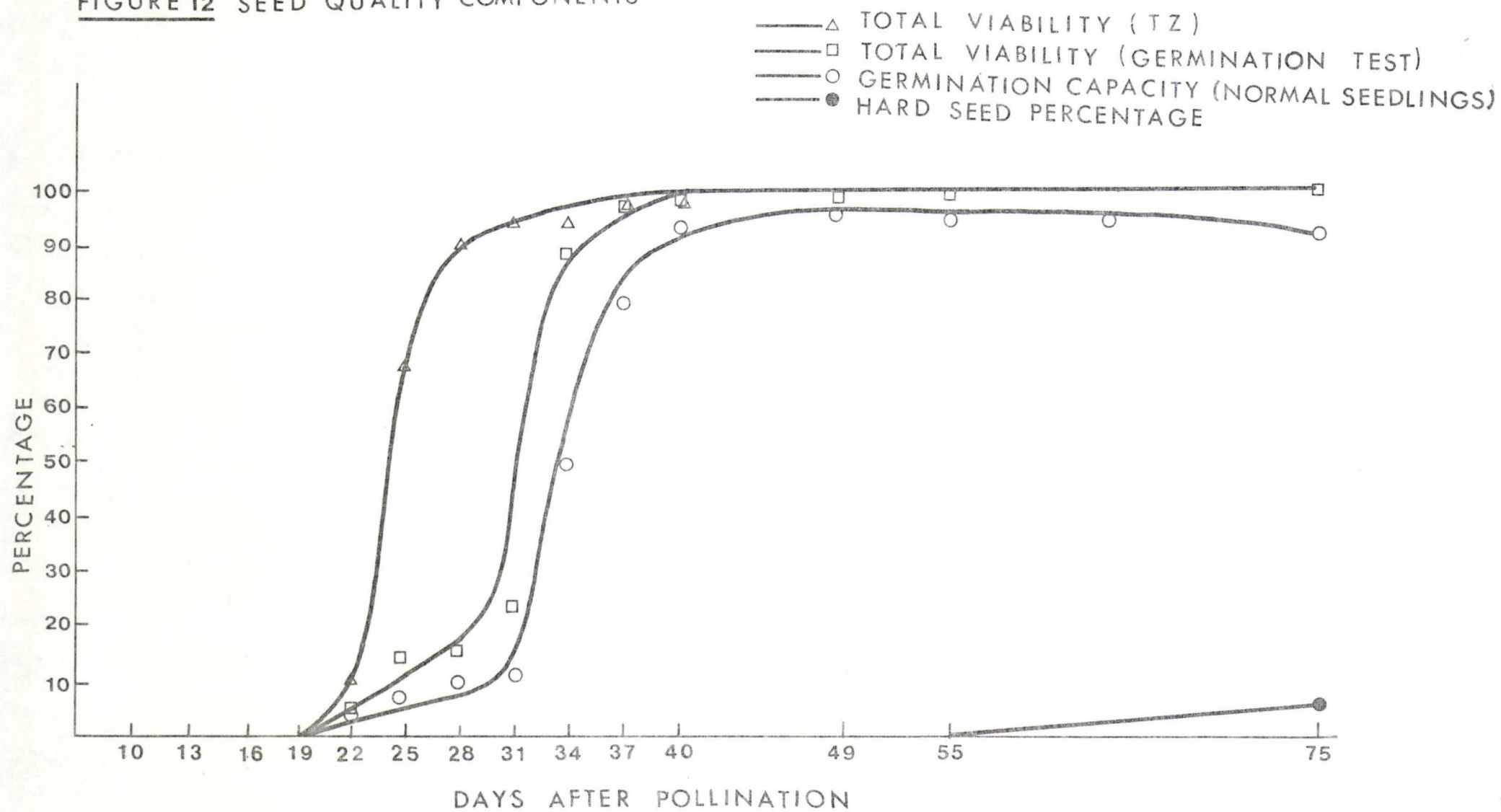
Pods harvested 49 days after pollination, ranged in colour from yellow to dark brown except for a small number which still showed traces of greenness.

At the final harvest (75 days after pollination), all pods were black and the seedcoat was relatively firm. At this stage of seed development seedcoat colour was variable between yellow and brown. No green seeds were observed.

5. Germination Capacity (Normal Seedling)

No seeds harvested 10-19 days after pollination were capable of germination. The first germination result (3%) was recorded with tests on seeds which had been harvested 22 days after pollination. There appeared to be a slow increase in

FIGURE 12 SEED QUALITY COMPONENTS



germination capacity (3-11%) up to 31 days after pollination and a marked increase between 32 and 34 days. At seed maturity (40 days after pollination) germination was about 95%. Seeds between 40 and 55 days old tended to show a consistent germination in the range 95-96%. As there was a shortage of seed available for study, the final sample tested was obtained from a harvest 75 days after pollination when the pods were black to ensure complete seed ripeness. When these seeds were subjected to a germination test, it was found that 92% produced normal seedlings with 2% abnormal seedlings and 6% hard seed.

6. Viability

Viability results obtained from a tetrazolium test (TZ) and also as total viability from a germination test are presented in Figure 12. The interpretation of viable seed from the T.Z. test was carried out according to the I.S.T.A. rules for small-seeded legumes. The total viability figure of seed from the germination test included the sum of normal seedlings, abnormal seedlings, hard seeds and fresh ungerminated seeds.

The T.Z. test showed that 10% of seeds were viable 22 days after pollination. The viability of seed removed from plants 25 to 28 days after pollination rose sharply, the percentage of viable seeds harvested at 25 and 28 days after pollination being 70% and 90% respectively. High viability (96%) was first attained with seed harvested 37 days after pollination.

Laboratory germination test results showed that viable seeds (5%) were first found in samples of 22 day old seed. Total viability of seed increased gradually from 23 up to 31 days after pollination and was greatly increased in 34 day old samples. While a viability of 88% was obtained 34 days after

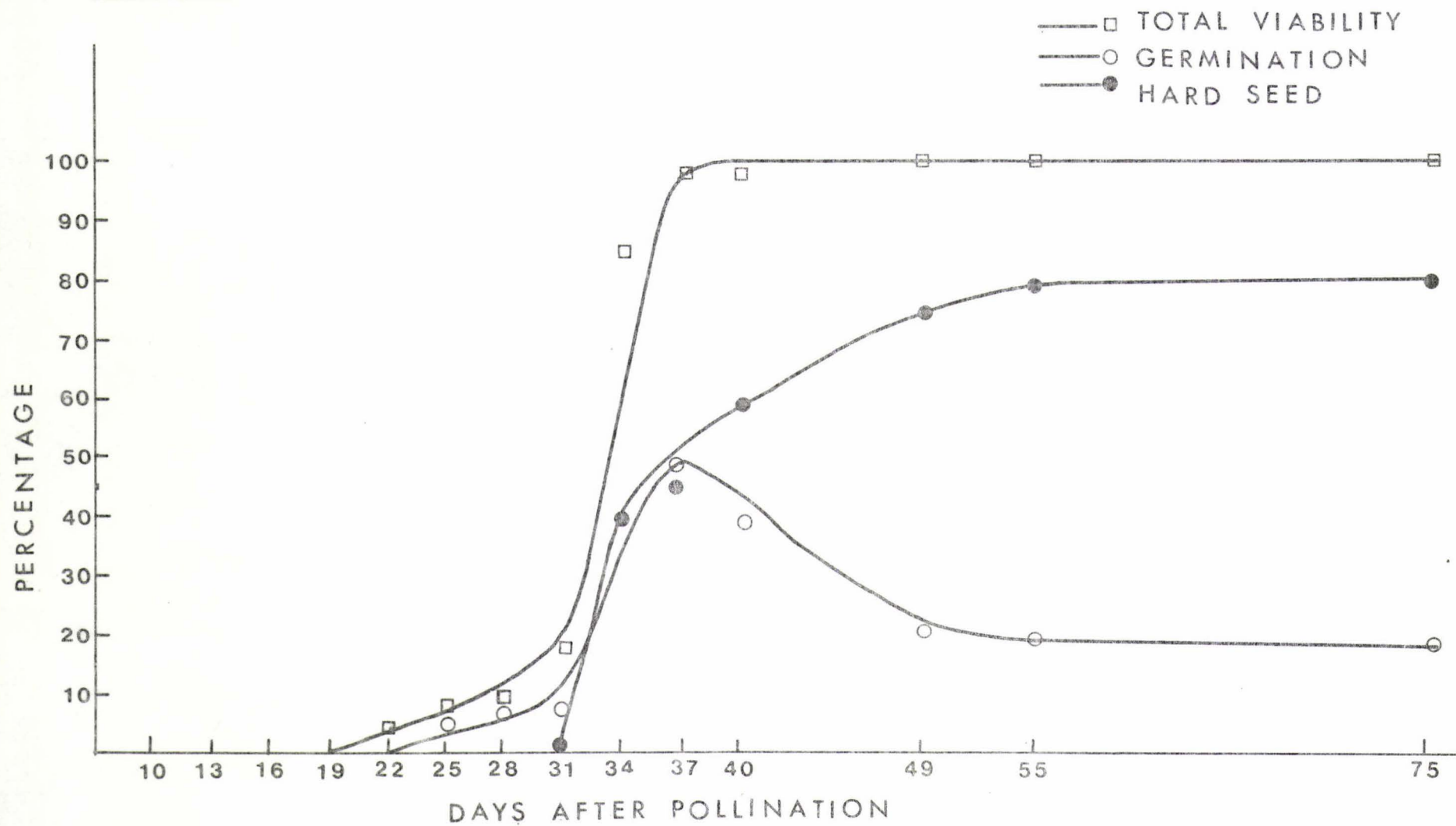
pollination, there tended to be a gradual increase in this value which reached in excess of 98% in samples of seed harvested 40 days after pollination.

