AN ABSTRACT OF THE THESIS OF

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Title: Seed Maturation in Subterranean Clover (Trifolium Subterraneum L.)

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Abstract Approved: _____
Don F. Grabe

A seed maturation study was conducted to determine the earliest date seed of subterranean clover (Trifolium subterraneum L.) may be safely harvested without reduction in yield or seed quality. In 1981 and 1982, seed and bur weight, seed and bur moisture content, germination and seedling vigor were studied to determine when seeds were mature in 'Mt. Barker' and 'Nangeela' subclover. Indirect maturity indices were evaluated for use in determining when maximum dry weight is attained. Sampling was begun after flowers had formed on the uppermost reproductive nodes and was continued for 70 days in 1981 and 62 days in 1982.

Maximum seed dry weight occurred in Mt. Barker at 54% moisture and 44 days after flowering in 1981 and at 52% seed moisture and 38 days after flowering in 1982. Nangeela attained maximum seed dry weight 46 and 40 days after flowering at seed moisture contents of 53% and 51% in 1981 and 1982, respectively.

Seed and bur moisture were closely correlated ($r = 0.98$ and $r = 0.99$ for Mt. Barker and $r = 0.98$ and $r = 0.99$ for Nangeela) in 1981

and 1982. Seed and bur dry weight were also highly correlated (r = 0.94 and 0.98 for Mt. Barker and r = 0.96 and r = 0.95 for Nangeela) in 1981 and 1982.

Scarified seeds attained the 90% level of germination shortly after seed development. Seed weight and germination were not closely correlated. Unscarified seeds attained the 95% level of impermeability 26 to 30 days after flowering.

Maximum seedling vigor was reached 6 and 10 days after maximum dry weight for Mt. Barker, and 2 and 10 days after maximum dry weight for Nangeela in 1981 and 1982, respectively. Seeds at this stage were capable of germinating quickly and produced large, strong seedlings.

Bur moisture content can be used as a simple index of seed maturity in subclover. Under Willamette Valley conditions, maximum seed dry weight and vigor of Mt. Barker and Nangeela are reached at bur moisture contents of 49 to 58%.

SEED MATURATION IN SUBTERRANEAN CLOVER (*TRIFOLIUM SUBTERRANEUM* L.)

by

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DEDICATION

This thesis is dedicated to my family, especially my mother and father, who throughout my education provided me with support, motivation, encouragement and the desire to excel as a student and individual. Without their care and understanding, this thesis would never have been written.

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INTRODUCTION

In Oregon, subterranean clover (*Trifolium subterraneum* L.), or subclover, seed is most commonly harvested with vacuum harvesters in the fall after the crop has been mowed and the dried stems and leaves removed. At this stage, the plant has completely dried down and the seed burs are detached and lying on or near the soil surface. In preparation for vacuum harvesting, hay-making equipment is used to clear the field of dried stems and leaves which cover the seed burs (Steiner and Grabe, 1982). After removal of the hay crop, the field may undergo further drying or it is prepared for the vacuum harvester. Harvest preparation involves dragging a spike-tooth harrow or other implement through the field several times to separate the stems and burs from the crown of the plant. Growers have been known to go over their field as many as seven times.

Because of the cumbersome and expensive vacuum harvesting methods, a more efficient harvesting procedure, using conventional equipment, would be desirable. A possible alternative to the vacuum harvester would be to cut the plants at ground level with a windrower while the crop is still green and the burs are still attached to the plant. The seed would then be harvested from the windrow with a combine when seeds were dry enough for harvest and storage. Success of such a system would depend on a knowledge of when the seeds are mature and can be safely harvested.

Aldrich (1943) termed maturity as that point in plant growth where maximum grain development is first attained. Shaw and Loomis

(1950) referred to the time when a seed reaches its maximum dry weight as physiological maturity. This point has been determined for many grass, cereal, and legume seed crops, but has not been clearly defined for subclover.

Since maximum dry weight is difficult to determine, more convenient estimates of maturity have been developed. Convenient indices include days from flowering to maturity (Anderson, 1955; Hyde et al., 1959), and seed moisture content when maximum dry weight is first attained (Harlan, 1920; Burnett and Bakke, 1930; Frey et al., 1958).

Subclover cultivars vary substantially in duration of flowering (Francis and Gladstones, 1974). Subclover has an indeterminate growth habit and the actual period of flowering and resulting seed growth and development may extend over several weeks causing inflorescences to show a wide range of development at harvest (Collins and Quinlivan, 1980).

Taylor (1980) found seed development from individually tagged flowers of 'Daliak' subclover to be complete 42 days after flowering under a controlled greenhouse environment. Taylor notes that pod walls attained near maximum weight earlier, at day 22.

Collins and Quinlivan (1980) reported seed yields of four strains of subclover peaked between 74 and 86 days after the onset of flowering. Near the completion of seed development, the crop was in an advanced stage of senescence (90% of the leaf blades and petioles were dead), but the stems were still green and turgid. Maximum seed yields were not attained until some time after leaf senescence, up to 17 days later for one cultivar. The rate of accumulation of seed dry

weight was of the order of 6 g/m^2/day for most of the seed development phase.

Thirty days after labeling individual florets, Tennant (1965) found the germination percentages of buried and unburied seed of 'Dwalganup' and 'Geraldton' subclover to be approximately 87 and 68%, and 92 and 82%, respectively. These figures represent a substantial increase from day 22 when the respective germination percentages were 9 and 1%, and 77 and 55%. Buried seed consistently had a higher germination value than the unburied seed. Francis and Gladstones (1974) harvested seed from individually tagged flowers of subclover 20 and 30 days after flowering. Many of the cultivars had attained nearly 100% viability 30 days after flowering.

The major objective of this research was to determine when maturity is reached in seeds of 'Mt. Barker' and 'Nangeela' subclover. Indirect maturity indices were evaluated for use in determining when maximum dry weight is attained. Maturity indices included seed and bur weight, seed and bur moisture content, germination, and seedling vigor.

MATERIALS AND METHODS

Two cultivars of subclover that are commercially important for seed production in Oregon were selected for this study. Mt. Barker is classified as mid-season maturing and Nangeela is classified as late mid-season. Seed for establishing the plots was vacuum harvested from commercial seed fields in Roseburg, Oregon, in the summer of 1979.

The field experiments were conducted on the Oregon State University Hyslop Crop Science Field Laboratory near Corvallis, Oregon. The soil is a Woodburn silt loam, a member of the fine, silty, mixed, mesic, family of Aquultic Argixerolls. In 1981, plot size was 10.7 m x 43.6 m for Mt. Barker and 6.1 m x 43.6 m for Nangeela. In 1982, plot size was 9.1 m x 39.0 m for both cultivars. The seed was drilled 1.5 cm deep in rows 15 cm apart the previous October at a rate of 22.5 kg/ha. Planting dates were 15 October in 1980 and 20 October in 1981.

First flowering was recorded as the date when flowers first appeared on approximately half the plants. Sampling began on 15 June in both years at which time flowers on the uppermost nodes were being pollinated. Samples were harvested every 2 days for 70 days in 1981 and 62 days in 1982 until the crop canopy was completely senescent. Sample size was 20 x 20 cm. Samples were harvested with sheep shears and brought from the field in small sealed plastic bags to minimize moisture loss. Measurements of seed dry weight, bur dry weight, seed moisture, bur moisture, germination percentage and seedling weight were made on four samples per cultivar on each harvest date. Whole

plant moisture was determined on two samples per cultivar.

Moisture and dry weight measurements were made on 50 seeds and 25 burs per sample. The sample was dried for 24 hours at 104 C and moisture content was calculated on a wet weight basis. Whole-plant moisture content was also determined after drying at 104 C for 24 hours. Seeds were considered to be mature when maximum dry weight was attained.

The seeds were hand scarified with sandpaper and germination tests were made in rolled-paper toweling at 18 C for 11 days. A seed was considered germinated when the shoot had attained a length of 5 mm and when the radicle had reached 1 cm in length. Seedlings were removed from the rolled-paper toweling at the end of the test and dried in an oven at 35 C for 24 hours. Seedling dry weight was then determined as an index of seed vigor.

In the second year of the study, the seeds were tested for hard seed content. Fifty seeds from each of the four samples were placed in small envelopes and allowed to dry in the laboratory for a minimum of 7 days. Unscarified seeds were placed in rolled-paper toweling and germinated at 18 C. Determination of the hard seed percentage was made on the 7th day.

RESULTS AND DISCUSSION

First flowering occurred 184 days after planting on 17 April in 1981 and 187 days after planting on 25 April in 1982. Initial flowers were formed at nodes 8, 9, and 10 and did not set seed. Aitken (1941) found Mt. Barker to produce vegetatively at nodes 1 through 10 and reproductively at nodes 11 through 20. The period from first flowering to the formation of flowers along the uppermost nodes covered a 59-day period in 1981. This period was shortened to 51 days in 1982. Since subclover flowering is indeterminate, flowering is herein used to refer to that time when flowers had formed on the uppermost reproductive nodes. At the time of sampling, the individual seeds exhibited several stages of development.

Moisture and germination percentages and seed and seedling dry weights for Mt. Barker and Nangeela in 1981 and 1982 are presented in Figures 1 to 4. In 1981, maximum seed dry weight was reached on 29 July for Mt. Barker and 31 July for Nangeela at seed moisture contents of 54% and 53%. This represents a period of 44 and 46 days after flowering for Mt. Barker and Nangeela. In 1982, maximum seed dry weight was found to occur 6 days earlier on 23 July for Mt. Barker and 25 July for Nangeela at seed moisture contents of 52% and 51%. Field temperatures recorded in May 1982 were above average while total precipitation in May was below the monthly average. The hastening of maturity in 1982 probably reflected the warmer temperatures and drier conditions compared to the previous year.

Seeds of Mt. Barker and Nangeela at maximum dry weight averaged 13.8 mg and 17.3 mg each, respectively. Tennant (1965) found seeds

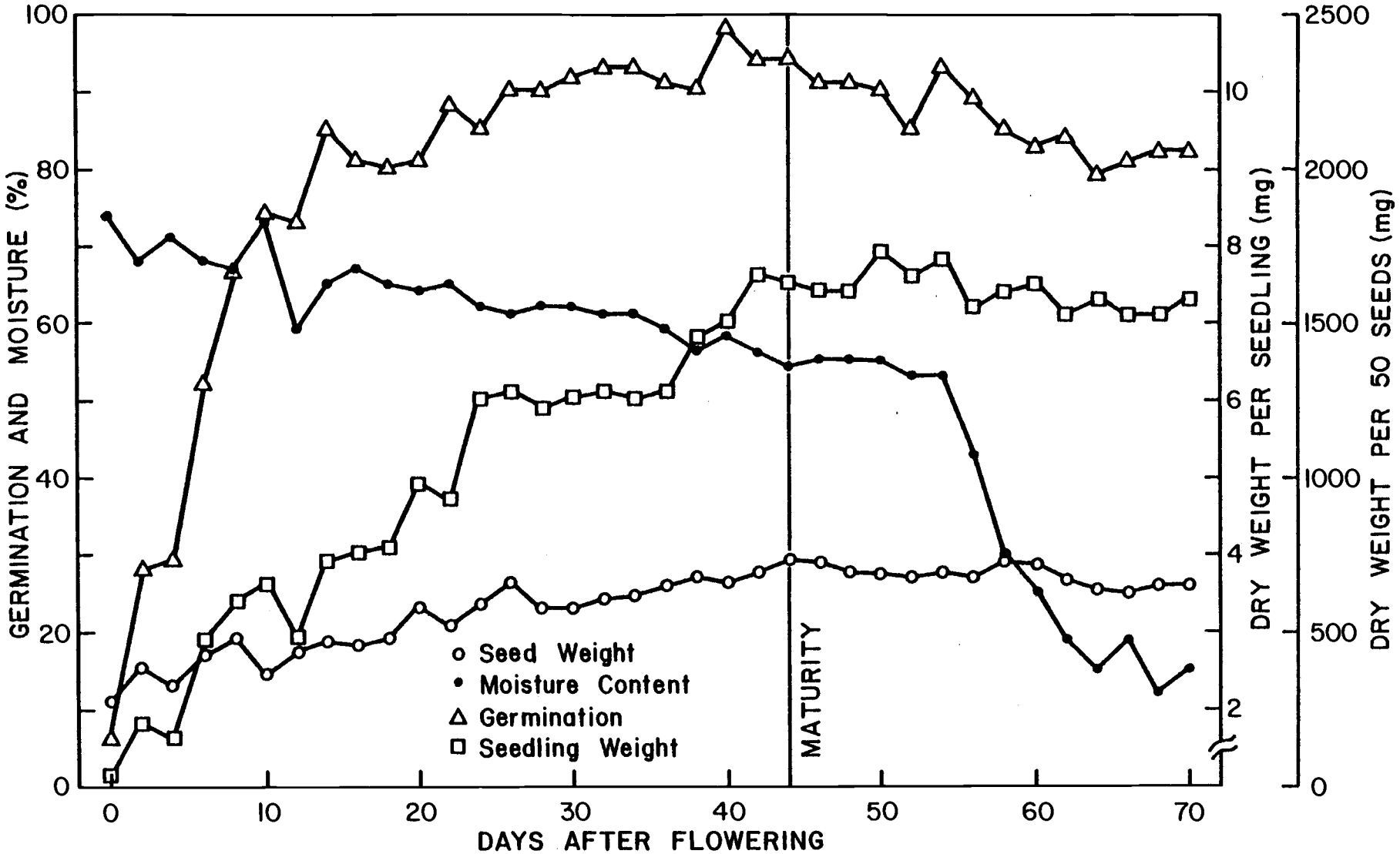

Figure 1. Dry weight, moisture content and germination percentage of seeds and dry weight of seedlings of Mt. Barker subclover sampled at various stages of maturity, 1981.

