STUDIES ON THE GROWTH AND DEVELOPMENT OF CAULIFLOWER (*Brassica oleracea* var. *botrytis*)

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ABSTRACT

Three experiments were carried out to provide information on the effects of certain environmental factors on the growth and development of the cauliflower crop.

The effects of nutrition, moisture and light were selected in the first experiment as they are factors which can be controlled to some extent by grower practice. Four treatments were applied, control, low nutrition, low moisture and shading.

The variety Flore Blanca was sown in early May and the plants were grown in a glasshouse. The dry matter percentage of the leaves decreased under shading and increased with low nutrition. These two treatments also reduced plant growth more than low moisture and it was suggested that this may indicate that these factors are more important in plant competition than soil moisture. No effect of the treatments were found on leaf number and once 22 leaves were formed curds were initiated. The spread of curd initiation was not affected and it was suggested that nutrients, moisture and light were unlikely to effect the spread of curd initiation in a cauliflower crop providing they were evenly applied.

The second experiment was designed to study the cold requirements for curd and flower initiation with a range of cauliflower varieties. The plants were grown in a glasshouse during the summer months, where the minimum temperature was maintained at 16°C. Control plants did not leave the glasshouse whereas cold treated plants were removed at varying ages for varying treatment periods to cold rooms, where the temperature was maintained at 5.6°C. With the two summer varieties grown, AYR and Snowball M, curd initiation took place without a cold treatment, but was necessary for flower

initiation. Of the two autumn varieties used Flora Blanca did not require cold for curd initiation but Strain 230 did. Flora Blanca produced weak flowering with some control plants, but cold was required for satisfactory flowering of all plants. Strain 230 had not flowered by the end of the experiment. The two winter varieties, Y-5 and White Acre, required cold for curd initiation and like Strain 230 they had not flowered by the end of the experiment. It was assumed that with these later varieties cold was required for flowering. Effects of the cold treatments on reducing the spread of curd initiation were also noted.

The final experiment consisted of a December sowing of a summer (Snowball M) and a winter (Y-6) variety. Weekly harvests were made until after curd maturity to collect data on partitioning of dry matter in the cauliflower crop. For a month from emergence leaf growth dominated resulting in a high percentage of total plant dry weight in the leaves. At curd initiation the percentage in the leaves fell rapidly. The percentage of total plant dry weight in the roots fell from emergence until the 28th day when it remained fairly constant till the end of the experiment. An allometric relationship was shown to exist between curd and leaf growth from curd initiation till curd maturity. With both varieties competition for assimilates occurred between the leaves and curds.

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INTRODUCTION

Recent research work reported by a number of workers (Salter and Fradgley, 1969a and 1969b) has shown that economically important plant characteristics of the cauliflower crop can be influenced by growing techniques. Other work (Salter, 1969; Salter and Ward, 1972) has demonstrated that the cold treatment of transplants can effect crop maturity characteristics. These studies, while demonstrating the possibilities of such techniques have also emphasized our lack of knowledge of many aspects of the growth and development of the cauliflower and how growing conditions can effect crop performance.

The present study consisted of three experiments. The first examined the effects of 3 major environmental factors on the growth and development of the cauliflower crop. The environmental factors selected are all under grower control to some extent. The second experiment was designed to gain further knowledge on the cold requirements of cauliflower varieties for curd initiation, as Salter and Wards' (1972) work had demonstrated a lack of data on this subject. The third experiment studied the pattern of distribution of dry matter between plant organs from seed sowing till after curd maturity for both a summer and winter variety. This last project was carried out as there is no published information of this nature available.

CHAPTER 1

REVIEW OF LITERATURE

1.1 Vegetative growth and development

1.1.1 Leaf initiation and number

Salter (1960) demonstrated that in the cauliflower, leaf initiation occurs at temperatures too low for normal growth. This was observed during the winter period when leaves continued to be initiated even when the temperatures in the frame did not rise above 0°C.

It was observed that when leaf number was plotted against accumulated day-degrees above 0°C, a linear relationship was observed until approximately 20 leaves had been formed. Shortly after the 20 leaf stage of development it became difficult to differentiate between leaf initials and the initials of bracts, which surrounded the apical dome during the transition stage between a vegetative and generative apex.

Sadik (1967) observed that the number of leaves initiated is dependent on the cultivar, age of the seedling and the duration of cold treatment. This was illustrated with the two varieties 'Snowball M' (Summer) and Feb-Early March (Winter).