7. Storage Longevity

In addition to the determination of physiological components and quality of freshly harvested seed, samples of pods from different harvests were stored in the laboratory for 12 weeks for a comparative study of seed longevity. The germination results obtained showed a lower germination percentage when seeds were stored in pods for 12 weeks under ambient conditions (12° - 24° C and 42-70% R.H.) than results obtained from seeds germinated immediately after harvest (Figure 12). This difference is very small for stored samples of seed obtained from plants 22-31 days after pollination. Seed samples 22 and 31 days after pollination showed a germination percentage of 2% and 8% respectively. A peak of germination (40-49%) occurred with seeds which had been removed from plants 34-37 days after pollination and stored for 12 weeks. Following this peak, there was a subsequent decrease in germination percentage caused by an increase in the percentage of hard seed formed. One particular aspect to be noted is that the onset of hard seed development occurred with stored seed originally harvested 34 days after pollination. As can be seen in Figure 13, the germination result of seeds stored for 12 weeks declined from 49% in stored samples of 37 day old seed to 18% in 75 day old seed. On the other hand a corresponding increase in hard seed content was observed reaching a maximum (79%) in stored samples of seed harvested 55 days after pollination.

When a comparison was made of seedling size between tests on immature seed (31 days old) and more mature seed (55

FIGURE 13 SEED QUALITY COMPONENTS AFTER 3 MONTH STORAGE



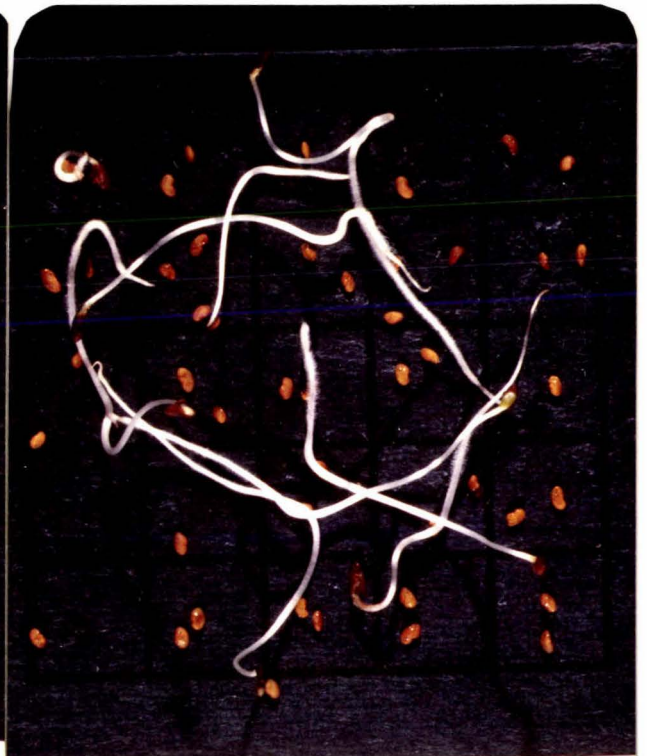
day old), it was observed that seedlings obtained from mature seed samples were larger and healthier than those obtained from immature seed (Plate 9). Apart from producing weak seedlings, immature seeds were also particularly susceptible to attack from fungi during a laboratory germination test.

PLATE 9.

GERMINATION TESTS ON SAMPLES OF IMMATURE AND
MATURE LUCERNE SEEDS AFTER 3 MONTH STORAGE



seedlings of 31 day old seeds
(immature seeds)



seedlings of 55 day old seeds
(mature seeds)

DISCUSSION

1. Stages of Seed Development

Mean values of individual seed weight suggest that changes in both FW and DW with time are similar. Changes in seed weight of lucerne during seed development follow three distinct phases similar to those previously described in red clover, white clover and perennial ryegrass by Hyde (1950) and Hyde et al (1959).

In lucerne, the growth stage refers to the period of seed development up to 22 days after pollination. Seed doubled its initial weight every three days during this period. A marked increase in seed size and embryo size was observed during this period and confirmed the statement of Hyde (1950) that the rapid increase in seed weight during this stage is presumably due to cell multiplication in both the embryo and cotyledons. Early in this stage of development the seed has a high moisture content (77-87%) and at the end of this stage seed dry weight was approximately 30% of its final value and 3% of seeds were capable of germination. This latter aspect does not agree with the work of Hyde (1950) and Hyde et al (1959) with other species which showed that no white clover, red clover or perennial ryegrass seeds were viable at this stage. This may be due to differences in the rate of seed growth between species and under different environmental conditions. The rate of growth of seed 22 days after pollination may still be rapid although such seeds had grown large enough to suggest they may contain small but sufficient amounts of food reserve material to assist seed germination.

A more gradual increase in seed weight occurred during the period from 23-40 days after pollination. This stage of

growth may be referred to as the food reserve accumulation stage as termed by Hyde (1950). Maximum seed dry weight was reached 40 days after pollination. At this point seed was considered to be physiologically mature as suggested by Shaw and Loomis (1950). Total viability of seed as determined by a laboratory germination test increased slowly from 23-31 days and markedly increased between seed samples harvested 32-34 days after pollination. A high level of seed viability had been attained a few days before seed maturity. The amount of seed viability is thought to be associated with the level of food reserve material in the seed. The low germination percentage of immature seed may be due to infestation by fungi during testing and by the production of a high percentage of abnormal seedlings. This latter aspect was particularly evident when germinating young seeds (31-34 days after pollination) indicating that the soft embryo tissues can be easily damaged even when seeds are removed from pods by hand. The degree of damage appeared to be less when seed was harvested at an older stage as the seedcoat became firmer. However, when germinating freshly harvested seed at the time of seed maturity, levels of abnormal seedlings of approximately 5% were still found. Changes in pod and seed colour with increasing maturity may be due to variation in the levels of chlorophyll content as found in perennial ryegrass by Griffith et al (1967). In the present study pod colour changed from green to yellow and could be detected a few days before seed maturity. This agrees with the findings of Hyde et al (1959) that the onset of colour changes in grass and legume seeds occurs prior to seed maturity at the second stage of seed development. However, when colour changes are used as a guide to harvest suitability the results can be

misleading since seasonal weather conditions can influence the onset of colour changes as reported by Hill (1971). At the end of this stage seed moisture content is still high (58%) and consequently no hard seed was found when such seed was tested immediately after harvest.