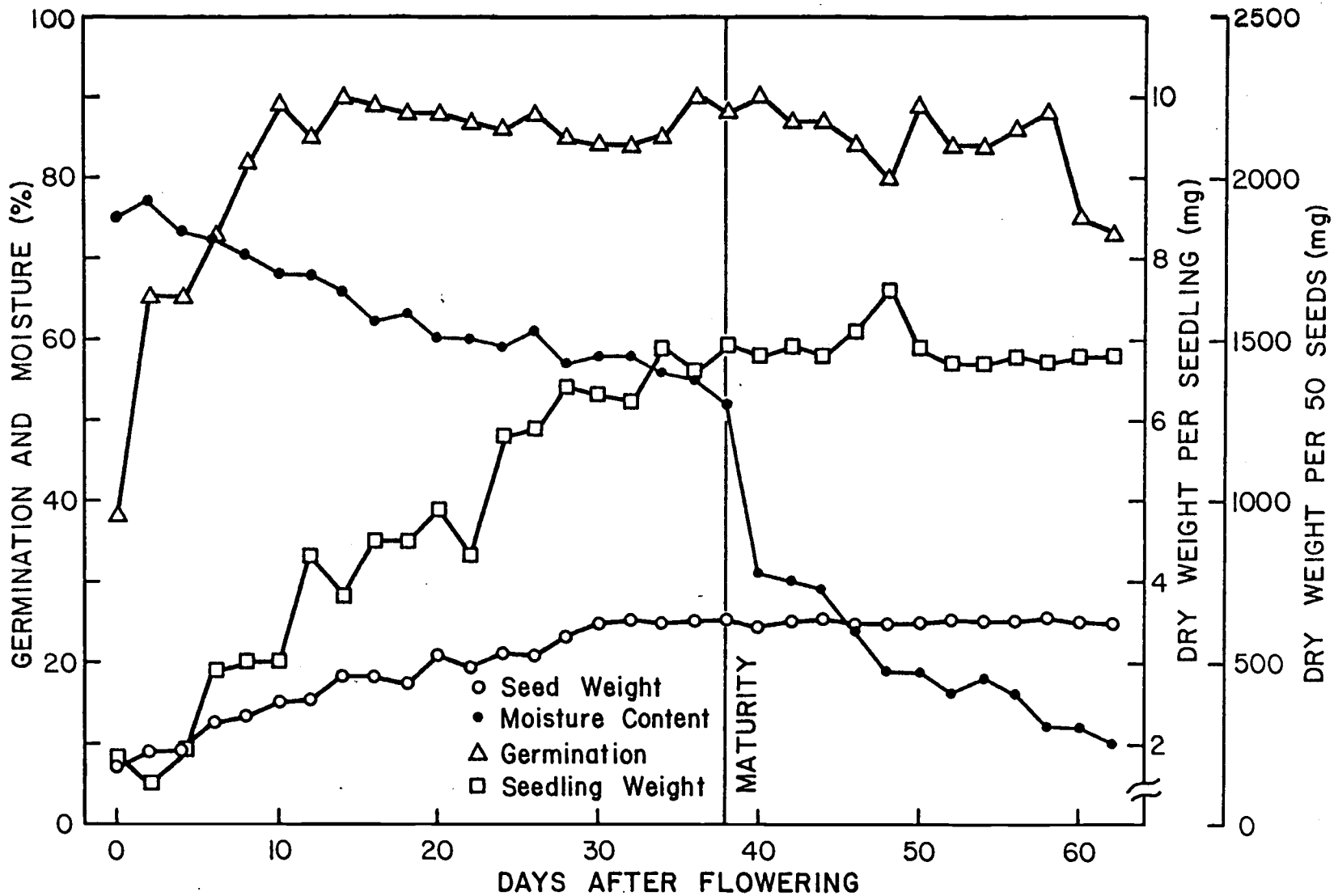

Figure 2. Dry weight, moisture content and germination percentage of seeds and dry weight of seedlings of Mt. Barker subclover sampled at various stages of maturity, 1982.

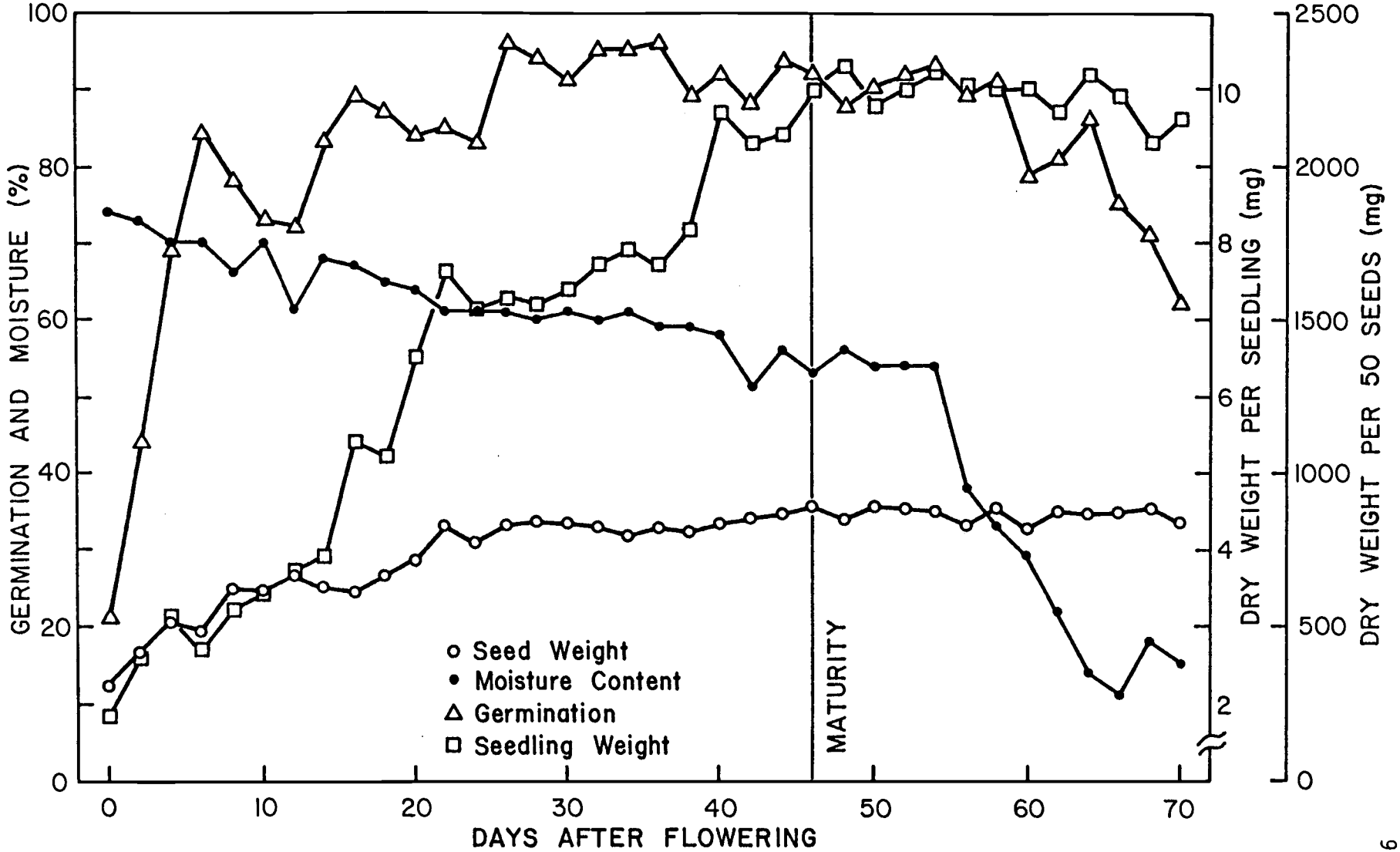

Figure 3. Dry weight, moisture content and germination percentage of seeds and dry weight of seedlings of Nangeela subclover sampled at various stages of maturity, 1981.

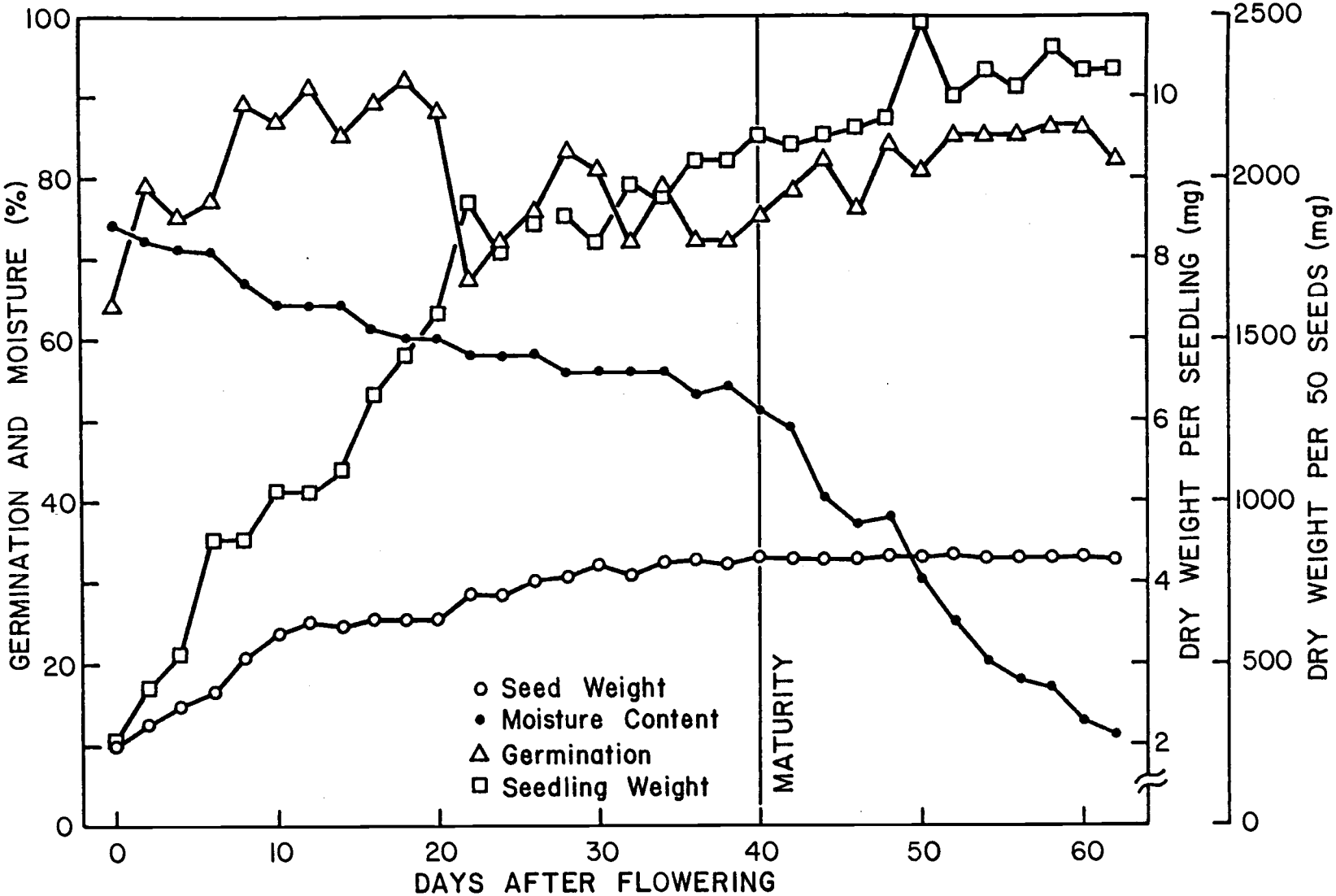

Figure 4. Dry weight, moisture content and germination percentage of seeds and dry weight of seedlings of Nangeela subclover sampled at various stages of maturity, 1982.

from individually labeled flowers of Dwalganup and Geraldton subclover weighed approximately 7.4 mg and 5.6 mg 54 days after anthesis. Tennant reported that seeds from unburied burs weighed less than those sampled from buried burs. In Oregon, the seed bur does not usually bury itself in the soil. After fertilization, the peduncle elongates pushing the seed bur to the soil surface only. Taylor (1980), in a greenhouse study of development of bur components in individually tagged flowers, found the seed weight of Daliak subclover to be approximately 5.2 mg at maximum dry weight.