In the case of 'Snowball M' which does not normally require low temperature for curd initiation application of cold treatment for a period of 3 weeks to 4 weeks old seedlings increased the number of leaves but increasing the duration of cold treatment resulted in fewer number of leaves. Cold treatment on older seedlings (8 weeks old), had very little influence on leaf number.

Salter (1969) reached a similar conclusion as he reports that with young seedlings a long period of low temperature reduced leaf number and with old seedlings temperature had little effect. Sadik (1967) showed that with a winter variety that required a cold treatment for curd initiation the response was different. With Feb-Early March (Winter), the application of cold initiated curds earlier and therefore the effect of leaf number was much reduced.

Parkinson (1952) has observed that high temperature in the range of 21°C - 28.5°C increased final leaf number for winter varieties.

1.1.2 Leaf growth

Salter (1960) observed that in the cauliflower plant growth is determinate in form for after initiation of the curd the increase in total dry weight of leaves was due to the growth of existing leaves and not to the formation of new ones. The reduction in leaf weight caused by the senesence and death of the older leaves when there are no new leaves to take their place produced a reduction in the overall growth rate of the plant.

1.1.3 Leaf area

1.1.3.1 Moisture effects

Salter (1959) compared the effect of four different moisture treatments on the mean leaf area of the cauliflower plant. The treatments were 25%, 50% and 75% maximum percentage depletion of available water in the root zone of the crop and the control treatment was kept at field capacity.

The results at harvest showed that the size of the individual leaves were reduced when 50% or more of the available water was depleted before irrigation was applied. The leaf shape was affected by the treatments resulting in significantly different regressions of leaf area dimensions. Under the drier treatment when 75% available moisture was depleted, the leaves were smaller and were strap shaped in contrast to the large broad leaves produced under the wet treatment.

1.1.3.2 Density moisture interaction

Salter (1961) observed that during the early period of growth of cauliflower plants, little difference was observed in the leaf area between the closest and wider spacing. However a week before cutting commenced there was a general decline in the rate of leaf area increase of plants without irrigation, but with irrigation a decline occurred only at the closest spacing.

1.1.4 Relationship between leaf number and area to curd growth

Salter (1960) suggested that if a relationship between leaf number and time of curd initiation could be established, the possibility existed of quantitatively relating the times of curd initiation and maturity.

Salter (1960) has shown that the increase in dry weight of the whole plant from germination until curd maturity is an exponential function of accumulated day-degrees above a base temperature of 5.5°C. Thus in cauliflower the change from the vegetative to the generative phase of growth did not influence the relative growth rate of the plants.

The fact that curd maturity coincided with the maximum leaf area of the plant suggested a possible relationship between the two. The relation between curd and leaf growth was allometric from the time of curd initiation until curd maturity, i.e. while both organs are growing. After this stage the leaves begin to senesce and the relationship was no longer allometric as described by Salter (1960). He also observed that the maximum leaf weight coincided with the stage of curd maturity and as growth of the curd was related to that of the leaves it can be concluded that the size of the curd at maturity will be closely related to the total amount of leaf material present.

A first attempt made by Salter (1969) by sampling plants from a population at intervals of time to see whether at comparative stages of curd initiation there was a trend of leaf number with time. Since only a small percentage of the population was found to be of a comparable stage of development this method was not found to be an efficient method to prove the trend.

Nevertheless there were positive indications that plants which had larger final leaf numbers had later times of curd initiation and earlier times of curd initiation were associated with smaller leaf numbers.

1.2 Curd growth and development

1.2.1 Curd initiation

1.2.1.1 Cold temperature

Salter (1960) demonstrated that there was a progressive change in the appearance of the stem apex associated with the initiation of the curd. Development of curd started in 'Snow Ball M' when about 20 leaves had been initiated and the normal apical dome was about 200 μ in diameter. The dome widened in the axils of which secondary meristem developed and formed the primary peduncle of the infloresconce. Later further bracts and secondary peduncles grew on these and in turn yielded further orders of peduncles.

Cruciferous plants exhibit a wide range of temperature requirements for head or curd initiation. Quantitative cold requirements and effects on time of curd initiation for only a few varieties of cauliflower have been described, e.g. Haine (1959), Sadik (1962), Kato (1964), Salter (1969), Carew and Thompson (1948), Salter and Ward (1972).