The ripening stage of lucerne observed in this experiment was longer than the ripening stage for red clover and white clover (3-5 days) reported by Hyde et al (1959). Species characteristics and weather conditions seem to be responsible for differences in the length of time occupied by this stage. It appears that seed growth rate in lucerne is not as rapid as in red clover and white clover since lucerne takes 40 days after pollination to reach seed maturity. Weather conditions during the seed ripening stage were cool and moist and pollination occurred perhaps 6-8 weeks later than would occur in a normal growing season. In relation to similar weather conditions Al-Tikirty et al (1974) reported that crown vetch seeds developing during cool and moist conditions reached maturity 14 days later than seed development in a normal growing season. On this basis, it would be expected that cold and moist weather conditions might have a bearing on prolonging the ripening stage of lucerne. In this experiment the time taken from maturity (58% M.C.) till seed ripening (14% M.C.) was 35 days. The rate of seed drying was therefore approximately 1.2% per day.

2. Viability and Germination Capacity

Viable seed results obtained from tetrazolium testing are initially higher than the values obtained from a laboratory germination test. Ninety percent of seeds were found to be viable by the T.Z. tests on seed harvested 28 days after

pollination whereas the germination test showed only 16% of normal seedlings. This difference is possibly due to the presence of active enzyme systems in the young embryo which although they reacted well with the tetrazolium solution were insufficient to enable the seed to be germinable. These results do not agree with those of Hill and Watkin (1975) who found a good relationship between T.Z. test and germination results with freshly harvested grass species.

3. Seed Longevity

Results from this study indicate that seed quality components such as total viability, germination and hard seed percentage were altered by even a relatively short storage period. Total viability of young seed harvested 22-34 days after pollination was much lower after storage for 12 weeks when compared with results of seeds tested immediately after harvest. The rate of germination of young seed tested after 3 months storage was also slower than with tests on freshly harvested seed. The overall results agree with the previous work by Hyde (1950) and Hill and Watkin (1975), that immature seed is inclined to lose germination capacity more quickly than mature seed during storage. Their explanation was that lack of food reserve material in immature seed causes shortened storage life since seed harvested at this stage has not reached a maximum dry weight. Another aspect of seed quality in legumes which is considered important is the hard seed condition. There is a great difference in the rate of onset of hard-seededness between freshly harvested seed and seed tested after 3 months storage. No hard seed was found in even mature seed samples tested immediately after harvest except in seed harvested 75 days after pollination (6%). However after 3

months storage it was observed that 45% of immature seeds (34 days after pollination) were impermeable to water. This result agrees with the work by Win Pe (pers. comm.) on red clover seed that the onset of hard seededness was observed as early as 14 days after pollination when seed was tested after 3 months storage whereas hard seed first appeared after maturity (30 days after pollination) when seed was tested immediately after harvest. The findings of Hyde (1950) in relation to the onset of hard seed in small seeded legumes do not agree with the freshly harvested seed results for lucerne in the present study. However they do agree with the 3 months storage results. Seed age (number of days after pollination) is apparently an important factor governing the hard seed condition. The absence of hard seed in samples removed from the plant up to 55 days after pollination and tested immediately after harvest was possibly due to high seed moisture content (75-42%). Hyde (1954) has shown that in red and white clover hard seed development occurs as a result of seed drying to a level that causes seedcoat impermeability (14% in white and red clover). He showed that the loss of moisture through the palisade layer was the main cause of impermeability. This situation could explain differences in the hard seed content of seed of high moisture content tested immediately after removal from the plant and the much higher values (up to 79%) obtained when seed was allowed to air dry to 9-10% seed moisture content during a short storage period.

CONCLUSION

In lucerne the assessment of seed growth rate by the determination of seed dry weight reveals three distinct phases during seed development. The growth stage involves the period up to 22 days after pollination; the food reserve accumulation

stage occupies the period between 23-40 days after pollination, and the ripening stage occupies the period between 41 and 75 days after pollination.

With regard to seed viability at harvest, results from tetrazolium tests show a higher value than laboratory germination test results, particularly in the case of young seed up to 28 days after pollination. Such differences were attributed to the role of fungal infestation and a high proportion of abnormal seedlings. To ensure high seed quality (high germination capacity, heavy seed, seed producing vigorous seedlings) it is necessary that seed should not be harvested until it is mature (40 days after pollination).

Storage results of the seed development trial indicate that immature seed tend to lose viability more rapidly than mature seed. To maintain high seed quality during storage it is important that seed be harvested after maturity.

The great differences in the extent of hard-seededness when seed samples of different ages were tested immediately after harvest (high % MC) and again after 3 months storage (low % MC) indicate that the amount of hard seed in lucerne is governed by both seed age (number of days after pollination) storage conditions and the level of seed moisture content.

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APPENDIX 1

ANALYSIS OF VARIANCE OF HERBAGE FRESH WEIGHT (KG/HA).

SOURCE	DF	SS	MS	F CAL	F REQ 1PC	F REQ 5PC	LSD 1PC	LSD 5PC
REPLICATE	3.	262884.818	87628.272	5.103	4.31	2.84		
TREATMENT A	3.	182291115.935	60763705.312	3538.569	4.31	2.84	125.277	93.633
TREATMENT B	3.	53940470.060	17980156.686	1047.073	4.31	2.84	125.277	93.633
AXB INTERACTION	9.	8922450.509	991383.390	57.733	2.88	2.12	250.554	187.267
ERROR	45.	772732.443	17171.832					

COEFF VAR = 4.02

MEANS FOR AXB INTERACTION

MEANS FOR CUTTING

	30X30 CM.	20X20 CM.	15X15 CM.	10X10 CM.	
FHC	418.751	505.251	2919.501	3015.751	1714.813 d
FLC	1209.751	1512.001	4837.251	6243.501	3450.626 c
SHC	2198.251	2205.001	4469.751	6238.501	3777.876 b
SLC	2420.001	2433.001	5231.501	6252.001	4084.126 a

MEANS FOR

SPACING	1561.688	1663.813	4364.501	5437.439
	d	c	b	a

FACTOR A IS SPACING AND FACTOR B IS CUTTING

APPENDIX 2

ANALYSIS OF VARIANCE OF HERBAGE DRY WEIGHT (KG/HA).

SOURCE	DF	SS	MS	F CAL	F REQ 1PC	F REQ 5PC	LSD 1PC	LSD 5PC
REPLICATE	3.	10043.5647	3347.8549	4.463	4.31	2.84		
TREATMENT A	3.	9786589.0645	3262196.3548	4348.895	4.31	2.84	26.184	19.570
TREATMENT B	3.	2605376.3147	868458.7716	1157.759	4.31	2.84	26.184	19.570
AXB INTERACTION	9.	462317.0610	51368.5623	68.480	2.88	2.12	52.367	39.140
ERROR	45.	33755.4358	750.1208					

COEFF VAR = 3.79

MEANS FOR AXB INTERACTION

MEANS FOR CUTTING

	30X30 CM.	20X20 CM.	15X15 CM.	10X10 CM.	
FHC	87.501	105.001	659.001	683.001	383.626 d
FLC	252.501	310.751	1100.001	1412.001	768.813 c
SHC	472.001	480.001	1018.251	1333.501	825.938 b
SLC	490.251	514.251	1202.001	1433.501	910.001 a

MEANS FOR

SPACING	325.564	352.501	994.813	1215.501
	d	c	b	a

FACTOR A IS SPACING AND FACTOR B IS CUTTING

APPENDIX 3

ANALYSIS OF VARIANCE OF DRY MATTER PERCENTAGE OF HERBAGE YIELD

SOURCE	DF	SS	MS	F CAL	F REQ 1PC	F REQ 5PC	LSD 1PC	LSD 5PC
REPLICATE	3.	0.0842	0.0281	0.192	4.31	2.84		
TREATMENT A	3.	42.5742	14.1914	97.301	4.31	2.84	0.365	0.273
TREATMENT B	3.	0.2230	0.0743	0.510	4.31	2.84	0.365	0.273
AXB INTERACTION	9.	11.3427	1.2603	8.641	2.88	2.12	0.730	0.546
ERROR	45.	6.5633	0.1459					

COEFF VAR = 1.76

	MEANS FOR AXB INTERACTION				MEANS FOR CUTTING
	30X30 CM.	20X20 CM.	15X15 CM.	10X10 CM.	
FHC	20.876	20.751	22.576	22.651	21.714
FLC	20.876	20.551	22.726	22.626	21.695
SHC	21.201	21.776	22.426	21.401	21.701
SLC	20.276	21.151	23.001	22.926	21.839
MEANS FOR SPACING	20.807	21.057	22.682	22.401	
	b	b	a	a	

FACTOR A IS SPACING AND FACTOR B IS CUTTING

APPENDIX 4.