Crop moisture content of Mt. Barker and Nangeela at maximum seed dry weight was 58% and 57% in 1981, and 42% and 51% in 1982. At this stage, the crop was still green and the burs firmly attached to the plant. The percentage crop moisture alone does not appear to be a good index of seed maturity.

Mt. Barker is characterized as a mid-season cultivar and Nangeela, a late mid-season cultivar. Despite differences in their classification, seed maturation rate was similar under Oregon conditions, Nangeela reaching maximum dry weight 2 days after Mt. Barker in both years. Full development of Nangeela was apparently curtailed by lack of rainfall later in the season.

Some seeds of Mt. Barker and Nangeela were capable of germinating on the first sample date, and germination percentage increased rapidly as the seeds developed. For both cultivars, the 90% level of germination was reached 26 days after flowering in 1981, but 12 to 14 days earlier in 1982. Seed moisture content at this stage in both years averaged 63%. Tennant (1965) found buried seed of Dwalganup

and Geraldton subclover germinated approximately 87% and 92% 30 days after anthesis, while unburied seed germinated 68% and 82%.

Mt. Barker and Nangeela seeds sampled soon after seed formation were small in size yet quick to germinate. At the time of maximum dry weight in 1981, germination percentages after scarification for Mt. Barker and Nangeela were 94% and 92%, respectively. In 1982, the values were 88% and 75%. A slight decline in germination occurred in both cultivars after maximum germination was attained, because scarification by sandpaper injured the radicle of the subclover seed. As the seed increased in size and the radicle became more pronounced, so did the injury to the radicle. It can be seen, however, that as germination decreased because of this mechanical injury, the mean dry weight per seedling remained at a high level or increased. Seed weight and germination were not closely correlated.

Seedling dry weight increased at a slightly lower rate than that of seed weight. In 1981, seedling dry weight peaked 6 days after seed weight in Mt. Barker and 2 days after seed weight in Nangeela. In 1982, this period increased to 10 days for both cultivars. The simple correlation coefficients for seed and seedling weights were 0.97 and 0.98 for Mt. Barker and 0.93 and 0.96 for Nangeela in 1981 and 1982, respectively. As the seed matured, deposition of stored food or translocating materials increased. At the time the seed reached its full size, it contained essentially all the food materials necessary to produce a vigorous seedling.

The development of hard seed began soon after seed formation and hard seed content increased in both cultivars during the 62-day sampling period in 1982 (Figure 5). Mt. Barker and Nangeela seeds

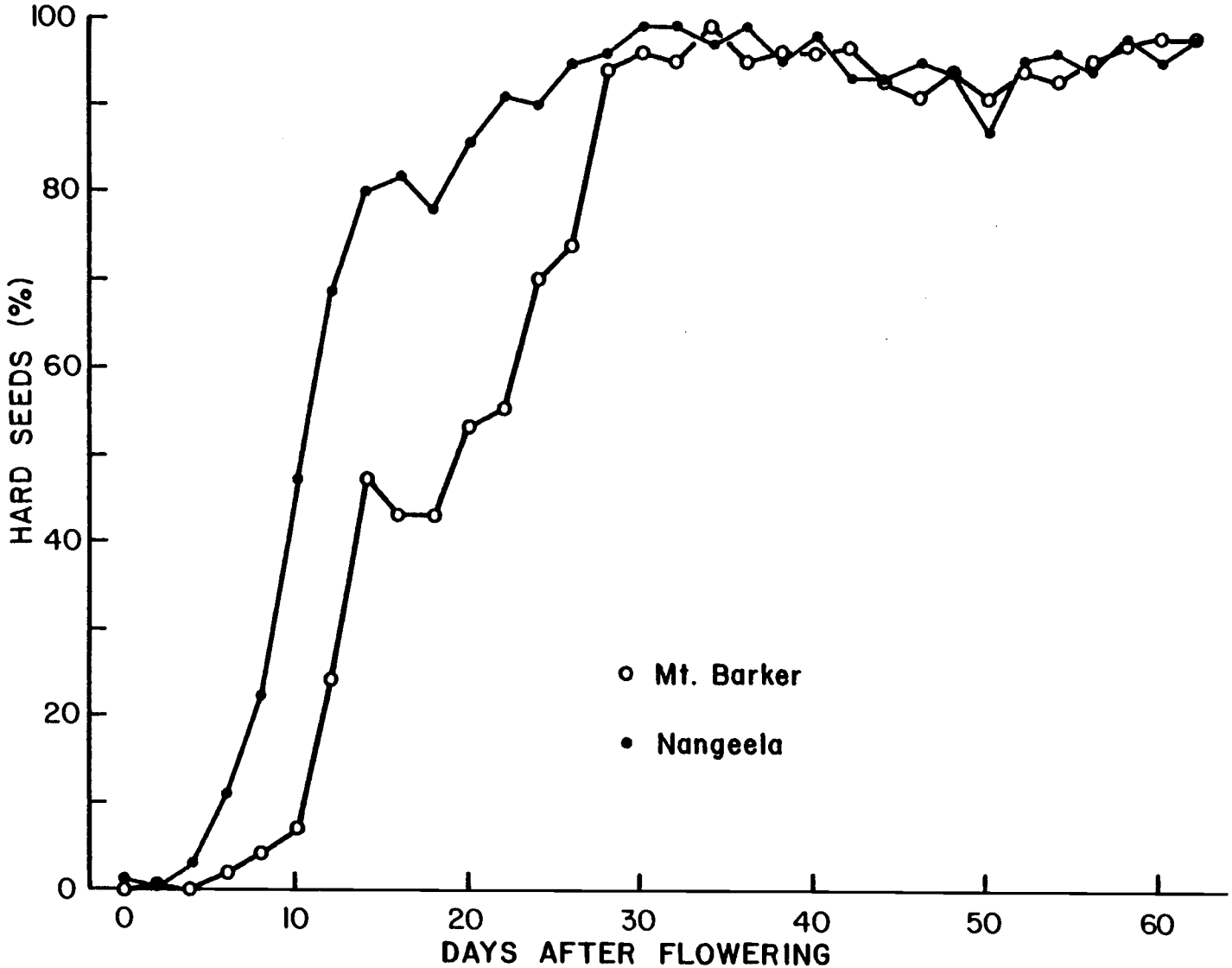

Figure 5. Increase in hard seed content of Mt. Barker and Nangeela subclover harvested at various stages of maturity, 1982.

attained the 95% level of impermeability 26 to 30 days after flowering. This agrees with work by Aitken (1939) and Loftus Hills (1942) who reported that hardseededness increased during the period of seed development. Loftus Hills concluded that of three cultivars tested, Mt. Barker, 'Tallarook', and Dwalganup, Mt. Barker contained the highest percentage of impermeable seeds. Hardseededness in subclover is valuable to the seed as it prevents germination at times when seedlings would be unlikely to survive.

Subclover seeds produced in Australia often exhibit embryo dormancy, but seeds in this study did not. Morley (1958) found that subclover seeds possessing embryo dormancy were capable of repeated water imbibition and subsequent drying without any loss in viability.

Bur moisture at seed maturity was 58% and 53% for Mt. Barker, and 53% and 49% for Nangeela in 1981 and 1982, respectively (Figures 6 to 9). Bur moisture content was closely correlated with seed moisture content, the r values for Mt. Barker and Nangeela being 0.98 and 0.98 in 1981, and 0.99 and 0.99 in 1982. Bur dry weight was highly correlated with seed weight for both cultivars and within each year of the study. The correlation coefficients for Mt. Barker and Nangeela were $r = 0.94$ and $r = 0.96$ in 1981, and $r = 0.98$ and $r = 0.95$ in 1982. This close relationship between bur and seed moisture content and dry weight indicates that bur moisture is as useful as seed moisture as an index of seed maturity. The process of hand threshing each bur to remove seeds for determining moisture content is slow and tedious, while burs are quicker and easier to sample and weigh. The use of bur moisture content as an index of seed maturity would constitute a notable savings in time.

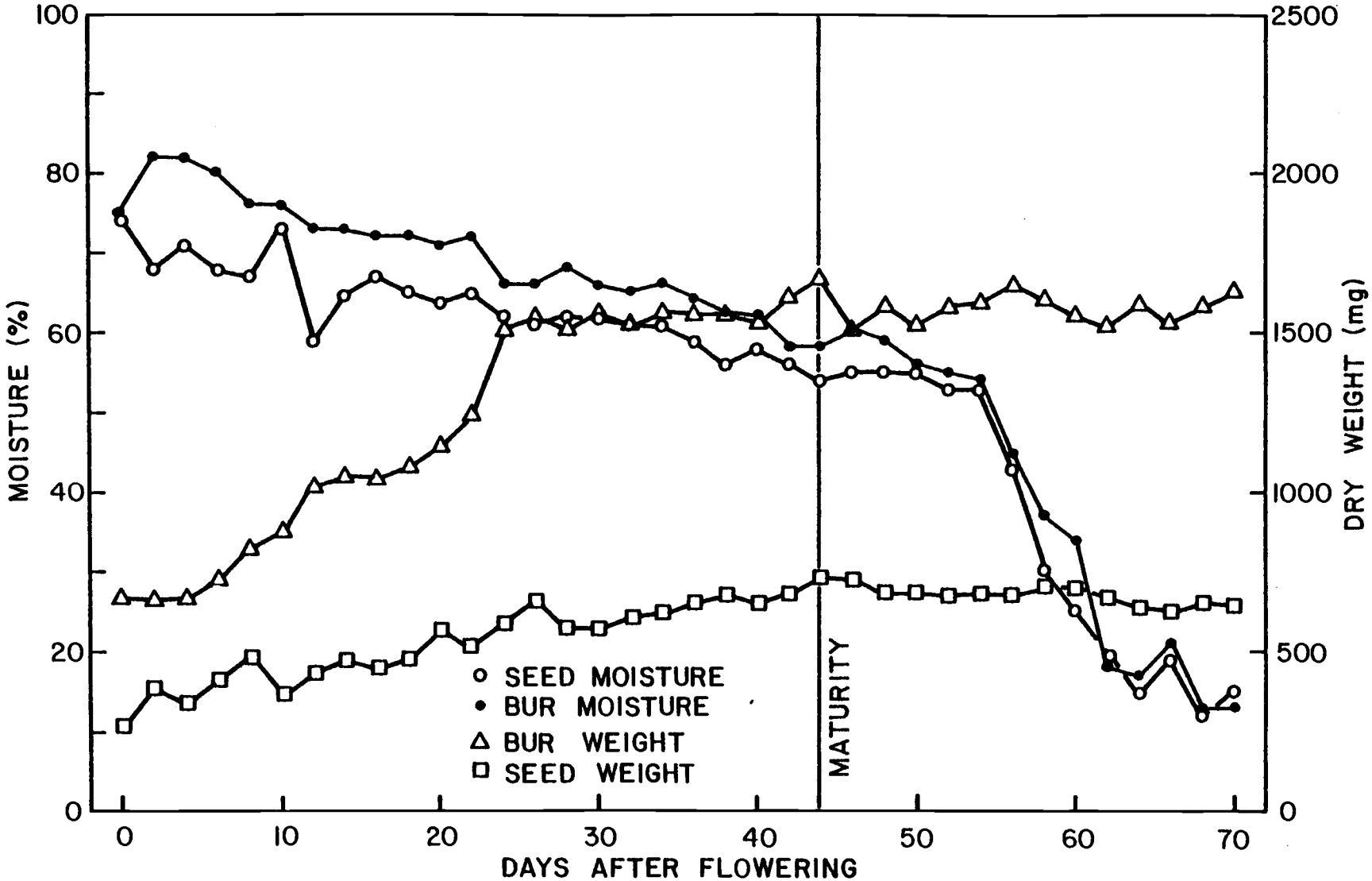

Figure 6. Dry weight and moisture content of 50 seeds and 25 burs of Mt. Barker subclover sampled at various stages of maturity, 1981.