Haine (1959) working on experiments on winter cauliflower maintained at temperatures above or below 15.5°C, has shown that curd initiation required exposure to cool condition for a longer period in late varieties such as Roscoff No.4 than in early heading varieties such as Extra Early Roscoff and Roscoff No.1.

Sadik (1962) used two varieties 'Snow Ball M' and Feb-Early March cultivars and studied the effect of temperature on curd initiation. Sadik (1967) concluded that 'Snow Ball M' and 'Feb-Early March' have distinctive cold requirements for curd initiation. 'Snow Ball M' behaves as a summer cultivar since it forms a curd with or without a cold treatment. Feb-Early March is a winter cultivar since it requires a cold treatment for curd initiation.

Kato (1965) demonstrated that when seedlings of the variety 'Early Snow Ball A' planted in early spring were exposed to temperature of 10°C, 16.5°C and 25°C immediately after transplanting that curd initiation occurred after 5 and 10 days respectively at the first two temperatures and not at all at 25°C, proving therefore that low temperatures are important for very young seedlings of this variety to induce curd initiation.

Carew and Thompson (1948) demonstrated that when plants were exposed to 4.5°C - 10°C for two weeks it hastened curd initiation more uniformly within a plant population.

Salter and Ward (1972) studied the question of exposure of plants to cold treatment and the duration of the treatment on curd initiation for three varieties. Their results indicated that cold treatment of plants for one week at a temperature of 2$\pm$ 1°C significantly hastened curd initiation and thereby shortened the length of the harvest period of 2 out of 3 varieties (Table 1.1)

Table 1.1 Effect of cold treatment on the number of days from 5 - 95 per cent cut.

Treatment	1 week	2 weeks	3 weeks	4 weeks	Control
All the year round	11.5	16.0	13.0	13.5	15.5
South Pacific	20.0	21.8	-	-	38.8
Asmer Hylite	18.2	27.5	-	-	31.5

The reason according to Salter and Ward (1972) why 'All the year round' causing an anamolous result is that the variety given cold treatment for one week experienced exceptionally warm weather immediately after planting which may have had a de-vernalising effect.

Further work carried out by Salter and Ward have shown that the application of cold temperatures during the induction phase for both summer and autumn varieties resulted in more uniform curd initiation within a population than with untreated plants. Although detailed studies of curd initiation were not carried out in their experiments there is a strong indirect evidence that initiation was affected by the cold treatments because of the effect on the maturity characteristics of the crop and the correlation which has been shown to exist between the time of curd initiation and maturity (Salter 1960). Their work on spread of maturity by Salter and Ward (1972) would be discussed further in section 1.2.2.1.

1.2.1.2 Day length

Salter and Ward (1972) have shown that light is not essential for curd formation. In their experiments plants initiated curds when stored in the dark at a temperature of 2°C for a period of 2-4 weeks.

1.2.1.3 Growth regulators

Salter and Ward (1969) observed that in many biennial plants Gibberellic acid (G.A.) could be used as an effective substitute for the low temperature requirement for flowering. Accordingly because of the possibility of influencing curd initiation in cauliflower by the use of growth accelerates or retardants a preliminary observational study was carried out to determine the effect of applying a number of chemicals at different concentrations and at various stages of growth on the maturity characteristics of transplanted and direct-drilled crops of the variety Champion.

The first attempt on the use of growth regulators was initiated by Salter and Ward (1969) and though the trial was only an observational one there were indications that all the four chemicals (viz $G.A._3$ at 10 and 100 p.p.m., G.A. 4/7 mixture at 5 and 50 p.p.m., chlormequate chloride at 500 and 2000 p.p.m. and Alar at 500 and 2000 p.p.m.) had resulted in more uniformly maturing crops than the control. The preliminary trial indicated that the concentration used were non-phytotoxic on cauliflower plants.

A further trial was repeated by Salter and Ward (1972), however the results of all the three experiments conducted showed no significant effect of any of the three treatments on the maturity characteristic of two transplanted crops of All the Year Round and South Pacific. The maximum effect of any of the treatments on the length of harvest was approximately 20%, but many of the differences between treatments and the controls were less than 10%. As a result, no definite conclusions could be arrived at.

1.2.1.4 Effect of cultural factors

Salter and Fradgley (1969) studied the effects of cultural factors on curd initiation. As the study was concerned with both curd initiation and maturity their results are discussed under curd maturity (1.2.2.2).