ANALYSIS OF VARIANCE OF SEED YIELD PER UNIT AREA (KG/HA).

SOURCE	DF	SS	MS	F CAL	F REQ 1PC	F REQ 5PC	LSD 1PC	LSD 5PC
REPLICATE	3.	280.053	93.351	3.032	4.20	2.79		
TREATMENT A	4.	68066.451	17016.612	552.706	3.72	2.56	5.218	3.923
TREATMENT B	3.	18962.918	6320.972	205.308	4.20	2.79	4.667	3.509
AXB INTERACTION	12.	25270.853	2105.904	68.401	2.56	1.95	10.436	7.847
ERROR	57.	1754.906	30.787					

COEFF VAR = 19.43

MEANS FOR AXB INTERACTION

MEANS FOR SPACING

	CONTROL	FHC	FLC	SHC	SLC	
30X30 CM.	124.716	55.974	24.736	11.949	6.171	44.709 a
20X20 CM.	137.356	44.169	20.401	7.441	5.061	42.885 a
15X15 CM.	49.659	12.994	7.634	6.479	4.921	16.337 b
10X10 CM.	23.269	13.149	10.594	2.881	1.704	10.319 c
MEANS FOR CUTTING	83.750	31.571	15.841	7.187	4.464	
	a	b	c	d	d	

FACTOR A IS CUTTING. FACTOR B IS SPACING

APPENDIX 5.

ANALYSIS OF VARIANCE OF SEED YIELD PER PLANT (GR/PL).

SOURCE	DF	SS	MS	F CAL	F REQ 1PC	F REQ 5PC	LSD 1PC	LSD 5PC
REPLICATE	3.	0.041	0.013	1.952	4.20	2.79		
TREATMENT A	4.	6.300	1.575	224.390	3.72	2.56	0.079	0.059
TREATMENT B	3.	5.522	1.840	262.229	4.20	2.79	0.070	0.053
AXB INTERACTION	12.	4.148	0.345	49.252	2.56	1.95	0.158	0.118
ERROR	57.	0.400	0.007					

COEFF VAR = 23.98

	MEANS FOR AXB INTERACTION					MEANS FOR SPACING
	CONTROL	FHC	FLC	SHC	SLC	
30X30 CM.	1.583	1.165	0.520	0.275	0.162	0.741 a
20X20 CM.	1.322	0.387	0.211	0.166	0.073	0.432 b
15X15 CM.	0.384	0.168	0.087	0.102	0.037	0.155 c
10X10 CM.	0.113	0.086	0.066	0.061	0.022	0.070 d
MEANS FOR CUTTING	0.851	0.451	0.221	0.151	0.073	
	a	b	c	d	e	

FACTOR A IS CUTTING. FACTOR B IS SPACING

APPENDIX 6.

ANALYSIS OF VARIANCE OF SEED NUMBER PER PLANT.

SOURCE	DF	SS	MS	F CAL	F REQ 1PC	F REQ 5PC	LSD 1PC	LSD 5PC
REPLICATE	3.	8884.327	2961.442	1.769	4.20	2.79		
TREATMENT A	4.	1074193.998	268548.499	160.426	3.72	2.56	38.478	28.931
TREATMENT B	3.	1191658.708	397219.569	237.291	4.20	2.79	34.416	25.876
AXB INTERACTION	12.	753570.629	62797.552	37.514	2.56	1.95	76.956	57.862
ERROR	57.	95416.625	1673.975					
COEFF VAR =	24.40							

MEANS FOR AXB INTERACTION

MEANS FOR SPACING

	CONTROL	FHC	FLC	SHC	SLC	
30X30 CM.	667.151	566.426	270.576	153.126	93.351	350.126 a
20X20 CM.	577.251	196.351	110.276	96.626	43.801	204.861 b
15X15 CM.	168.001	88.276	47.726	63.426	23.251	78.136 c
10X10 CM.	53.301	46.576	36.276	38.601	13.726	37.696 d
MEANS FOR CUTTING	366.426	224.407	116.214	87.945	43.532	
	a	b	c	d	e	

FACTOR A IS CUTTING. FACTOR B IS SPACING

APPENDIX 7.

ANALYSIS OF VARIANCE OF POD NUMBER PER PLANT.

SOURCE	DF	SS	MS	F CAL	F REQ 1PC	F REQ 5PC	LSD 1PC	LSD 5PC
REPLICATE	3.	3526.213	1175.404	5.377	4.20	2.70		
TREATMENT A	4.	220569.961	55142.490	252.238	3.72	2.56	13.905	10.455
TREATMENT B	3.	224252.397	74750.799	341.932	4.20	2.79	12.437	9.351
AXB INTERACTION	12.	131051.608	10920.967	49.956	2.56	1.95	27.810	20.910
ERROR	57.	12460.939	218.613					
COEFF VAR =		21.05						

MEANS FOR AXB INTERACTION

MEANS FOR SPACING

	CONTROL	FHC	FLC	SHC	SLC	
30X30 CM.	327.951	207.426	101.176	74.251	43.876	150.936 a
20X20 CM.	231.126	82.251	37.701	37.951	21.701	82.146 b
15X15 CM.	87.926	32.076	24.701	24.376	9.351	35.686 c
10X10 CM.	18.626	15.626	11.976	8.501	6.426	12.231 d
MEANS FOR CUTTING	166.407	84.345	43.889	36.270	20.339	
	a	b	c	c	d	

FACTOR A IS CUTTING. FACTOR B IS SPACING

APPENDIX 8.

ANALYSIS OF VARIANCE OF CLUSTER NUMBER PER PLANT.

SOURCE	DF	SS	MS	F CAL	F REQ 1PC	F REQ 5PC	LSD 1PC	LSD 5PC
REPLICATE	3.	58.897	19.632	4.436	4.20	2.79		
TREATMENT A	4.	10372.626	2593.156	585.913	3.72	2.56	1.979	1.488
TREATMENT B	3.	6302.167	2100.722	474.649	4.20	2.79	1.770	1.331
AXB INTERACTION	12.	4178.646	348.220	78.679	2.56	1.95	3.957	2.975
ERROR	57.	252.273	4.425					
COEFF VAR =	14.09							

MEANS FOR AXB INTERACTION

MEANS FOR SPACING

	CONTROL	FHC	FLC	SHC	SLC	
30X30 CM.	62.301	33.401	17.951	15.026	10.001	27.736 a
20X20 CM.	52.626	16.551	8.251	8.251	4.576	18.051 b
15X15 CM.	22.901	9.651	6.451	6.351	2.801	9.631 c
10X10 CM.	7.876	5.601	3.651	2.351	1.951	4.286 d
MEANS FOR CUTTING	36.426	16.301	9.076	7.995	4.832	
	a	b	c	c	d	

FACTOR A IS CUTTING. FACTOR B IS SPACING

APPENDIX 9.

ANALYSIS OF VARIANCE OF MAXIMUM FLOWER NUMBER PER PLANT.

SOURCE	DF	SS	MS	F CAL	F REQ 1PC	F REQ 5PC	LSD 1PC	LSD 5PC
REPLICATE	3.	2.989	0.996	0.241	4.20	2.79		
TREATMENT A	4.	989.302	247.325	59.867	3.72	2.56	1.911	1.437
TREATMENT B	3.	364.349	121.449	29.398	4.20	2.79	1.710	1.285
AXB INTERACTION	12.	163.438	13.619	3.297	2.56	1.95	3.823	2.874
ERROR	57.	235.480	4.131					
COEFF VAR =		33.19						

MEANS FOR AXB INTERACTION

MEANS FOR SPACING

	CONTROL	FHC	FLC	SHC	SLC	
30X30 CM.	16.051	5.551	7.551	6.751	6.151	8.411 a
20X20 CM.	17.951	4.301	5.601	5.751	4.551	7.631 a
15X15 CM.	12.901	2.851	4.451	4.401	3.151	5.551 b
10X10 CM.	5.401	1.751	3.001	2.001	2.351	2.901 c
MEANS FOR CUTTING	13.076	3.613	5.151	4.726	4.051	
	a	c	b	bc	bc	

FACTOR A IS CUTTING. FACTOR B IS SPACING

APPENDIX 10.