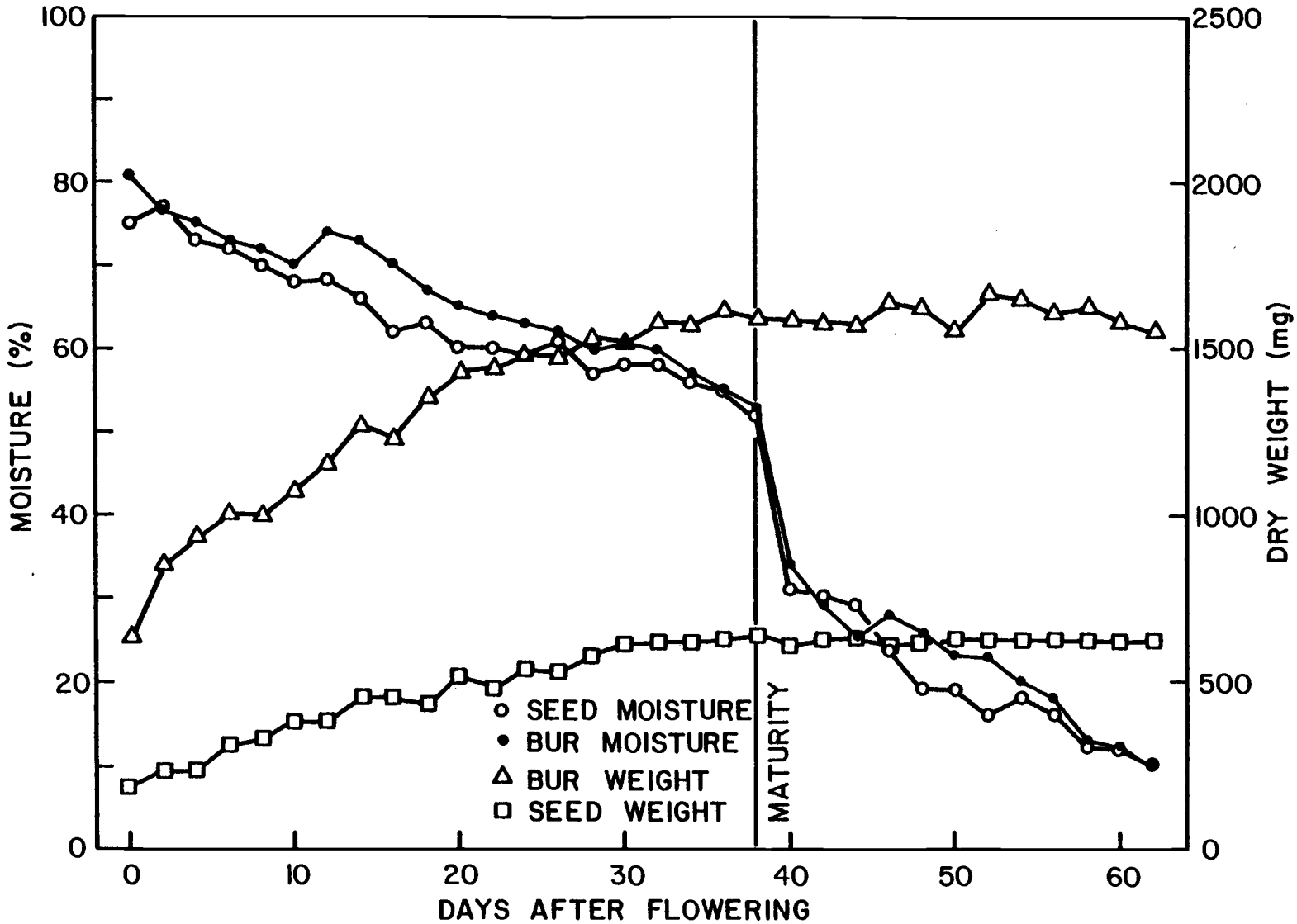

Figure 7. Dry weight and moisture content of 50 seeds and 25 burs of Mt. Barker subclover sampled at various stages of maturity, 1982.

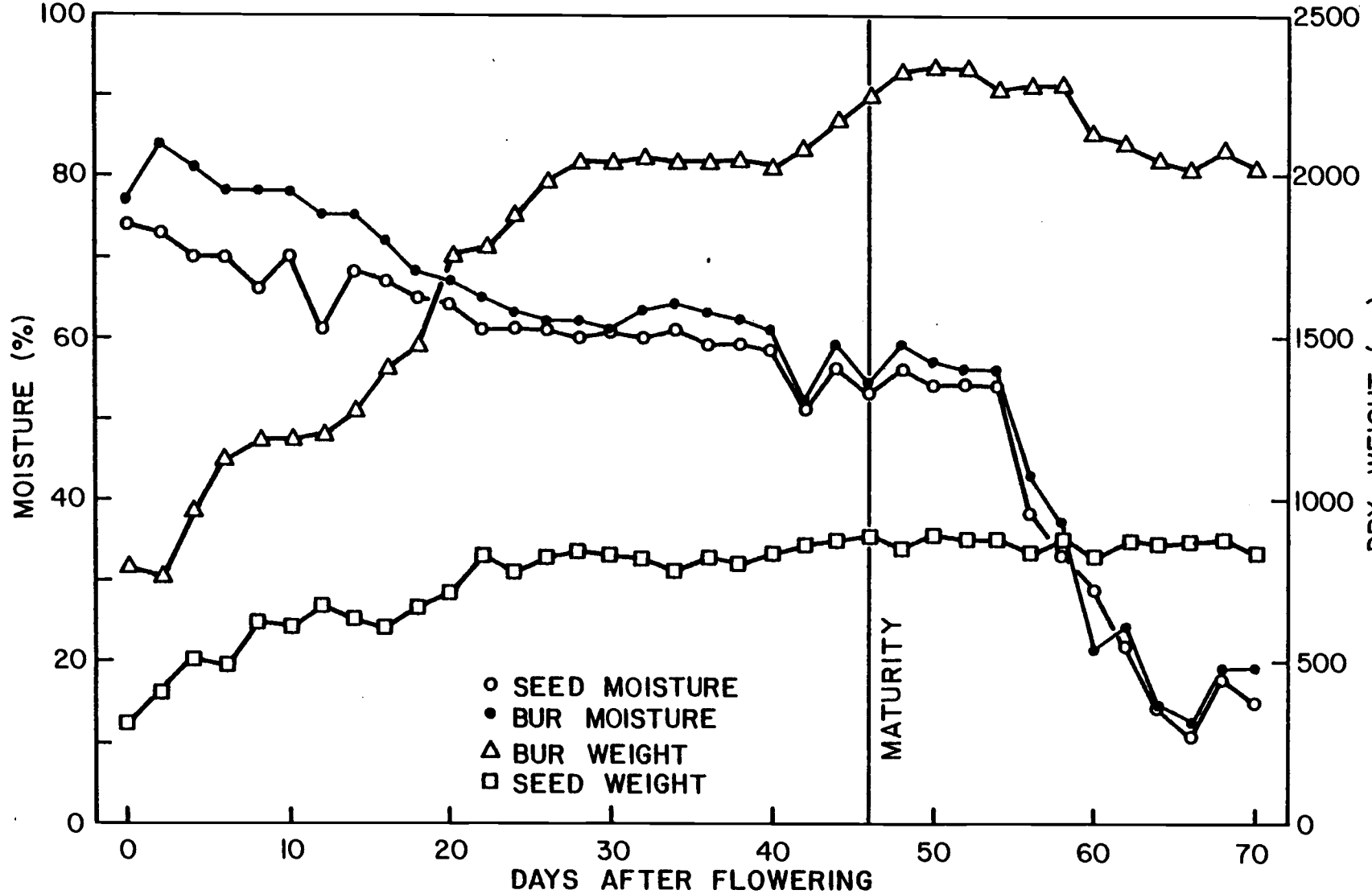

Figure 8. Dry weight and moisture content of 50 seeds and 25 burs of Nangeela subclover sampled at various stages of maturity, 1981.

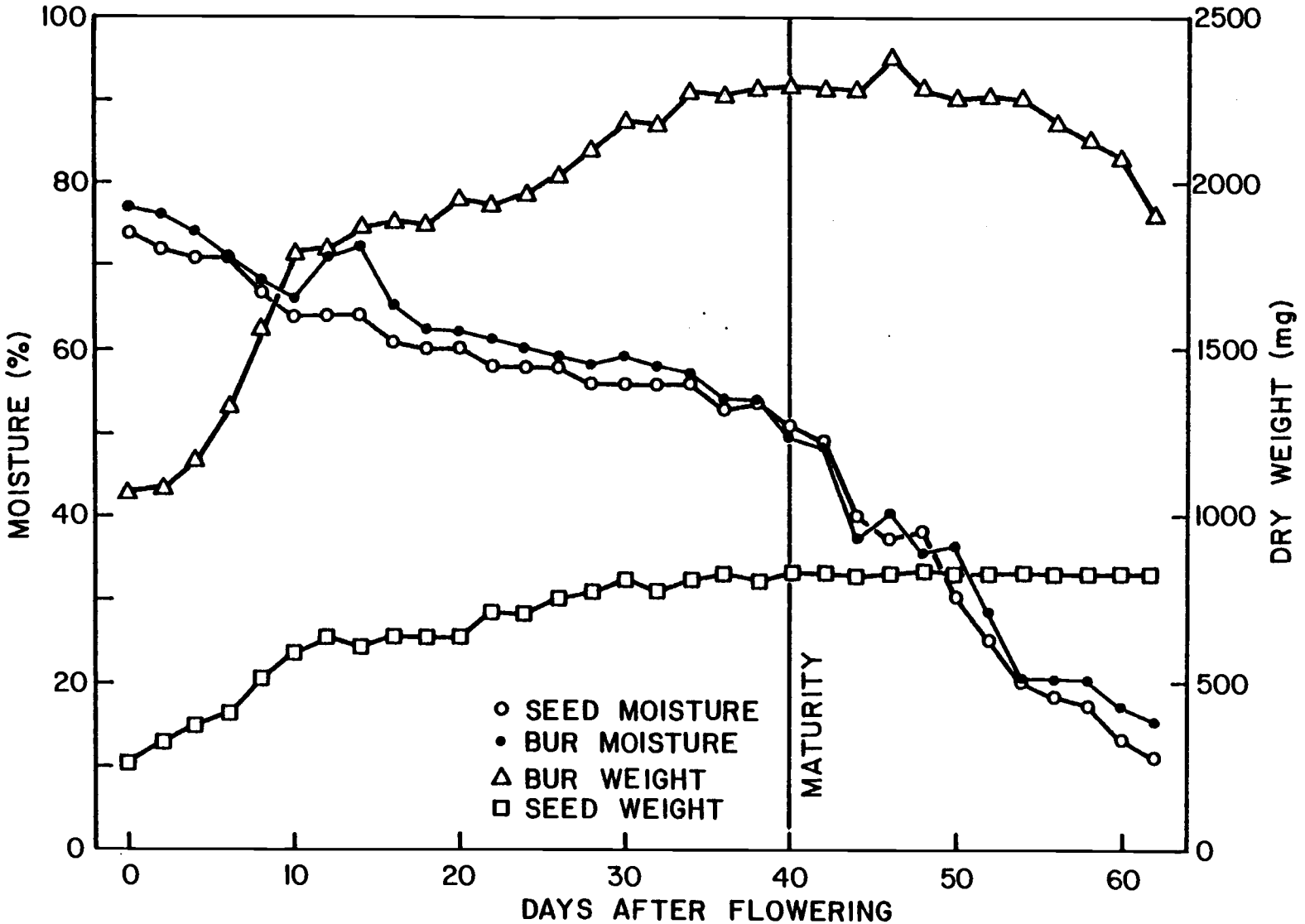

Figure 9. Dry weight and moisture content of 50 seeds and 25 burs of Nangeela subclover sampled at various stages of maturity, 1982.

It was very difficult to establish a precise date when subclover seeds reached maximum dry weight. While early seed development was quite rapid, later development was slow and gradual so it was not easy to detect when further growth had stopped. In contrast, grass and cereal seeds develop and mature over a narrower time span and the precise dates of maturity are easier to detect (Grabe, 1956; Frey et al., 1958; and Hyde et al., 1959).

Several factors contributed to the apparently slow maturation rate of subclover seed in this study. Most of the seed developed from flowers that were pollinated within a few days of the original sampling date of June 15. Since subclover flowering is indeterminate, however, additional flowers and seeds formed after that time. These later developing seeds added small increments of weight to the sample after the majority of seeds had reached maximum dry weight. Also, sampling was done on a bulk basis rather than on an individual flower basis, in order to develop a practical method for determining seed crop maturity. Thus, while an individual seed may reach maturity in 42 days (Taylor, 1980), a somewhat longer time is required for all seeds in the crop to mature.