1.2.2 Curd Maturity

1.2.2.1 Effect of low temperature

Many varieties of cauliflower require exposure to cool conditions before curd initiation takes place as discussed previously (1.2.1.1).

Salter and Ward (1972) referred to the lack of information on why different plants in a population initiated curds at different times, although they apparently experienced similar environmental conditions. Those workers suggested that exposing plants to a known cold treatment might induce curd initiation more uniformly within a population thereby reducing the spread of maturity.

Studies were made to determine the influence of cold treatment of transplants on the maturity characteristics of representative varieties of three groups of Autumn Cauliflower over a period of three years. Treatment variables included store temperatures of 2°C and 5°C, length of treatments from 0 to 4 weeks, different transplant ages, and selection for uniformity of the plants before treatment.

A cold treatment of 2 ± 1°C was applied to three varieties, LeCerf B Autumn, South Pacific and Asmer Hylite on 8 week old plants for a period of 1, 2 and 3 weeks before being transplanted out in the field.

The results showed that all the cold treatments significantly shortened the length of the harvest period of all the three varieties. The minimum reduction in the length of harvest was about 7-8 days for all varieties. A 3 week cold treatment had the maximum effect in reducing the spread of the harvest of the variety South Pacific from 30-15 days and from 39-21 days with the variety Hylite. With the variety 'Le Cerf B Autumn' the maximum effect was obtained with a 3 week cold treatment which reduced the spread of maturity from 37-13 days, a reduction of 65%.

Studies on the effect of plant size indicated there were significantly different responses of the three varieties to the cold treatment, when given at the two transplant ages. There were also interaction between the effects of the cold treatment, age of transplant and plant selection treatment (uniformly), chiefly with the variety Le Cerf B. (Table 1.2).

Table 1.2 Effect of selection for plant uniformity on the response to the cold treatment as measured by the length of the harvest period (days) of three varieties in 1970.

Variety	Plant age weeks	Control	Treatment 2°C 2 weeks	Treatment 2°C 3 weeks	Treatment 5°C 2 weeks	Treatment 5°C 3 weeks
Le Cerf B						
Unselected	6	24	4	18	11	18
Selected	6	24	7	5	7	11
Unselected	8	26	31	28	37	35
Selected	8	23	17	26	24	45
South Pacific						
Unselected	6	16	18	26	23	19
Selected	6	16	18	14	21	15
Unselected	8	16	17	14	17	14
Selected	8	26	7	10	17	19
Hylite						
Unselected	6	19	14	32	19	16
Selected	6	30	14	16	17	25
Unselected	8	21	25	30	33	25
Selected	8	25	24	19	23	20

In general the cold treatment reduced the length of the cutting period of 'Le Cerf B' and Hylite when it was given to 6 weeks old plants but there was no effect on 8 weeks old plants. Conversely South Pacific responded when treated at 8 weeks but not when treated at 6 weeks. Of the temperature duration interaction, a cold treatment of 2°C for two weeks was most effective in hastening curd initiation and thereby resulting in reducing the length of the harvest period. The treatment combination giving the maximum effect on maturity period reduced the harvest period of unselected plants of 'Le Cerf B' from 24 days (control) to 4 days and of the selected plants of South Pacific from 30-14 days.

In general plants selected for uniformity of size before being cold treated produced more uniformly maturing crop than those from unselected plants, but there were exceptions to the general effect.

Finally, judging from all the work carried out by Salter (1969) and Salter and Ward (1972) on cold treatment effect on cauliflower it appears that a cold treatment of 2 $\pm$ 1°C for a period of 2 weeks given at the most receptive growth stage may be an effective means of inducing curd initiation to occur more uniformly. It also seems likely, however, that the stage of growth at which curd initiation can be influenced may vary between varieties and therefore a quantitative data on the cold requirements of many varieties would be needed before the method of influencing uniformity maturity could be applied to commercial crops.

1.2.2.2 Effect of Cultural factors

It was discussed earlier that the duration of the curd maturity period of cauliflower crops was related to the duration of the curd initiation. The effect of cultural variables on curd initiation characteristics with a similar effect on crop maturity characteristics of cauliflower crop was studied by Salter and Fradgley (1969a; 1969b).

The effect of 6 cultural practises were studied.

1. Use of graded and ungraded seed.
2. Transplant and direct drilling of the crop.
3. Different transplant ages.
4. Selection for uniformity at planting or thinning time.
5. Plant Density
6. Nitrogen levels during the early seedling stage of growth on curd initiation and maturity characteristic of cauliflower.