ANALYSIS OF VARIANCE OF TOTAL SHOOTS PER PLANT.

SOURCE	DF	SS	MS	F CAL	F REQ 1PC	F REQ 5PC	LSD 1PC	LSD 5PC
REPLICATE	3.	33.708	11.236	0.698	4.20	2.79		
TREATMENT A	4.	241.850	60.462	3.755	3.72	2.56	3.774	2.838
TREATMENT B	3.	4857.088	1619.029	100.542	4.20	2.79	3.376	2.538
AXB INTERACTION	12.	292.972	24.414	1.516	2.56	1.95	7.548	5.675
ERROR	57.	917.874	16.103					
COEFF VAR =	15.21							

MEANS FOR AXB INTERACTION

MEANS FOR SPACING

	CONTROL	FHC	FLC	SEC	SLC	
30X30 CM.	29.251	39.551	34.376	37.151	40.051	36.076 a
20X20 CM.	31.051	28.801	29.601	28.901	32.651	30.201 b
15X15 CM.	22.201	27.576	25.251	21.601	24.626	24.251 c
10X10 CM.	13.951	15.851	11.751	15.501	17.901	14.991 d
MEANS FOR CUTTING	24.114	27.945	25.245	25.739	28.807	
	b	ab	b	b	a	

FACTOR A IS CUTTING. FACTOR B IS SPACING

APPENDIX 11.

ANALYSIS OF VARIANCE OF REPRODUCTIVE SHOOTS PER PLANT.

SOURCE	DF	SS	MS	F CAL	F REQ 1PC	F REQ 5PC	LSD 1PC	LSD 5PC
REPLICATE	3.	2.006	0.668	1.425	4.20	2.79		
TREATMENT A	4.	119.197	29.799	63.477	3.72	2.56	0.644	0.484
TREATMENT B	3.	131.512	43.837	93.381	4.20	2.79	0.576	0.433
AXB INTERACTION	12.	13.365	1.113	2.372	2.56	1.95	1.289	0.969
ERROR	57.	26.758	0.469					
COEFF VAR =	18.04							

MEANS FOR AXB INTERACTION

MEANS FOR SPACING

	CONTROL	FHC	FLC	SHC	SLC	
30X30 CM.	7.251	6.401	5.201	5.501	3.501	5.571 a
20X20 CM.	6.601	5.251	3.151	3.801	2.476	4.256 b
15X15 CM.	5.601	4.301	2.101	2.951	1.501	3.291 c
10X10 CM.	3.351	2.501	1.901	1.201	1.426	2.076 d
MEANS FOR						
CUTTING	5.701	4.614	3.089	3.364	2.226	
	a	b	c	c	d	

FACTOR A IS CUTTING. FACTOR B IS SPACING

APPENDIX 12.

ANALYSIS OF VARIANCE OF PERCENTAGE OF SHOOTS PRODUCED SEED.

SOURCE	DF	SS	MS	F CAL	F REQ 1PC	F REQ 5PC	LSD 1PC	LSD 5PC
REPLICATE	3.	10.257	3.419	0.398	4.20	2.79		
TREATMENT A	4.	2200.707	550.176	64.044	3.72	2.56	2.756	2.072
TREATMENT B	3.	37.336	12.445	1.449	4.20	2.79	2.465	1.854
AXB INTERACTION	12.	308.458	25.704	2.992	2.56	1.95	5.513	4.145
ERROR	57.	489.667	8.590					
COEFF VAR =	20.06							

MEANS FOR AXB INTERACTION

MEANS FOR SPACING

	CONTROL	FHC	FLC	SHC	SLC	
30X30 CM.	23.026	16.376	15.076	14.901	9.326	15.741 a
20X20 CM.	21.351	18.076	10.726	13.151	7.776	14.216 a
15X15 CM.	25.601	15.951	8.301	13.701	6.226	13.956 a
10X10 CM.	24.001	16.351	16.226	7.976	8.151	14.541 a
MEANS FOR CUTTING	23.495	16.689	12.582	12.432	7.870	
	a	b	c	c	d	

FACTOR A IS CUTTING. FACTOR B IS SPACING

APPENDIX 13.

ANALYSIS OF VARIANCE OF 1000 SEED WEIGHT (GM).

SOURCE	DF	SS	MS	F CAL	F REQ 1PC	F REQ 5PC	LSD 1PC	LSD 5PC
REPLICATE	3.	0.007	0.002	0.518	4.20	2.79		
TREATMENT A	4.	4.403	1.100	220.829	3.72	2.56	0.066	0.050
TREATMENT B	3.	0.575	0.191	38.494	4.20	2.79	0.059	0.048
AXB INTERACTION	12.	0.042	0.003	0.716	2.56	1.95	0.133	0.100
ERROR	57.	0.284	0.005					

COEFF VAR = 3.79

MEANS FOR AXB INTERACTION

MEANS FOR SPACING

	CONTROL	FHC	FLC	SHC	SLC	
30X30 CM.	2.373	2.060	1.939	1.788	1.725	1.977 a
20X20 CM.	2.292	1.971	1.915	1.719	1.631	1.905 b
15X15 CM.	2.280	1.886	1.788	1.598	1.525	1.815 c
10X10 CM.	2.109	1.820	1.773	1.572	1.498	1.755 d
MEANS FOR CUTTING	2.264	1.934	1.854	1.669	1.595	
	a	b	c	d	e	

FACTOR A IS CUTTING. FACTOR B IS SPACING

APPENDIX 14.

ANALYSIS OF VARIANCE OF FLORETS PER FLOWER.

SOURCE	DF	SS	MS	F CAL	F REQ 1PC	F REQ 5PC	LSD 1PC	LSD 5PC
REPLICATE	3.	3.562	1.187	0.980	4.20	2.79		
TREATMENT A	4.	56.221	14.055	11.605	3.72	2.56	1.035	0.778
TREATMENT B	3.	54.267	18.089	14.936	4.20	2.79	0.926	0.696
AXB INTERACTION	12.	31.375	2.614	2.159	2.56	1.95	2.070	1.556
ERROR	57.	69.035	1.211					

COEFF VAR = 10.87

	MEANS FOR AXB INTERACTION					MEANS FOR SPACING
	CONTROL	FHC	FLC	SHC	SLC	
30X30 CM.	10.001	9.951	11.026	10.901	9.801	10.336
20X20 CM.	13.126	9.526	11.001	11.301	10.876	11.166
15X15 CM.	11.476	7.951	9.326	11.201	10.601	10.111
10X10 CM.	9.426	7.026	8.451	9.626	9.801	8.866
MEANS FOR CUTTING	11.007	8.614	9.951	10.757	10.270	
	a	c	b	ab	ab	

FACTOR A IS CUTTING. FACTOR B IS SPACING

APPENDIX 15.

ANALYSIS OF VARIANCE OF SEED NUMBER PER POD.

SOURCE	DF	SS	MS	F CAL	F REQ 1PC	F REQ 5PC	LSD 1PC	LSD 5PC
REPLICATE	3.	0.916	0.305	0.814	4.20	2.79		
TREATMENT A	4.	5.280	1.320	3.617	3.72	2.56	0.569	0.425
TREATMENT B	3.	10.317	3.439	9.503	4.20	2.79	0.506	0.380
AXB INTERACTION	12.	11.163	0.930	2.570	2.56	1.95	1.131	0.851
ERROR	57.	20.629	0.361					
COEFF VAR =		23.12						

MEANS FOR AXB INTERACTION

MEANS FOR SPACING

	CONTROL	FHC	FLC	SHC	SLC	
30X30 CM.	2.044	2.714	2.669	2.094	2.204	2.345 a
20X20 CM.	2.568	2.401	2.904	2.546	1.949	2.474 b
15X15 CM.	1.939	2.753	1.954	2.606	2.601	2.370 b
10X10 CM.	2.831	3.366	3.064	4.494	2.336	3.218 b
MEANS FOR CUTTING	2.345	2.809	2.647	2.935	2.272	
	b	a	ab	a	b	

FACTOR A IS CUTTING. FACTOR B IS SPACING

APPENDIX 16.