Bur moisture content can be used as a simple index of seed maturity in subclover. Under Willamette Valley conditions, maximum seed dry weight and vigor of Mt. Barker and Nangeela are reached at bur moisture contents of 49 to 58%.

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APPENDICES

LITERATURE REVIEW

Subterranean clover, Trifolium subterraneum L., is a prostrate growing winter annual legume. Subterranean clover, or subclover, is native to the Mediterranean Basin and is well suited to use in pastures (Donald, 1959). Under normal conditions, the plant grows from seed planted in the fall and proceeds through winter with little growth occurring. In the spring, growth is very rapid and by mid-summer the seeds have fully developed and the plants die (Rampton, 1945).

Most of the numerous articles on the growth and development of subterranean clover are based on research conducted in Australia. At present, there is no available information concerning the development and maturation of subclover seed in relation to time of harvest in Oregon.

Canopy Development and Flower Initiation

Subclover is characterized as having a short main axis and strong lateral growth (Aitken and Drake, 1941). A number of the major growth characteristics of subclover are influenced by the time of flowering. The number of runners and laterals from a developing plant and their branching are strongly influenced by this inherited character. The capacity of the plant to produce leaves and seeds is largely dependent on the quantitative production of runners and lateral growth.

Aitken and Drake (1941) found that approximately five basal leaves formed prior to the rosette stage occurring in winter. From the basal nodes, approximately five prostrate runners are produced,

each having about three nodes. In the cultivar Mt. Barker, approximately 16 basal runners are capable of being produced per plant (Aitken and Drake, 1941). It is believed that further runner initiation is prevented by flowering at the top of the main axis. Commencement of internode elongation coincides with flower initiation at the growing point. Each of the approximately 16 runners are capable of producing about 20 or more nodes. No lateral growth occurs on the first two or three nodes. These nodes are vegetative and produce leaves only. Subsequent nodes, four through nine, are vegetative but possess the capability of producing lateral runners. The uppermost nodes on the runner, ten through twenty, are termed reproductive and are the nodes which produce the flowers.

Most of the viable seed is produced from the nine uppermost nodes. Flowers formed on the lower nodes are dwarfed by the plant's canopy. Little viable seed is formed from these flowers (Aitken and Drake, 1941).

Subclover is a long-day plant (Aitken, 1955) which shows considerable variability in flowering among cultivars. The two primary factors which cause large shifts in the flowering time of subclover are temperature and photoperiod (Aitken, 1955; Evans, 1959; Morley and Evans, 1959). Aitken defined flower initiation as the time when the first double ridge appears on the shoot apex.

Aitken and Drake (1941) found the time between planting and flower initiation to be that period which is most subject to environmental variation. From his study, Evans (1959) concluded inflorescence initiation to be the most limiting step in the plant's life

cycle. The most important factor affecting subsequent stages of plant growth, flower development and seed maturation is temperature.

Among cultivars there are differences in low temperature (vernalization) requirements for floral initiation (Aitken, 1955; Evans, 1959; Morley and Evans, 1959; Collins and Smith, 1975). Evans (1959) studied the floral initiation of eight cultivars of subclover. In his study, the cultivar Mt. Barker required 4 weeks at 7°C for floral initiation while early flowering cultivars like Dwalganup and Clare required a 2-week period. Collins and Smith (1974), utilizing temperatures of 7, 11, 14, and 17°C, found the rate of development in Caranamah, Yarloop, Woogenellup, and Mt. Barker to increase with decreasing temperatures. The authors note that this effect was greater with the later flowering cultivars. Vernalization of developing subclover embryos, germinating seeds, or young seedlings with low temperature exposure will hasten flower initiation (Aitken, 1955a; Evans, 1959; and Morley and Evans, 1959).

Roberts and Struckmeyer (1938) found the photoperiod requirements of plants to decrease with decreasing night temperature. Adams (1934) suggested that daylength may be more critical for the later flowering cultivars then for the earlier flowering ones. Aitken (1955) found the late flowering cultivars required temperatures below 13°C for a period of time if flowering was to occur. In the early flowering cultivars, the critical temperature was above 13°C and there was a marked interaction with photoperiod. It appears that vernalization is able to confer independence of daylength on previously long-day plants.

Collins and Aitken (1970) found leaf removal to be an added factor known to influence flower initiation in subclover. In their study, they found the removal of fully matured leaves delayed flowering up to 30 days in the cultivar Mt. Barker. This has important implications on the development of subclover when the crop is to be utilized for grazing. Flowering may be delayed because the basal axillary buds, which have been removed mechanically by clipping or by animal grazing, require a longer period of time to develop.

Reproductive Development

The subclover inflorescence consists of three to seven, usually four, perfect florets attached to a peduncle (Morley, 1961). The florets are approximately 12 mm long and have a tubular-type calyx with five green lobes slightly longer than the tube. The corolla is white with pink veins. The subclover floret is self-fertilized. Pollination occurs when the corolla has elongated to the level of the tips of the calyx lobes.

The bur consists of four to five sterile or partially developed florets forming a prong-like structure. The cluster of sterile florets turn upward and surround the developing fruit forming a bur. Following fertilization, the peduncles elongate approximately 4 to 5 cm and bend toward the ground (Yates, 1957). This forces the developing fruit into the ground. On the lighter sandy soils, the burs bury themselves. On heavier clay soils, the burs usually remain on the soil surface (Yates, 1960).

Three to four seeds are commonly formed per flower cluster; however, differences exist between cultivars. One cultivar, Burnerang, produces a high proportion of twin seeds resulting from

equal development of two ovules in one ovary. Genotypical variations also exist among cultivars in relation to seed color. The testa of the subclover seed is usually a purple-black color. Bud mutations may occur preventing normal anthocyanin distribution and coloring in the seed. Absence of the anthocyanin pigment from the floral parts and vegetative structures is linked with a colorless testa. This results in white or amber seed being produced. Cultivars exhibiting white seed from such a mutation include Reigert's, Dwalganup, and Mt. Barker.

Cultivar Selection

There is considerable variation within the species of subterranean clover. Some of the different strains are readily recognizable, but others are not. Quinlivan (1962) notes the classification of several hundred different subclover strains. These differences allow the strains to adapt to a number of diverse environments for growth and development. The variation in time of maturity serves as the most important difference between strains. Additional characteristics used to distinguish between cultivars include pubescence, leaf pattern, anthocyanin content and distribution, and flower and seed color.

For convenience, Aitken and Drake (1941) classified the many cultivars of subclover into early, early mid-season, mid-season, late mid-season, and late groups. Their classification system was based on the visual observation of flowering time in a wide variety of cultivars. Aitken and Drake regarded the time of flowering as an expression of length of the vegetative period and the plant's capacity to branch.

Rampton (1945) found the early strains of subclover to be of little value in Oregon. Generally, the later strains are those which have the higher forage and seed yields. For Oregon conditions, Rampton recommended the planting of Mt. Barker, a mid-season cultivar, and Tallarook, a late mid-season cultivar. In addition to the above two, Steiner (1982) lists Nangeela, a late mid-season cultivar, and Woogenellup, an early mid-season cultivar, as being suitable for seed production in Oregon. He notes that all cultivars are capable of producing 1100 kg per hectare under Oregon's environmental conditions.

Harvest

Subterranean clover, as the name implies, produces a large proportion of its seed in the soil or below the vegetative mat formed on the soil surface. The crop's prostrate growth habit, bur burial tendencies, and vegetative mat formation make harvesting subclover difficult. The fact that the seed is formed on or under the ground with the foliage on top, places the harvesting of this crop in a class by itself.

Early methods used to harvest the burs include mowing and raking, use of sheepskin on rollers to facilitate bur pick-up, a special lifting attachment on the mower, and the use of a hay rake (Wilkie, 1946). Ballard (1956) lists four phases of harvesting subclover seed on a commercial scale. They are: (1) removing the top growth, (2) gathering the seed pods, (3) threshing the seed pods, and (4) cleaning the threshed seed.

In soils where the burs are buried, the surface needs to be loosened to expose the burs. If the burs are not buried, then no

special treatment is necessary. However, when a hard crust has formed sealing off the burs, some sort of light harrowing is required.

There are two methods currently being used to harvest subclover seed in Oregon. One such method employs the use of the Horwood Bagshaw vacuum harvester. Before the field is harvested, the clover must be mowed and removed, leaving the burs on the ground. The field is then left to dry for a period of time. Once dry, the field is gone over with the vacuum harvester. Harvesting in this manner is a very slow process. One harvester will cover about two hectares per day. In the field, the vacuum harvester moves at a rate of 2.9 kilometers an hour, covers a 1.2 meter swath, and has a hopper which holds 227 kilograms of seed. After harvesting, enough seed is left on the ground to reestablish the clover the following fall.

In the other method of harvesting, the field is windrowed with a conventional windrower when the crop is dry. A combine can then be used to harvest the seed from the windrows. A Murphy flail-type pickup attached to the combine is then used to pick up burs left on the ground.

Seed Quality

Embryo dormancy

Subterranean clover possesses two types of germination-regulating mechanisms: embryo and impermeability dormancy. Morley (1958) speculated that inhibition of germination has arisen in strains of subclover to ensure survival in their natural habitat. The mechanism is valuable as it prevents germination at times when seedlings would be unlikely to survive.

Loftus Hills (1942, 1944a) was the first to study the phenomenon of embryo dormancy in subclover seeds. He distinguished between seeds which were impermeable to water (hard seeds) and seeds which are incapable of germinating because the embryo itself is physiologically immature (embryo dormant seeds). Loftus Hills (1944a) found that embryo dormancy was a varietal character and dormant seeds tended to germinate better at lower temperatures. Morley (1958), in his studies on dormancy, found subclover seed originating from strains in cool moist climates having less embryo dormancy than those from the warmer arid climate. He also noted that embryo-controlled dormancy is highly heritable in some strains.

Grant Lipp and Ballard (1964) separated three cultivars of subclover seed into different size classes. The samples were further separated into hard and soft seed. Their results show for all cultivars examined that small seeds were more dormant than large and hard seeds have a higher percentage of embryo dormancy than soft seeds.

Young, Kay and Evans (1970) summarized those factors which they felt influenced dormancy in subclover as: (a) environmental factors which acted on the parent plant, (b) age of the seed, (c) temperature of incubation, (d) carbon dioxide level of incubation, (e) removal of seedcoat, and (f) genotype of the embryo.

It was the belief of several investigators (Taylor and Rossiter, 1967; Quinlivan and Nicol, 1971; Quinlivan, 1971) that embryo dormancy prevented out-of-season germination during summer rains. In a study conducted by Taylor and Rossiter (1967), the authors found an increased degree of germination from subclover seed which had been

leached with water. They ascribed this result to the presence of a germination inhibitor in the embryo which can be leached out with water. Subclover seeds possessing embryo dormancy are capable of repeated water imbibition and subsequent drying without any loss in viability (Morley, 1958). For this to be significantly effective in preventing out-of-season germination from summer rains, the inhibitor should not dissipate at too rapid a rate. The causative agent in the breakdown of embryo dormancy is high summer temperatures (Quinlivan and Nicol, 1971), the inhibitors present in the seed are susceptible to heat. Subclover seeds remaining after harvest are on or just under the soil and are subjected to high daily temperatures causing breakdown of the inhibitors. Quinlivan (1971) notes that the mechanism of embryo dormancy may be important in the prevention of germination during the late maturation period of seed development.

The duration of dormancy in freshly harvested subclover seed is questionable and relies on many factors. Woodforde (1935) considered normal germination to occur in subclover seed after a period of 3 to 4 months. His results showed an increase in germination after a 3-month period from 7, 20 and 22 percent to 81, 72 and 79 percent, respectively. Woodforde concluded that the natural process of maturation had occurred.

Loftus Hills (1944a) conducted a study on the process of after-harvest ripening on samples of subclover seed harvested in 1940 and 1941. The conclusions drawn from his work are:

1. Seeds of subclover which showed a large percentage of delayed germination required over 12 months to mature fully when stored indoors.

2. Seeds with a moderate amount of delayed germination required periods from 7 to 12 months to mature completely.

3. None of the seeds tested had progressed enough in maturity to germinate by the fifth month.

In relation to other subclover strains, Mt. Barker and Nangeela are considered moderately dormant (Loftus Hills, 1944c).