1. Graded seed

In experiments in which graded and ungraded seed was used for drilled crops, Salter and Fradgley (1969a; 1969b) observed that the use of graded seed had no effect on the earliness of crops of any of the varieties grown. However, crops of Champion and South Pacific grown from graded seed had significantly shorter maturity periods than those grown from ungraded seed and thus produced greater uniformity of maturity. This presumably was due to the treatments effect on curd initiation which would be reflected later by the response of the plants at curd maturity. There was no advantage of grading seed with the transplanted crop.

2. Transplanting and Direct Drilling

Direct drilled crops mature earlier and the length of the harvesting period is shorter. This was shown by Salter and Fradgley (1969a; 1969b) with the two varieties 'All the Year Round' and Champion. With both these varieties they observed that direct sowing of the seed into the field significantly reduced the time to 50% curd initiation and reduced the spread of curd initiation (the period when 10-90% of the curds were initiated), compared with transplanted plants. It was also observed that direct sown plants had a significantly lower leaf number at the time of curd initiation than transplanted plants.

The results of direct sowing over transplanting have been very consistent over a period of years illustrating thereby that curd initiation was enhanced resulting in early maturity from drilling.

From their experiments, they concluded that direct drilled crops in general require a very high standard of soil husbandry, a fine tilth of optimum moisture requirements and uniform seed bed conditions. Thus to obtain uniformly maturing crop, graded seed should be grown singly in situ by precision drill, and the resulting plants should be kept well supplied with nutrients and frequently irrigated. They should also be free from the competitive effects of weeds or other cauliflower plants until well grown. If this practise is adopted about 70-80% curds could be obtained on a single occasion.

3. Different Transplant Ages

The effect of transplant age on curd initiation and maturity characteristics of cauliflower tended to become greater with age. This was illustrated by Salter and Fradgley (1969a), where later plantings from the same sowing delayed curd initiation and maturity with each variety sown. Similar effects of older transplants, delaying maturity have been reported by Love (1963), Garthwaite (1967) and Williams (1967).

Table 1.3 Effect of age transplant in time of maturity and length of maturity period of cauliflower crop.

Variety	Days from sowing to 50% maturity Plantings		Length of maturity Period (Days) Plantings	
1963	1st	2nd	1st	2nd
AYR	127	143	15.3	25.7
September Green	146	163	30.7	49.0
Atlantis	153	178	21.5	35.2
1964				
AYR	118	123	25.1	25.6
Champion	131	144	51.9	50.7
Melbourne Market	142	158	31.6	28.7

4. Selection of Uniformity at Planting or thinning time

Salter and Fredgley (1969a) found that selection of plants for uniformity at planting time did not increase the uniformity of maturity at harvest time. The reasons could be that selection for uniformity based on plant size need not necessarily be that they are all of the same physiological condition. Also the variation of the transplanting check between plants may be another reason.

With both the varieties, All the Year Round and Champion grown in 1965 selecting for a uniform size of plant when thinning the seedlings resulted in small increases in yield and in numbers of plants which were marketable, but the differences were not significant. Selection had no effect on quality of the crop.

5. Plant Density and Nutrition

Parkinson (1952) reported that shortage of nitrogen delayed curd initiation and maturity of the variety All the Year Round. His explanation is based on the fact that when plants are grown under competitive conditions in the seed bed some of these may become short of nitrogen. This application of readily available nitrogen in the early stages might enable every plant to obtain sufficient nitrogen to achieve curd initiation without delay and hence a more uniformly maturing crop may result. However results of experiments by Salter and Fradgley (1969a) showed that there were no effect of 3 applications of nitrate solution to young seedlings raised in crowded beds, though there was however a general consistent trend for N-treated direct drilled crops to have a slightly shorter maturity period than comparable crops grown without the N treatment. Salter and Fradgley (1969a) attribute the reason to be due to the nitrogen treatment minimising the spot variation in the soil nitrogen content found under field conditions.

1.2.3 Curd quality and yield

1. Bracted heads

Haine (1959) working on experiments on winter cauliflower has shown that when the temperature was maintained continuously above 16.5°C plants remained vegetative. The time required under cool conditions for curd initiation was cumulative, but fluctuating temperatures tended to produce bracted heads. Similar observations were also recorded by Sadik (1967), who also showed that shorter periods of low temperatures resulted in leafy heads.