ANALYSIS OF VARIANCE OF POD NUMBER PER CLUSTER.

SOURCE	DF	SS	MS	F CAL	F REQ 1PC	F REQ 5PC	LSD 1PC	LSD 5PC
REPLICATE	3.	1.606	0.535	1.324	4.20	2.79		
TREATMENT A	4.	2.642	0.660	1.633	3.72	2.56	0.598	0.450
TREATMENT B	3.	58.358	19.452	48.096	4.20	2.79	0.535	0.402
AXB INTERACTION	12.	11.602	0.966	2.390	2.56	1.95	1.196	0.899
ERROR	57.	23.054	0.404					

COEFF VAR = 15.27

MEANS FOR AXB INTERACTION

MEANS FOR SPACING

	CONTROL	FHC	FLC	SHC	SLC	
30X30 CM.	5.251	6.201	5.626	4.926	4.351	5.271 a
20X20 CM.	4.376	4.951	4.601	4.626	4.801	4.671 b
15X15 CM.	3.801	3.301	3.826	3.901	3.326	3.631 c
10X10 CM.	2.351	2.801	3.326	3.676	3.301	3.091 d
MEANS FOR CUTTING	3.945	4.314	4.345	4.282	3.945	
	a	a	a	a	a	

FACTOR A IS CUTTING. FACTOR B IS SPACING

APPENDIX 17

MEAN VALUES OF TOTAL FLOWERS PER PLANT

SPACINGS/CUTTING TREATMENT	CONTROL	FHC	FLC	SHC	SLC	AVERAGE
30x30 cm.	78.7	35.5	24.9	34.9	13.3	46.8
20x20 cm.	63.7	28.4	11.2	23.1	10.4	34.2
15x15 cm.	34.5	20.0	11.4	16.1	9.8	22.9
10x10 cm.	14.6	8.0	6.7	6.1	3.5	9.7
AVERAGE	47.8	22.9	13.5	20.1	9.3	

APPENDIX 18.

ANALYSIS OF VARIANCE OF % MC. AT HARVEST.

SOURCE	DF	SS	MS	F CAL	F REQ 1PC	F REQ 5PC	LSD 1PC	LSD 5PC
REPLICATE	3.	0.883	0.294	0.307	4.20	2.79		
TREATMENT A	4.	142.957	35.739	37.257	3.72	2.56	0.921	0.693
TREATMENT B	3.	14.221	4.740	4.942	4.20	2.79	0.824	0.619
AXB INTERACTION	12.	40.528	3.377	3.521	2.56	1.95	1.842	1.385
ERROR	57.	54.677	0.959					

COEFF VAR = 8.41

	MEANS FOR AXB INTERACTION					MEANS FOR SPACING
	CONTROL	FHC	FLC	SHC	SLC	
30X30 CM.	9.081	12.056	14.011	12.509	12.479	12.027 a
20X20 CM.	9.734	10.871	13.606	12.519	12.154	11.777 a
15X15 CM.	10.829	11.331	14.429	12.039	10.601	11.846 a
10X10 CM.	9.886	11.644	13.851	10.264	9.019	10.933 b
MEANS FOR CUTTING	9.882	11.475	13.974	11.832	11.063	
	d	b	a	b	c	

FACTOR A IS CUTTING. FACTOR B IS SPACING

APPENDIX 19.

ANALYSIS OF VARIANCE OF GERMINATION RESULTS OF SEED PRODUCTION TRIAL AT DIFFERENT HARVESTS TESTED IMMEDIATELY AFTER HARVEST AND AFTER STORAGE.

SOURCE	DF	SS	MS	F CAL	F REQ 1PC	F REQ 5PC	LSD 1PC	LSD 5PC
REPLICATE	3.	8.066	2.688	0.978	4.31	2.84		
TREATMENT A	2.	7729.633	3864.816	1406.199	5.18	3.23	1.418	1.060
TREATMENT B	4.	1374.166	343.541	124.996	3.83	2.61	1.830	1.368
AXB INTERACTION	8.	2701.033	337.629	122.845	2.99	2.18	3.170	2.370
ERROR	42.	115.433	2.748					

COEFF VAR = 4.23

MEANS FOR AXB INTERACTION

MEANS FOR CUTTING

	AT HARVEST	AFTER 6 WEEKS STORAGE	AFTER 12 WEEKS STORAGE	
CONTROL	9.251	39.001	48.751	32.334 a
FHC	16.251	36.001	53.001	35.084 b
FLC	39.501	45.001	43.001	42.501 c
SHC	26.001	57.251	52.751	45.334 d
SLC	28.751	34.501	58.501	40.584 e
MEANS FOR STORAGE	23.951	42.351	51.201	
	a	b	c	

FACTOR A IS STORAGE. FACTOR B IS CUTTING

APPENDIX 20.

ANALYSIS OF VARIANCE OF HARD SEED PERCENTAGE OF SEED PRODUCTION TRIAL AT DIFFERENT HARVESTS TESTED IMMEDIATELY AFTER HARVEST AND AFTER STORAGE.

SOURCE	DF	SS	MS	F CAL	F REQ 1PC	F REQ 5PC	LSD 1PC	LSD 5PC
REPLICATE	3.	3.250	1.083	0.511	4.31	2.84		
TREATMENT A	2.	8360.100	4180.050	1972.608	5.18	3.23	1.245	0.930
TREATMENT B	4.	1401.733	350.433	165.373	3.83	2.61	1.607	1.201
AXB INTERACTION	8.	2853.566	356.695	168.328	2.99	2.18	2.783	2.080
ERROR	42.	89.000	2.119					
COEFF VAR =		2.63						

MEANS FOR AXB INTERACTION

MEANS FOR CUTTING

	AT HARVEST	AFTER 6 WEEKS STORAGE	AFTER 12 WEEKS STORAGE	
CONTROL	87.001	52.251	48.501	62.584 a
FHC	79.001	58.001	41.001	59.334 b
FLC	56.251	49.251	52.501	52.668 c
SHC	68.751	38.251	41.501	49.501 d
SLC	66.001	58.751	33.251	52.668 c
MEANS FOR STORAGE	71.401 a	51.301 b	43.351 c	

FACTOR A IS STORAGE. FACTOR B IS CUTTING

APPENDIX 21.

MOISTURE CONTENT AND MEAN RESULT OF FW AND DW OF INDIVIDUAL SEEDS HARVESTED AT DIFFERENT SEED AGES.

DAYS AFTER FOLLINATION	WEIGHT OF			/MC
	FW MG./SEED	DW MG./SEED	MOISTURE MG./SEED	
10	0.23	0.09	0.17	75
13	0.43	0.11	0.33	76
16	0.91	0.20	0.71	77
19	1.78	0.39	1.39	78
22	2.49	0.57	1.95	77
25	2.55	0.60	2.29	76
28	3.03	0.74	2.48	76
31	3.34	0.86	2.85	75
34	4.04	1.19	3.09	72
37	4.45	1.34	2.63	70
40	4.52	1.89	2.39	58
49	3.75	1.79	1.96	52
55	3.06	1.78	1.28	42
75	2.05	1.76	0.26	14

APPENDIX 22.