Embryo dormancy and germination

Regardless of the time involved with after-ripening, studies have been successfully conducted on by-passing dormancy in freshly harvested subclover seeds. Woodforde (1935) found that a 3-day pre-chill of 8°C increased the germination of two samples of subclover seed from 1 and 27 percent to 89 and 85 percent, respectively. In this study, dormant subclover seeds ranging from 2 months to 2 years old were used. Loftus Hills (1944b) showed that germination of dormant seeds was faster at 10°C than at 20 and 30°C. He noted, however, that germination percentages at 20°C equaled that at 10°C after an additional 8 to 10 days.

Utilizing a new method for breaking dormancy, Ballard (1958) exposed subclover seeds to differing concentrations of carbon dioxide. He found a marked response of dormant seeds to low carbon dioxide concentrations of from 0.3 to 4.5 percent. With a response to such low carbon dioxide concentrations, Ballard suggested that respiratory carbon dioxide evolved by dormant seeds, if allowed to accumulate in sealed vessels, could itself initiate germination. Ballard was able to detect inhibitory effects when carbon dioxide concentrations exceeded 5.0 percent. In addition, samples treated

with activated carbon failed to break dormancy. The activated carbon was used to absorb inhibitors in the seedcoat and liberate carbon dioxide which might then initiate germination.

Young, Kay, and Evans (1970) studied the germination characteristics of 11 cultivars of subclover. Mt. Barker and Bacchus Marsh germinate well at 20°C after pre-chilling at 0.5, 5 and 10°C. Work done on inclined versus flat plates showed that there may be some inhibitors present around the seed of Mt. Barker and Bacchus Marsh on flat plates. At low incubation temperatures, both cultivars had a much higher germination percentage on inclined plates then on flat plates. The two cultivars also responded favorably to increasing levels of KNO_3 at low temperatures.

Hardseededness

Aitken (1939) defined hard seeds as, "Those seeds in which impermeability of the seedcoat prevents water absorption." Her detailed work on hardseededness in subclover showed this phenomenon to be dependent on an impermeable, suberized thickening on the top of the Malpighian cells. Hard seeds are capable of germinating after treatment by some means which makes the seedcoat pervious to water. The process of altering a seedcoat to facilitate the entry of water is referred to as scarification.

Aitken's work showed hardseededness to be markedly influenced by the environment under which the seed is produced. She stated that formation of hard seeds is influenced by the length of the development period and the degree to which the seeds are dried. Aitken also found that hot, dry weather towards the end of the growing season would dry off the younger seeds of the later maturing cultivars

before they had fully developed. In this case, a higher percentage of soft seeds would be produced with the later maturing cultivars than with the earlier maturing type where the seed has a longer time to develop.

While embryo dormancy has been attributed to the varietal character of the seed (Loftus Hills, 1942; Morley, 1958), the degree to which hardseededness is genetically controlled has been relatively unclear at times. Loftus Hills (1944c) conducted a study on hard-seededness and the variation between cultivars of subclover. Among the 22 strains tested, he found no difference in the proportion of hard seeds produced. Loftus Hills suggests that, given suitable conditions, all strains are capable of producing a large proportion of hard seeds. In contrast, Donald (1959) found hardseededness to be a varietal characteristic. He concluded that Dwalganup is genetically different from Bacchus Marsh, Tallarook, and Mt. Barker in its ability to produce hard seeds. It has been suggested (Quinlivan and Millington, 1962) that Donald's work may have only selected out a strain which had the capacity to resist environmental conditions conducive to hard seed formation.

Quinlivan (1965) found strains with a high proportion of hard seeds in areas with a relatively long spring growing period. He concluded, as did Loftus Hills (1944c), that in given environmental conditions, all strains of subclover are capable of producing a high proportion of hard seed.

Taylor and Palmer (1979), in their study of some environmental conditions on seed development and hardseededness in subclover, found that varying the length of seed development does not necessarily

result in differences in hardseededness. Temperature treatments had a significant, though very small, effect on hard seed content. When moisture stress was applied to the plants, no significant differences were observed.

Working with two cultivars of subclover, Quinlivan (1966) reported different rates of softening when impermeable seed from the cultivars were exposed to daily fluctuating temperatures. Later, Gladstones (1967) was able to show similar varietal differences in impermeability among 68 different subclover cultivars. The work of these researchers has shown impermeability to be a varietal characteristic and that it is possible to breed or select for a level of hardseededness appropriate for a particular environment. In summary, work to date indicates that the degree of hardseededness in subclover is influenced by genotype, conditions during the growing season, and temperature to which the ripening seed is exposed.

Duration of Hardseededness

Hardseededness may last for relatively long periods of time in strains of subclover when stored in an environment of suitable moisture, temperature, and relative humidity. Meadly (1974) conducted a study on the behavior of hardseededness in the cultivar Dwalganup. Samples were tested regularly to ascertain the effect of extended storage at room temperature on viability. His findings showed the hard seed content of Dwalganup to remain relatively stable over the entire 37-year period. Insufficient seed reserves remained to continue testing after this period of time. Meadly also notes a drop in the mean germination percentage with time in association with a corresponding increase in abnormal seedlings and dead seeds.

Williams and Eliott (1960) found impermeability in subclover seed grown in five different locations in California decreased with time. In samples collected in June, hard seed content ranged from 58 to 91 percent. Seed from later dates of collection decreased in impermeable seed percentage and increased in germination percentage. Samples collected in October contained between 0-3% hard seeds and germinated 96-99%. Seed coat impermeability appears to exhibit a rapid decline when left exposed to summer environmental conditions.

An interesting study on the viability of permeable and impermeable subclover seeds was undertaken by Flood (1978). He found approximately 95% of the hard seeds to be viable after 18-20 years, while permeable seeds ranged from 37% to 42% in their germination capacity.

Methods of overcoming hardseededness have dealt primarily with seedcoat scarification. Hand and mechanical scarification has been used successfully as a technique to reduce impermeability (Loftus Hills, 1942). Scarification removes the impermeable layer in the seedcoat, allowing water to pass. Mechanical impaction has also been used successfully as a measure to overcome impermeability. Aitken (1939) found that impaction of the seedcoat caused a cleft in the strophiole through which water could pass. Other methods employed to overcome hardseededness in the laboratory are scarification with acid (Quinlivan, 1971), and notching the seedcoat with a razor blade (Taylor and Palmer, 1979).

Maturity

For many cereal and grass crops, the optimum stage for harvesting the seed crop is known. To aid in this determination, there

have been many estimates of crop maturity developed over the years. Early attempts to estimate maturity most commonly dealt with visual indicators like browning of the plant, leaf and stem senescence, or the external appearance of the seed unit (spike, panicle, or ear). Later, the stage of seed development received more attention. Measurements such as moisture content, dry weight accumulation, viability, and seedling vigor became increasingly common. Studies of this nature are well documented for cereal grains (Harlan, 1920; Bartel, 1941; Frey et al., 1958; Dessureaux et al., 1948; Collier, 1963; and Rajanna and Andrews, 1970), forage crops (Hermann and Hermann, 1939; McAlister, 1943; Griffith and Harrison, 1954; Anderson, 1955; Grabe, 1956; and Hyde et al., 1959) and a number of other species (Brimhall and Haber, 1950; Leininger and Urie, 1964; Browne, 1978; and TeKrony et al., 1979).

Aldrich (1943) termed maturity as that point in plant growth where maximum grain development is first attained. The time required for strains to reach the maximum dry weight was defined as relative maturity. Shaw and Loomis (1950) referred to the time when a seed reaches its maximum dry weight as physiological maturity. This point has also been referred to as functional maturity (Delouche, 1958) and morphological maturity (Anderson, 1955). In spite of the differences in the concept of maturity, it is generally accepted that the term physiological maturity refers to the time when maximum dry weight is first attained in seed development.

Although many procedures have been used to estimate maturity, most of the research has compared the relationship of maturity to:

(1) the accumulation of dry weight in the seed, (2) moisture content, and (3) germination.

The period of time in days from anthesis to maximum dry weight is a common estimate of maturity in crops. In subclover, Taylor (1980) found seed development in the cultivar Daliak to be complete 42 days after flowering under a controlled greenhouse environment. Taylor notes that pod walls attained near maximum weight earlier, at day 22. Aldrich (1943) found the day of silking to be the most significant time for establishing a base point for maturity in corn. Dessureaux et al. (1948) and Hallauer and Russell (1962) reported that the interval from silking to maturity was between 61 and 68 days and 60 and 63 days, respectively. Harlan (1920) reported that maximum dry weight of barley is attained 26 days after anthesis. Other investigators have found that physiological maturity is attained: 20 to 28 days after anthesis for oats (Frey et al., 1958); 24 to 26 days for wheat (Bartel, 1941); 33 to 45 days for sorghum (Kertsing et al., 1961); 28 days for safflower (Leininger and Urie, 1964); and 27 and 24 days after flowering for birdsfoot trefoil (Anderson, 1955) and red clover (Hyde et al., 1959), respectively.

Collins and Quinlivan (1980) found seed yields of four strains of subclover to peak between 74 days and 86 days after the onset of flowering. The rate of accumulation of seed dry weight was of the order of 6 g/m^2/day for most of the seed development phase.

In cereals, a close relationship has been shown to exist between seed moisture content and maximum seed dry weight. The moisture content of seeds at the time of maximum dry weight has been reported for barley as 42% (Harlan, 1920); oats, 45% (Frey et al., 1958);

wheat, 40% (Burnett and Bakke, 1930); and sorghum, 27% (Clark et al., 1968).

The use of seed moisture content as an index for physiological maturity may be considered insufficient when used alone. In corn, kernel moisture percentage was used originally as an indication of maturity. Dessureaux et al. (1948) reported the moisture content of corn to be between 31 and 44% at maximum dry weight. Later, Shaw and Thom (1951) found kernel moisture percentage inferior to maximum kernel dry weight as an indicator for physiological maturity.

A summary of the seed moisture levels and days after anthesis for seed maturation in several crops is presented in Table 1.

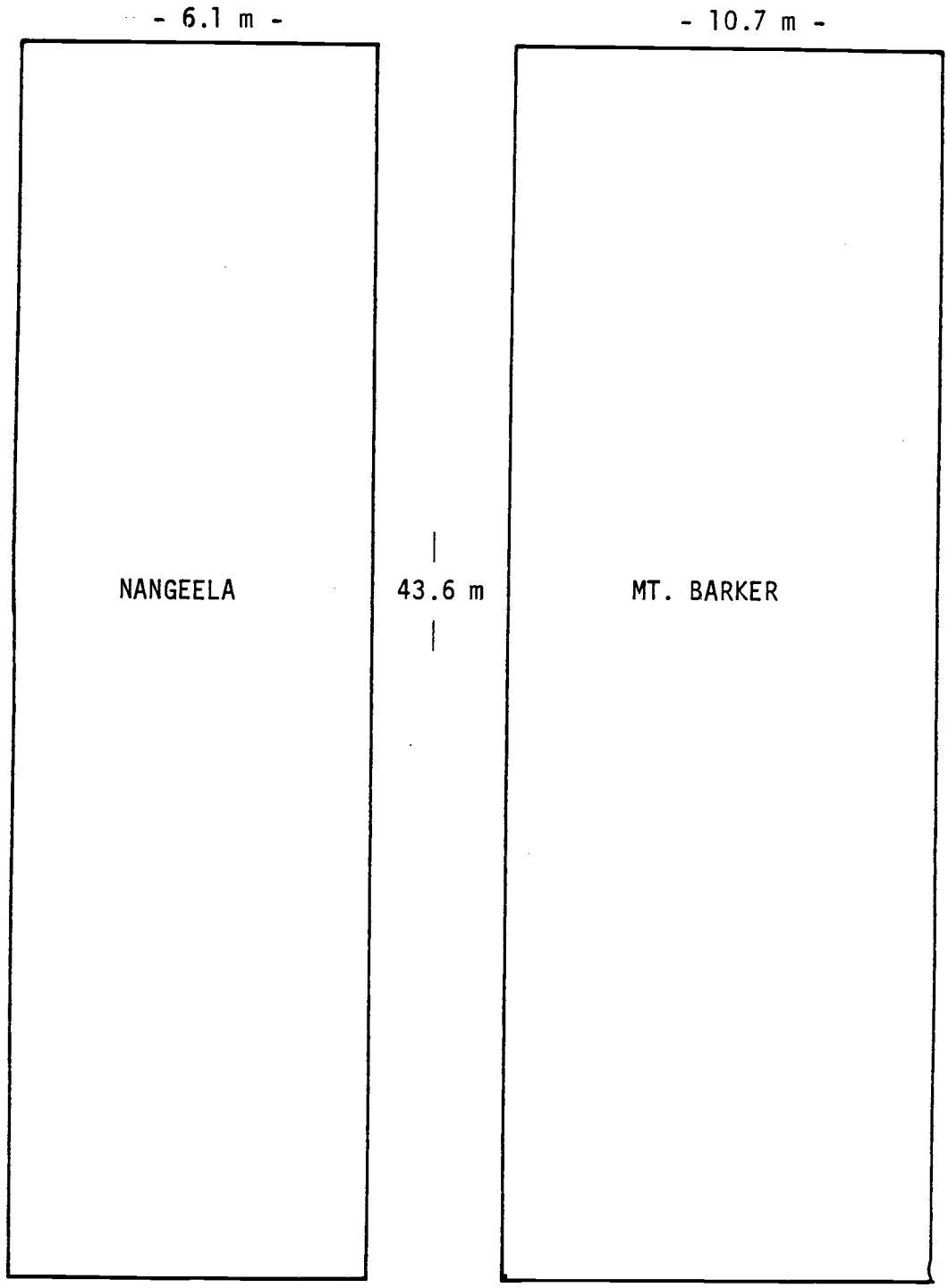
Emphasis has been placed on the use of germination as a measure of seed maturity. Germination has been found to increase with days after anthesis (Anderson, 1955; Grabe, 1956; Frey et al., 1958; Kertsing et al., 1961; and Rajanna and Andrews, 1970). In many of the studies, a close relationship exists between germination, moisture content, and seed dry weight. In rice, Rajanna and Andrews (1970) found that seeds sampled 19 days after anthesis reached an approximate 95% level of germination with some seeds capable of germinating on the 10th day after anthesis. Bartel (1941) reported the germination of immature wheat and barley seeds harvested 8 days after anthesis. The corresponding value for smooth bromegrass was 5 days (Grabe, 1956), oats 4 days (Frey et al., 1958), sorghum 12 days (Kertsing et al., 1961), safflower 4 days (Leininger and Urie, 1964), and crested wheatgrass 12 days (Hermann and Hermann, 1939).

Francis and Gladstones (1974) harvested seed from strains of subclover 20 to 30 days after flowering and subjected them to a

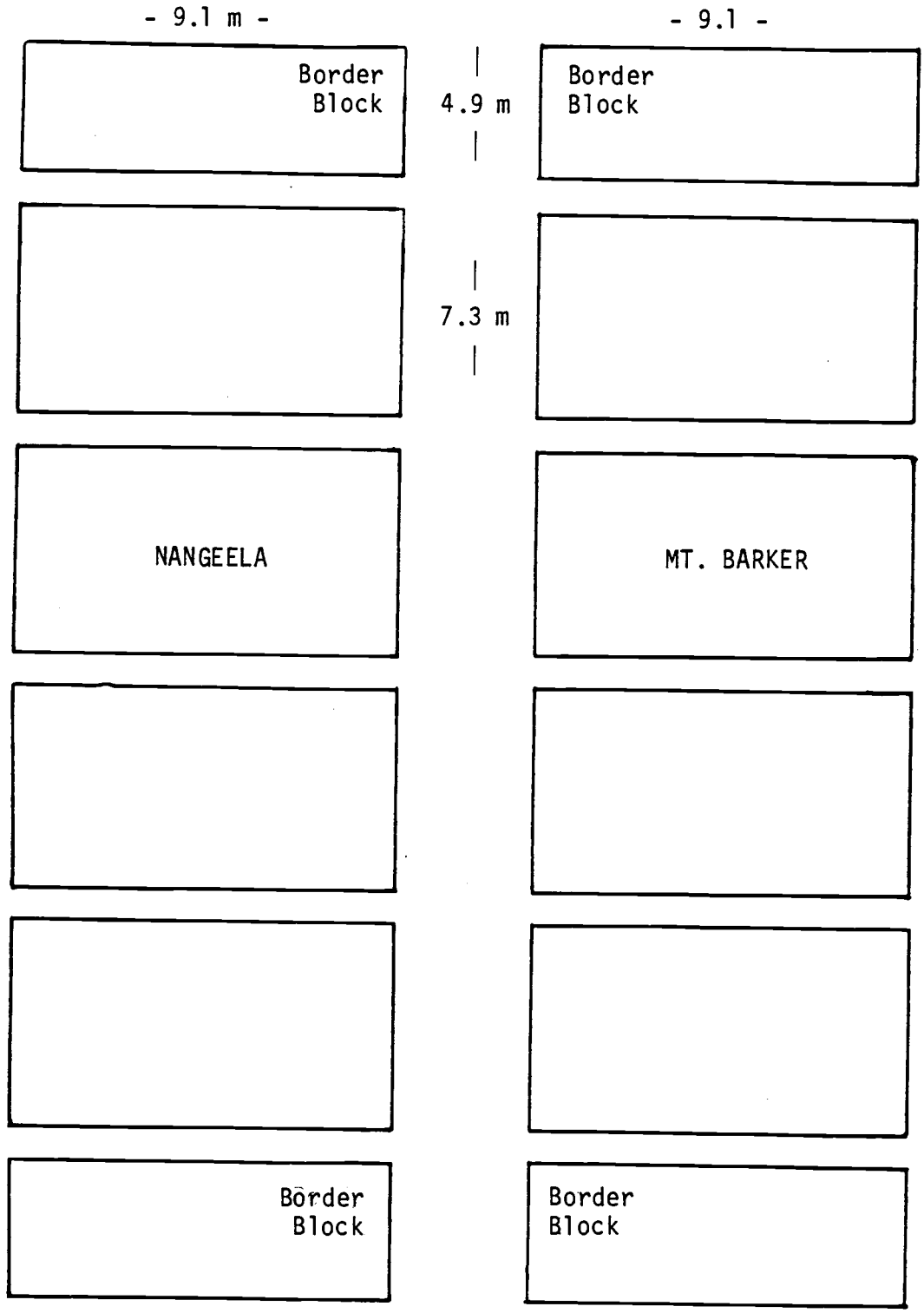
Appendix Table 1. Seed moisture levels and days after anthesis for maturity in several crops.

Crop	Moisture content %	Days after anthesis	Investigator
Barley	42	26	Harlan (1920)
Barley	40		Burnett & Bakke (1930)
Broomegrass, smooth	47	17-18	Grabe (1956)
Clover, red		24	Hyde et al. (1959)
Corn	31-44	61-68	Dessureaux et al. (1948)
Corn	30-42	50	Shaw & Thom (1951)
Corn	29-40	60-63	Hallauer & Russell (1962)
corn, sweet	40		Brimhall & Haber (1950)
Oats	45	20-28	Frey et al. (1958)
Rice	22-28	30	Rajanna & Andrews (1970)
Ryegrass, Italian	38	28	Hyde et al. (1959)
Ryegrass, perennial	44	28	Hyde et al. (1959)
Safflower	22-25	28	Leininger & Urie (1964)
Sorghum	25-30	33-45	Collier (1963)
Sorghum	27	36	Clark et al. (1968)
Soybeans	54-62		TeKrony et al. (1979)
Sugarbeets		40-45	TeKrony (1969)
Sunflower	28-30		Browne (1978)
Timothy		35-40	Stoddart (1959)
Wheat	40		Burnett & Bakke (1930)
Wheat		24-26	Bartel (1941)
Wheatgrass, crested		30	Hermann & Hermann (1939)

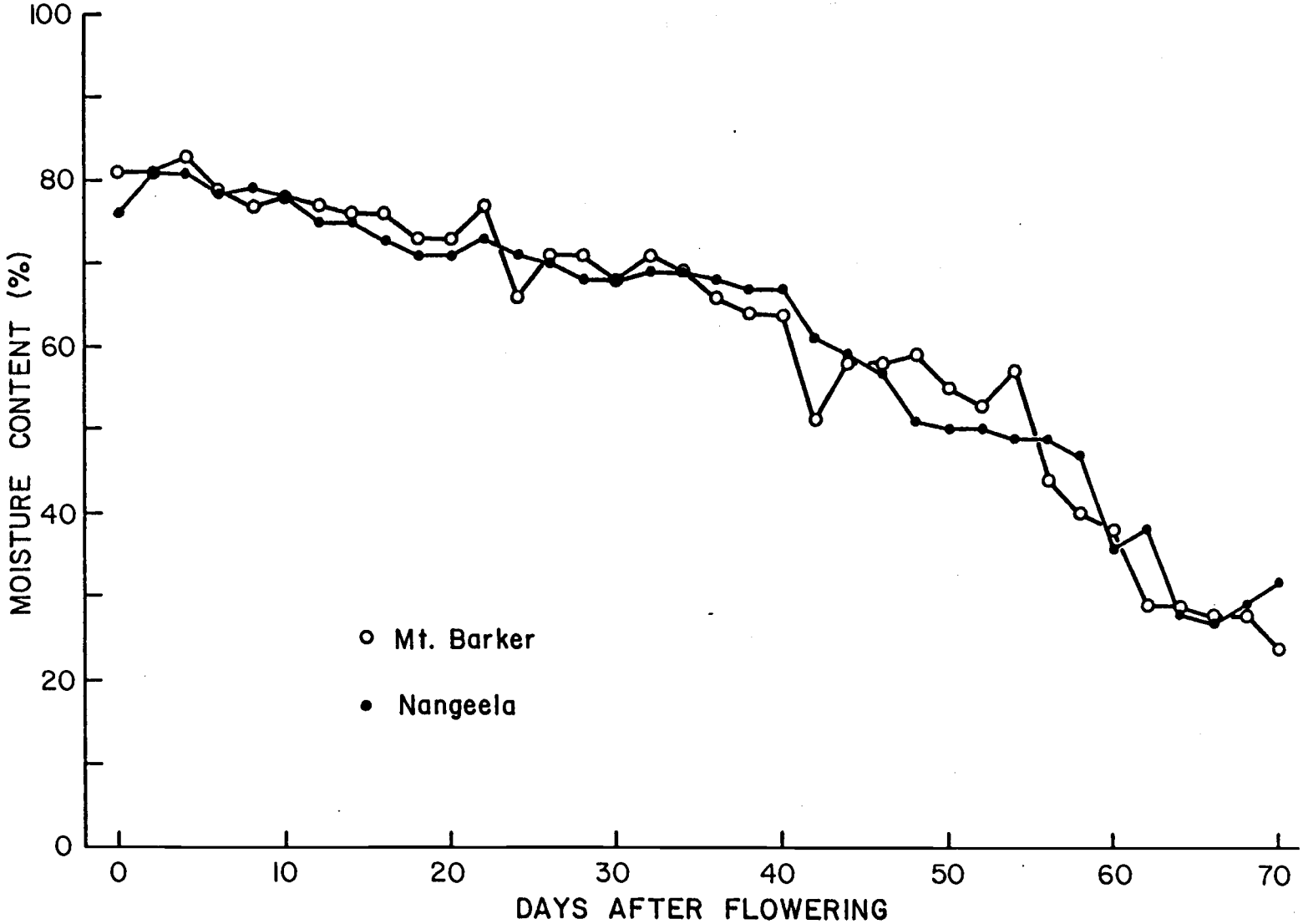
tetrazolium test. By 30 days after flowering, many of the 24 strains tested had attained nearly 100% seed viability.