GERMINATION RESULTS AND TETRAZOLIUM TEST RESULTS OF FRESHLY HARVESTED SEED OF DIFFERENT SEED AGE GROUPS.

a. TESTED IMMEDIATELY AFTER HARVEST

DAYS AFTER POLLINATION	NORMAL SEEDLING	ABNORMAL SEEDLING	HARD SEED	*F.S.	TOTAL VIABILITY	DEAD SEED	T.Z.	
							VIABLE	NON VIABLE
10	-	-	-	-	-	100	-	-
13	-	-	-	-	-	100	-	-
16	-	-	-	-	-	100	-	-
19	-	-	-	-	-	100	-	-
22	3	2	-	-	5	95	10	90
25	7	7	-	-	14	86	70	30
28	10	6	-	-	16	84	90	10
31	11	13	-	-	24	76	90	10
34	75	10	-	-	85	15	94	6
37	79	17	-	-	96	4	94	6
40	93	5	-	-	98	2	96	4
49	95	4	-	-	99	1	98	2
55	96	4	-	-	100	-	100	-
75	92	2	6	-	100	-	100	-

* Fresh ungerminated seed.

APPENDIX 22 CONT'D

b. TESTED AFTER 3 MONTHS STORAGE

DAYS AFTER POLLINATION	NORMAL SEEDLING	ABNORMAL SEEDLING	HARD SEED	F.S.	TOTAL VIABILITY	DEAD SEED
10	-	-	-	-	-	-
13	-	-	-	-	-	-
16	-	-	-	-	-	-
19	-	-	-	-	-	-
22	0	2	-	-	2	-
25	5	3	-	-	8	-
28	6	4	-	-	10	-
31	8	10	-	-	18	2
34	40	7	40	-	87	18
37	49	4	45	1	94	1
40	38	3	59	-	99	1
49	21	4	72	2	99	1
55	19	2	79	-	100	-
75	18	3	79	-	100	-

APPENDIX 23.

DAILY MAXIMUM AND MINIMUM TEMPERATURES °C RECORDED 25 CM. ABOVE GROUND LEVEL.

DATE	TEMPERATURE	DAYS OF THE WEEK							WEEKLY AVERAGE
		1	2	3	4	5	6	7	
11.10.76	MAX.	20	25	25	21	18	17	16	20
	MIN.	9	8	12	9	12	14	14	11
18.10.76	MAX.	24	20	22	20	20	17	23	21
	MIN.	11	13	8	8	11	9	12	10
25.10.76	MAX.	17	13	13	16	18	19	20	19
	MIN.	10	7	3	2	3	7	12	11
1.11.76	MAX.	22	15	19	20	24	24	24	21
	MIN.	11	8	8	8	10	9	10	9
8.11.76	MAX.	20	20	26	20	23	19	14	20
	MIN.	4	12	11	13	14	13	7	10
15.11.76	MAX.	19	19	20	19	19	15	18	19
	MIN.	12	12	12	5	12	7	6	10
22.11.76	MAX.	21	23	25	21	21	22	27	23
	MIN.	12	7	8	12	11	12	9	10
29.11.76	MAX.	24	26	22	22	20	21	23	23
	MIN.	12	8	12	15	13	8	8	11
6.12.76	MAX.	25	27	30	20	21	24	21	27
	MIN.	16	15	11	13	12	14	13	14
13.12.76	MAX.	27	25	25	21	22	21	21	23
	MIN.	16	13	13	11	14	13	12	13
20.12.76	MAX.	19	20	22	22	22	22	24	22
	MIN.	16	13	14	12	15	14	14	14
27.12.76	MAX.	22	18	15	15	15	18	23	22
	MIN.	15	12	10	10	11	10	12	12
3.1.77	MAX.	26	26	23	24	22	22	23	24
	MIN.	13	16	14	13	10	11	8	12
10.1.77	MAX.	19	24	24	26	27	28	23	24
	MIN.	7	-	-	12	10	12	14	11
17.1.77	MAX.	21	19	22	23	24	23	23	23
	MIN.	14	12	14	13	10	9	8	11
24.1.77	MAX.	23	27	22	25	23	28	25	25
	MIN.	13	17	14	13	15	15	13	14

APPENDIX 23 CONT'D

DATE	TEMPERATURE	DAYS OF THE WEEK							WEEKLY AVERAGE
		1	2	3	4	5	6	7	
31.1.77	MAX.	27	27	26	24	26	26	27	26
	MIN.	17	17	18	15	15	15	17	16
7.2.77	MAX.	24	27	31	33	33	31	38	31
	MIN.	17	14	14	15	12	14	26	16
14.2.77	MAX.	27	26	28	24	22	27	28	26
	MIN.	13	15	6	8	14	14	12	12
21.2.77	MAX.	37	28	28	35	33	28	38	32
	MIN.	17	10	16	18	17	16	13	15
28.2.77	MAX.	28	28	32	35	32	42	37	33
	MIN.	17	15	14	15	15	12	12	14
7.3.77	MAX.	39	37	25	42	32	36	31	35
	MIN.	20	14	18	15	13	7	10	14
14.3.77	MAX.	34	32	34	33	21	-	26	30
	MIN.	15	15	19	12	14	-	-	15
21.3.77	MAX.	33	38	27	32	35	38	33	32
	MIN.	12	8	10	13	12	12	12	11
28.3.77	MAX.	34	33	19	30	28	34	37	31
	MIN.	16	13	16	16	12	13	7	13
4.4.77	MAX.	-	34	32	30	32	33	35	32
	MIN.	-	11	9	8	11	10	11	10
11.4.77	MAX.	25	30	33	34	28	24	42	31
	MIN.	14	16	8	6	5	12	13	11
18.4.77	MAX.	30	35	24	28	23	22	24	27
	MIN.	14	13	14	12	20	16	15	15
25.4.77	MAX.	25	34	27	18	25	25	25	26
	MIN.	8	7	4	6	6	5	10	6
2.5.77	MAX.	25	22	16	23	26	18	16	21
	MIN.	9	4	4	2	3	10	4	5
9.5.77	MAX.	25	26	19	26	18	25	-	19
	MIN.	9	4	11	4	12	4	1	6
16.5.77	MAX.	19	20	17	17	19	20	21	19
	MIN.	10	3	2	3	4	6	5	5
23.5.77	MAX.	21	21	20	21	19	18	16	19
	MIN.	13	4	11	12	10	10	8	10
30.5.77	MAX.	17	18	19	20	19	18	-	19
	MIN.	9	4	3	2	5	2	-	4

APPENDIX 24.

DAILY MAXIMUM AND MINIMUM RELATIVE HUMIDITY PERCENTAGES RECORDED
25 CM. ABOVE GROUND LEVEL.

DATE	% RH	DAYS OF THE WEEK							WEEKLY AVERAGE
		1	2	3	4	5	6	7	
11.10.76	MAX.	78	85	97	97	97	79	78	87
	MIN.	40	55	54	76	58	52	64	57
18.10.76	MAX.	96	97	97	97	83	95	96	94
	MIN.	72	72	65	55	65	70	76	68
25.10.76	MAX.	88	96	83	97	98	-	97	93
	MIN.	-	62	60	59	54	-	54	58
1.11.76	MAX.	96	96	97	98	97	97	97	97
	MIN.	70	75	54	50	52	50	50	57
8.11.76	MAX.	96	94	97	97	96	97	97	96
	MIN.	60	61	52	56	68	64	70	62
15.11.77	MAX.	96	96	94	96	97	98	-	96
	MIN.	70	70	42	60	66	-	-	62
22.11.76	MAX.	96	97	94	95	96	96	97	96
	MIN.	64	53	52	62	64	59	40	56
29.11.76	MAX.	97	96	96	96	96	96	96	96
	MIN.	55	35	70	68	72	52	50	57
6.12.76	MAX.	92	90	97	97	95	96	-	95
	MIN.	54	50	60	58	52	53	-	54
13.12.76	MAX.	94	93	93	94	94	94	94	94
	MIN.	62	56	52	62	55	58	60	58
20.12.76	MAX.	95	94	94	95	95	95	95	95
	MIN.	50	68	72	60	65	68	68	64
27.12.76	MAX.	95	95	95	90	94	94	93	94
	MIN.	62	68	58	64	62	54	62	61
3.1.77	MAX.	92	94	94	94	94	92	92	93
	MIN.	78	60	58	58	58	65	64	63
10.1.77	MAX.	94	94	94	94	94	94	94	94
	MIN.	68	62	66	62	54	54	58	61
17.1.77	MAX.	92	97	96	92	92	92	92	93
	MIN.	55	54	55	53	40	58	62	54
24.1.77	MAX.	95	98	95	95	95	96	95	96
	MIN.	74	58	82	75	80	68	70	72

APPENDIX 24 CONT'D

DATE	% RH	DAYS OF THE WEEK							WEEKLY AVERAGE
		1	2	3	4	5	6	7	
31.1.77	MAX.	95	95	95	95	95	95	95	95
	MIN.	72	65	64	54	66	78	68	67
7.2.77	MAX.	95	94	95	95	95	95	72	92
	MIN.	70	60	60	55	50	50	48	56
14.2.77	MAX.	94	93	94	94	94	94	94	94
	MIN.	48	43	38	50	75	63	45	52
21.2.77	MAX.	94	94	94	94	94	94	93	94
	MIN.	45	62	56	53	56	56	46	53
28.2.77	MAX.	96	94	95	92	95	95	95	95
	MIN.	70	62	64	63	60	53	56	61
7.3.77	MAX.	94	94	95	95	95	95	94	95
	MIN.	55	68	82	50	55	54	62	61
14.3.77	MAX.	95	95	95	95	95	95	95	95
	MIN.	53	56	54	56	43	62	63	55
21.3.77	MAX.	90	94	94	95	95	95	89	93
	MIN.	70	64	77	76	50	58	46	63
28.3.77	MAX.	91	94	95	94	95	94	94	94
	MIN.	44	68	88	52	52	52	47	58
4.4.77	MAX.	95	94	94	96	97	94	93	95
	MIN.	40	50	56	54	58	52	56	52
11.4.77	MAX.	93	93	94	94	94	93	93	94
	MIN.	62	62	60	62	50	75	32	58
18.4.77	MAX.	98	95	95	98	93	98	98	96
	MIN.	65	65	72	70	72	82	75	72
25.4.77	MAX.	98	98	98	98	98	98	97	98
	MIN.	68	34	49	76	42	56	68	56
2.5.77	MAX.	95	98	98	98	98	98	97	97
	MIN.	63	91	82	46	60	48	70	66
9.5.77	MAX.	99	99	98	99	98	98	-	99
	MIN.	60	56	82	56	62	56	-	62
16.5.77	MAX.	100	100	98	96	57	94	45	84
	MIN.	50	54	52	54	56	55	38	51
23.5.77	MAX.	100	100	96	98	97	100	100	99
	MIN.	-	48	49	51	54	52	80	56
30.5.77	MAX.	100	100	97	96	95	98	100	98
	MIN.	83	53	54	60	79	52	90	67

APPENDIX 25.

A SUMMARY OF WEATHER CONDITIONS DURING THE
RIPENING STAGES

PERIOD OF RIPENING STAGE HARVEST DATE		DAILY MAXIMUM TEMPERATURE VARIATION °C	DAILY MINIMUM TEMPERATURE VARIATION °C
CONTROL PLOT	10 MARCH - 15 APRIL	19 - 42	7 - 20
FHC	24 MARCH - 29 APRIL	18 - 38	4 - 16
FLC	30 MARCH - 4 APRIL	16 - 37	2 - 16
SHC AND SEED DEVELOPMENT TRIAL	15 APRIL - 20 MAY	16 - 35	2 - 16
SLC	23 APRIL - 24 MAY	16 - 25	2 - 13

THE NUMBER OF DAYS HAVING RAIN MORE THAN 1.00 MM. WAS 4, 6, 15
AND 14 DAYS IN FEBRUARY, MARCH, APRIL AND MAY RESPECTIVELY.

APPENDIX 26.

DAILY MAXIMUM AND MINIMUM TEMPERATURE °C RECORDED IN THE LABORATORY.

DATE	TEMPERATURE	DAYS OF THE WEEK							WEEKLY AVERAGE
		1	2	3	4	5	6	7	
21.3.77	MAX.	24	24	22	21	22	22	24	23
	MIN.	20	20	20	19	18	17	18	19
28.3.77	MAX.	23	23	24	25	25	23	24	24
	MIN.	19	18	20	20	20	21	20	20
4.4.77	MAX.	23	24	24	23	21	21	23	23
	MIN.	21	20	18	19	18	18	19	19
11.4.77	MAX.	21	22	21	21	21	21	21	21
	MIN.	19	18	18	17	17	19	18	18
18.4.77	MAX.	22	22	21	19	20	19	21	20
	MIN.	17	17	16	16	16	16	16	16
25.4.77	MAX.	18	21	19	18	18	20	20	19
	MIN.	15	16	15	12	14	17	15	15
2.5.77	MAX.	19	19	18	20	20	19	19	19
	MIN.	13	14	14	13	14	13	12	13
9.5.77	MAX.	17	17	17	17	20	19	18	18
	MIN.	13	11	12	12	12	16	15	13
16.5.77	MAX.	17	15	15	18	19	20	18	17
	MIN.	13	12	11	10	12	15	15	13
23.5.77	MAX.	19	19	19	18	16	17	17	18
	MIN.	15	16	16	16	13	12	15	15
30.5.77	MAX.	18	18	19	18	20	17	17	18
	MIN.	15	15	14	14	16	17	16	15
6.6.77	MAX.	17	17	18	20	20	18	17	18
	MIN.	16	15	15	15	15	14	15	15
13.6.77	MAX.	21	19	19	20	20	18	18	19
	MIN.	17	16	16	16	18	15	15	16
20.6.77	MAX.	21	17	19	17	20	16	17	18
	MIN.	16	15	13	15	14	13	15	14
27.6.77	MAX.	18	18	19	19	20	19	17	19
	MIN.	15	15	15	15	13	16	13	15
4.7.77	MAX.	15	18	17	17	18	19	17	17
	MIN.	12	11	12	12	13	13	12	12
13.7.77	MAX.	20	19	19	20	21	21	20	20
	MIN.	14	12	12	14	16	16	15	14

APPENDIX 27.

DAILY MAXIMUM AND MINIMUM RELATIVE HUMIDITY PERCENTAGE RECORDED
IN THE LABORATORY.

DATE	TEMPERATURE	DAYS OF THE WEEK							WEEKLY AVERAGE
		1	2	3	4	5	6	7	
21.3.77	MAX.	60	60	67	68	62	59	60	62
	MIN.	48	56	60	58	54	56	56	55
28.3.77	MAX.	58	62	73	70	64	70	65	66
	MIN.	52	52	60	63	60	62	60	58
4.4.77	MAX.	64	64	63	58	60	68	68	64
	MIN.	60	54	49	52	54	60	64	56
11.4.77	MAX.	70	72	69	70	70	72	70	70
	MIN.	67	63	61	64	65	68	68	65
18.4.77	MAX.	68	68	60	64	59	62	68	64
	MIN.	62	48	54	54	67	53	60	54
25.4.77	MAX.	62	67	67	64	68	68	60	65
	MIN.	60	58	63	60	59	63	54	60
2.5.77	MAX.	67	65	69	68	65	65	62	66
	MIN.	62	62	63	63	62	60	58	61
9.5.77	MAX.	69	68	61	64	70	70	68	67
	MIN.	58	58	58	50	55	58	61	57
16.5.77	MAX.	72	68	65	60	61	60	67	65
	MIN.	64	60	58	50	50	55	58	56
23.5.77	MAX.	72	72	64	62	60	60	60	64
	MIN.	62	62	58	58	58	58	58	59
30.5.77	MAX.	68	62	59	68	68	64	64	65
	MIN.	62	50	50	56	62	61	61	57
6.6.77	MAX.	64	58	58	58	54	48	55	56
	MIN.	58	54	56	50	44	43	49	51
13.6.77	MAX.	58	56	60	64	60	58	58	59
	MIN.	49	52	56	55	58	54	50	53
20.6.77	MAX.	66	55	60	59	59	58	64	60
	MIN.	48	52	52	54	48	50	55	51
27.6.77	MAX.	65	68	64	65	62	61	60	64
	MIN.	56	62	60	59	54	54	55	57
4.7.77	MAX.	63	63	62	62	60	55	63	61
	MIN.	60	54	58	58	54	53	55	56
13.7.77	MAX.	62	56	52	54	58	52	50	55
	MIN.	50	51	50	50	50	48	48	50