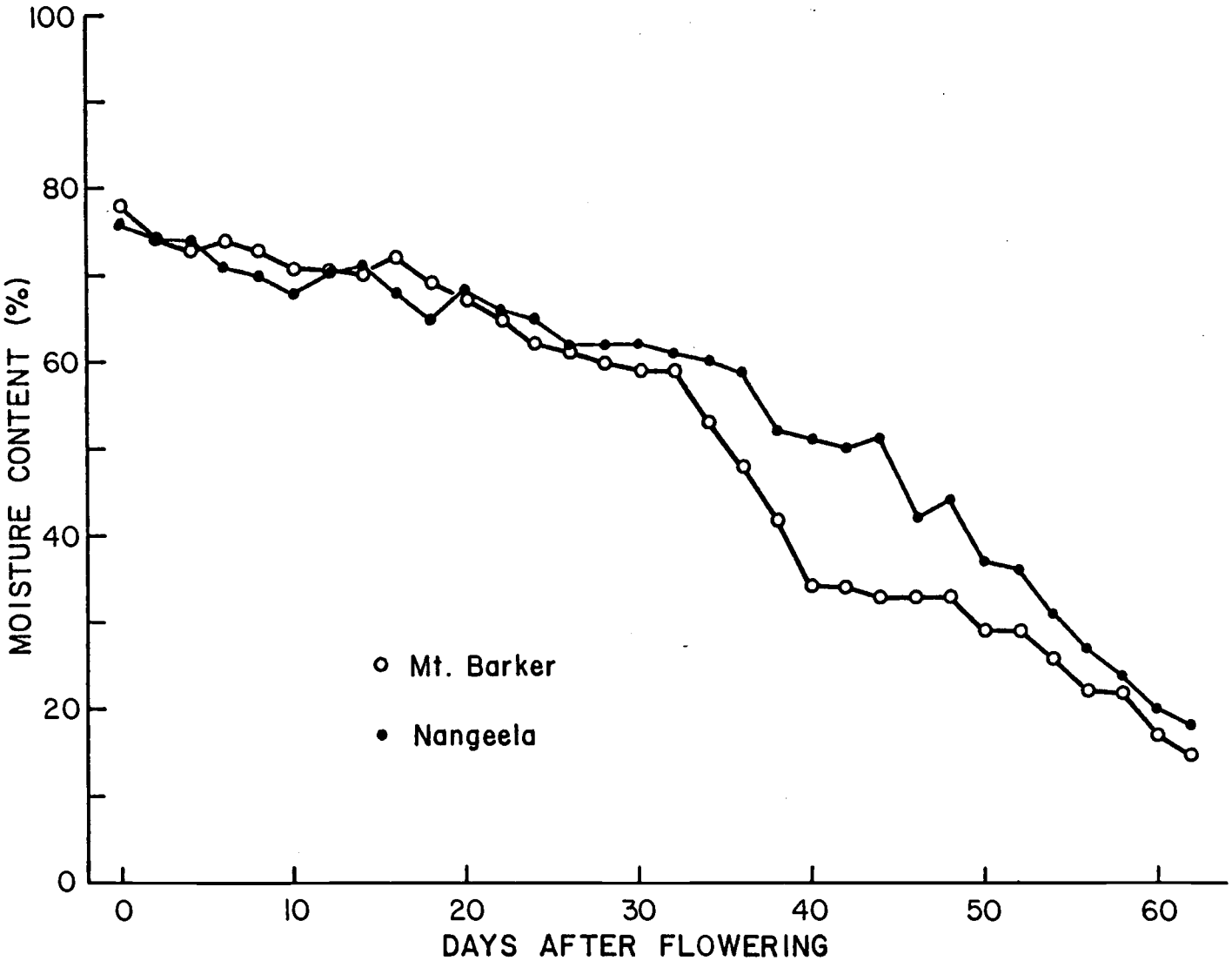
Appendix Figure 1. Field plot diagram of Mt. Barker and Nangeela in 1981.



Appendix Figure 2. Field plot diagram of Mt. Barker and Nangeela in 1982.



Appendix Figure 3. Crop moisture content at various stages of maturity, 1981.



Appendix Figure 4. Crop moisture content at various stages of maturity, 1982.

Appendix Table 2. Simple correlation coefficients for Mt. Barker and Nangeela, 1981.

	Cultivar	
Variables	Mt. Barker	Nangeela
Seed MC vs bur MC	.98	.98
Seed wgt. vs bur wgt.	.94	.96
Seedling wgt. vs seed wgt.	.97	.93
Seed wgt. vs germination	.79	.49

Appendix Table 3. Simple correlation coefficients for Mt. Barker and Nangeela, 1982.

	Cultivar	
Variables	Mt. Barker	Nangeela
Seed MC vs bur MC	.99	.99
Seed wgt. vs bur wgt.	.98	.95
Seedling wgt. vs seed wgt.	.98	.96
Seed wgt. vs germination	.62	.14

Appendix Table 4. Mean values of several maturity indicators for Mt. Barker harvested at two-day intervals following flowering in 1981.

Days after flowering	Seed weight	Bur weight	Seed moisture	Bur moisture
	mg		%	
0	260	665	74	75
2	390	661	68	82
4	338	666	71	82
6	422	736	68	80
8	488	823	67	76
10	368	883	73	76
12	442	1019	59	73
14	466	1049	65	73
16	452	1043	67	72
18	486	1088	65	72
20	570	1148	64	71
22	516	1236	65	72
24	590	1503	62	66
26	658	1555	61	66
28	574	1506	62	68
30	572	1557	62	66
32	604	1525	61	65
34	620	1569	61	66
36	652	1559	59	64
38	672	1567	56	62
40	654	1544	58	62
42	694	1615	56	58
44	732	1686	54	58
46	720	1502	55	60
48	692	1592	55	59
50	692	1535	55	56
52	675	1577	53	55
54	691	1596	53	54
56	674	1658	43	45
58	715	1607	30	37
60	710	1555	25	34
62	663	1525	19	18
64	647	1594	15	17
66	633	1538	19	21
68	659	1590	12	13
70	651	1638	15	13

Appendix Table 5. Mean values of several maturity indicators for Mt. Barker harvested at two-day intervals following flowering in 1982.

Days after flowering	Seed weight	Bur weight	Seed moisture	Bur moisture
	mg		%	
0	188	643	75	81
2	224	857	77	77
4	227	945	73	75
6	310	1053	72	73
8	341	1048	70	72
10	372	1085	68	70
12	383	1162	68	74
14	459	1274	66	73
16	456	1231	62	70
18	442	1357	63	67
20	519	1436	60	65
22	493	1445	60	64
24	535	1477	59	63
26	522	1465	61	62
28	575	1529	57	60
30	612	1507	58	62
32	628	1585	58	60
34	623	1568	56	57
36	632	1613	55	55
38	646	1594	52	53
40	605	1588	31	34
42	630	1581	30	29
44	640	1569	29	25
46	629	1648	24	28
48	628	1636	19	26
50	635	1555	19	23
52	641	1672	16	23
54	640	1659	18	20
56	637	1602	16	18
58	638	1635	12	13
60	635	1586	12	12
62	628	1559	10	10

Appendix Table 6. Mean values of several maturity indicators for Nangeela harvested at two-day intervals following flowering in 1981.

Days after flowering	Seed weight	Bur weight	Seed moisture	Bur moisture
	mg		%	
0	308	784	74	77
2	410	759	73	84
4	504	967	70	81
6	490	1139	70	78
8	622	1178	66	78
10	608	1193	70	78
12	664	1200	61	75
14	632	1274	68	75
16	604	1405	67	72
18	668	1480	65	68
20	706	1771	64	67
22	832	1790	61	65
24	762	1890	61	63
26	828	1980	61	62
28	842	2040	60	62
30	836	2035	61	61
32	820	2059	60	63
34	782	2040	61	64
36	818	2043	59	63
38	808	2045	59	62
40	838	2036	58	61
42	852	2067	51	52
44	866	2179	56	59
46	898	2254	53	54
48	850	2320	56	59
50	898	2344	54	57
52	891	2338	54	56
54	883	2261	54	56
56	842	2270	38	43
58	895	2274	33	37
60	828	2141	29	21
62	876	2114	22	24
64	863	2052	14	14
66	867	2025	11	12
68	883	2077	18	19
70	848	2029	15	19

Appendix Table 7. Mean values of several maturity indicators for Nangeela harvested at two-day intervals following flowering in 1982.

Days after flowering	Seed weight	Bur weight	Seed moisture	Bur moisture
	mg		%	
0	250	1082	74	77
2	314	1097	72	76
4	363	1169	71	74
6	403	1345	71	71
8	519	1556	67	68
10	594	1781	64	66
12	626	1808	64	71
14	604	1860	64	72
16	642	1891	61	65
18	641	1861	60	62
20	643	1951	60	62
22	708	1935	58	61
24	705	1969	58	60
26	751	2025	58	59
28	769	2101	56	58
30	800	2181	56	59
32	760	2165	56	58
34	807	2284	56	57
36	826	2260	53	54
38	802	2292	54	54
40	828	2293	51	49
42	820	2292	49	48
44	816	2289	40	37
46	824	2389	37	40
48	828	2294	38	35
50	825	2261	30	36
52	827	2258	25	28
54	823	2195	20	20
56	825	2131	18	20
58	821	2088	17	20
60	827	1905	13	17
62	822	1890	11	15

Appendix Table 8. Germination percentage and dry weight per seeding of Mt. Barker harvested at two-day intervals following flowering in 1981.

Days after flowering	4-day germination	11-day germination	Dry weight per seedling
	%		mg
0	2	6	1.1
2	13	28	1.8
4	12	29	1.6
6	31	52	2.9
8	43	67	3.4
10	55	74	3.6
12	51	73	2.9
14	68	85	3.9
16	50	81	4.0
18	53	80	4.1
20	62	81	4.9
22	54	88	4.7
24	60	85	6.0
26	72	90	6.1
28	76	90	5.9
30	80	92	6.0
32	73	93	6.1
34	83	93	6.0
36	76	91	6.1
38	75	90	6.8
40	86	98	7.0
42	77	94	7.6
44	77	94	7.5
46	75	91	7.4
48	80	91	7.4
50	76	90	7.9
52	76	85	7.6
54	84	93	7.8
56	78	89	7.2
58	71	85	7.4
60	70	83	7.5
62	74	84	7.1
64	70	79	7.3
66	68	81	7.1
68	63	82	7.1
70	65	82	7.3

Appendix Table 9. Germination percentage and dry weight per seedling of Mt. Barker harvested at two-day intervals following flowering in 1982.

Days after flowering	4-day germination	11-day germination	Dry weight per seedling
	%		mg
0	25	38	1.8
2	47	65	1.5
4	50	65	1.9
6	67	73	2.9
8	72	82	3.0
10	82	89	3.0
12	81	85	4.3
14	87	90	3.8
16	88	89	4.5
18	68	88	4.5
20	74	88	4.9
22	62	87	4.3
24	60	86	5.8
26	50	88	5.9
28	78	85	6.4
30	75	84	6.3
32	75	84	6.2
34	72	85	6.9
36	69	90	6.6
38	57	88	6.9
40	45	90	6.8
42	44	87	6.9
44	42	87	6.8
46	45	84	7.1
48	51	80	7.6
50	54	89	6.9
52	66	84	6.7
54	69	84	6.7
56	71	86	6.8
58	59	88	6.7
60	64	75	6.8
62	69	73	6.8

Appendix Table 10. Germination percentage and dry weight per seedling of Nangeela harvested at two-day intervals following flowering in 1981.

Days after flowering	4-day germination	11-day germination	Dry weight per seedling
	%		mg
0	9	21	1.8
2	15	44	2.6
4	44	69	3.1
6	51	84	2.7
8	47	78	3.2
10	47	73	3.4
12	41	72	3.7
14	60	83	3.9
16	65	89	5.4
18	52	87	5.2
20	57	84	6.5
22	59	85	7.6
24	50	83	7.1
26	84	96	7.3
28	85	94	7.2
30	79	91	7.4
32	82	95	7.7
34	81	95	7.9
36	85	96	7.7
38	84	89	8.2
40	82	92	9.7
42	83	88	9.3
44	84	94	9.4
46	77	92	10.0
48	80	88	10.3
50	84	90	9.8
52	84	92	10.0
54	88	93	10.2
56	75	89	10.0
58	78	91	10.0
60	67	79	10.0
62	68	81	9.7
64	74	86	10.2
66	66	75	9.9
68	55	71	9.3
70	54	62	9.6

Appendix Table 11. Germination percentage and dry weight per seedling of Nangeela harvested at two-day intervals following flowering in 1982.

Days after flowering	4-day germination	11-day germination	Dry weight per seedling
	%		mg
0	46	64	2.0
2	69	79	2.7
4	69	75	3.1
6	75	77	4.5
8	78	89	4.5
10	78	87	5.1
12	84	91	5.1
14	76	85	5.4
16	85	89	6.3
18	89	92	6.8
20	84	88	7.3
22	45	67	8.7
24	57	72	8.1
26	69	76	8.4
28	72	83	8.5
30	79	81	8.2
32	58	72	8.9
34	70	79	8.8
36	56	72	9.2
38	65	72	9.3
40	69	75	9.5
42	68	78	9.4
44	67	82	9.5
46	68	76	9.6
48	64	84	9.7
50	66	81	11.0
52	60	85	10.0
54	70	85	10.3
56	63	85	10.1
58	63	86	10.6
60	58	86	10.3
62	65	82	10.3

Appendix Table 12. Increase in hard seed percentage of Mt. Barker and Nangeela seeds, 1982.

Days after flowering	Mt. Barker Hard seeds	Nangeela Hard seeds
	%	
0	0	1
2	.5	0
4	0	3
6	2	11
8	4	22
10	7	47
12	24	69
14	47	80
16	43	82
18	43	78
20	53	86
22	55	91
24	70	90
26	74	95
28	94	96
30	96	99
32	95	99
34	99	97
36	95	99
38	96	95
40	96	98
42	97	93
44	93	93
46	91	95
48	94	94
50	91	87
52	94	95
54	93	96
56	95	94
58	97	98
60	98	95
62	98	98

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