2. Loose Curds

According to Nieuwhof (1969), cauliflower makes heavy demands on the soil. If growth is slow the plants form little foliage and result in premature loose heads. If growth is too rampant head formation is retarded and the head may show bracts and may also grow loosely.

On light soil it is observed that curds tend to grow loosely after a sudden rise in temperature. Loose curds are also formed when there is an excess of Nitrogen.

3. Riceyness

A well known disorder of cauliflower is riceyness in which the curd acquires a somewhat velvety appearance owing to the development of small white flower buds at the heading stage. The pedicel may also show some longitudinal growth.

Little is known about the influence of the environment on the incidence of riceyness and Nieuwhof (1969) postulates that its occurrence is sometimes related to high temperatures.

4. Browning of curds

In some seasons the marketable crop of early summer cauliflower is reduced by a disorder of the curd in which the curd turns brown. The nature of this disorder has been established following irrigation experiments at the N.V.R.S. and Luddington Experimental Horticultural Station as reported by Anon (1962). Experiments have shown that browning is more common if a dry spell occurs before curding. The exact critical period has not been ascertained, but the three weeks before cutting is probably the most important. The cause of the trouble is insufficient water in the soil during a period when water loss from the plant is high, such as on a hot day with a continuous breeze.

5. Yield and Quality

Salter and Fradgley (1969) studied the effects of six cultural treatments as described in 2.2.2 on marketable yield, percentage perfect quality curds produced by Autumn cauliflower in experiments carried out over a period of five years.

In general the yields and quality of drilled and transplanted crops were similar with all varieties each year and neither the use of graded seed nor the nitrogen treatments had any significant effect on yield or curd quality. Both increasing plant density in the seed bed and increasing age of transplant caused a reduction in yield on most occasions.

1.3 Flowering

1.3.1 Effect of temperature and variety with respect to flower initiation.

Sadik (1967) used two varieties 'Snow Ball M' and 'February Early March' cultivars in studying the effect of temperature and day length on floral induction and showed that floral induction was accomplished by growing plants at 5.5°C. 'Snowball M' behaves as a summer cultivar since it forms a curd with or without a cold treatment but requires a cold treatment for flowering. Feb-Early March is a winter cultivar since it requires a cold treatment for curd initiation and flowering, Feb-Early March variety required more cold for flower induction than 'Snow Ball M'.

In the same experiment Sadik (1967) also proved that the cold treatment is independent of daylength, for plants not subjected to cold treatment failed to produce flowers whether grown under long or short days.

1.3.2

Sadik and Ozburn (1968) observed that starch and soluble sugar content rose significantly in the leaves when cauliflower plants were grown at 20° - $26^{\circ}C$ followed by two weeks growth at $5^{\circ}C$. This induced the plants to flower. The increase in carbohydrate level during growth at $5^{\circ}C$ led to an investigation of the possible role of carbohydrates in flowering. Treatments for the investigation were designed to either prevent carbohydrate synthesis during growth at $5^{\circ}C$ or to deplete carbohydrate immediately following the cold treatment and to study the effect of these treatments on flowering. They observed that starch and sugar content increased following one week of cold in the presence of a light and carbon dioxide. The treatment resulted in 58% of the plants flowering. With exclusion of light or carbondioxide during the first week of growth at $5^{\circ}C$, sugar and starch content did not increase. Plants grown under this condition did not flower. The sugar and starch content was reduced significantly from their previous level.

Sadik and Ozburn (1968) therefore showed that flowering of cauliflower plants can be prevented if carbohydrate synthesis is blocked during cold treatment or if carbohydrates are depleted following cold treatment.

However it is premature to draw a direct correlation between carbohydrate level and flowering, since other metabolic process can be affected by carbon dioxide and light exclusion. The fact, however still remains that high carbohydrate levels in plants seem to accompany or precede flowering.

It should be noted that Brouwer (1966) demonstrated that with a number of species, lowering the temperature lead to a greater reduction in leaf growth than photosynthese; which resulted in the accumulation of carbohydrates.

This accumulation of carbohydrates would not occur where the temperature is kept low all the time and these conditions will induce flowering. It is possible therefore that the accumulating of carbohydrates reported by Sadik and Osburn (1968) are coincidental with the change from high to low temperatures but not necessary for flowering.

1.4 Partitioning

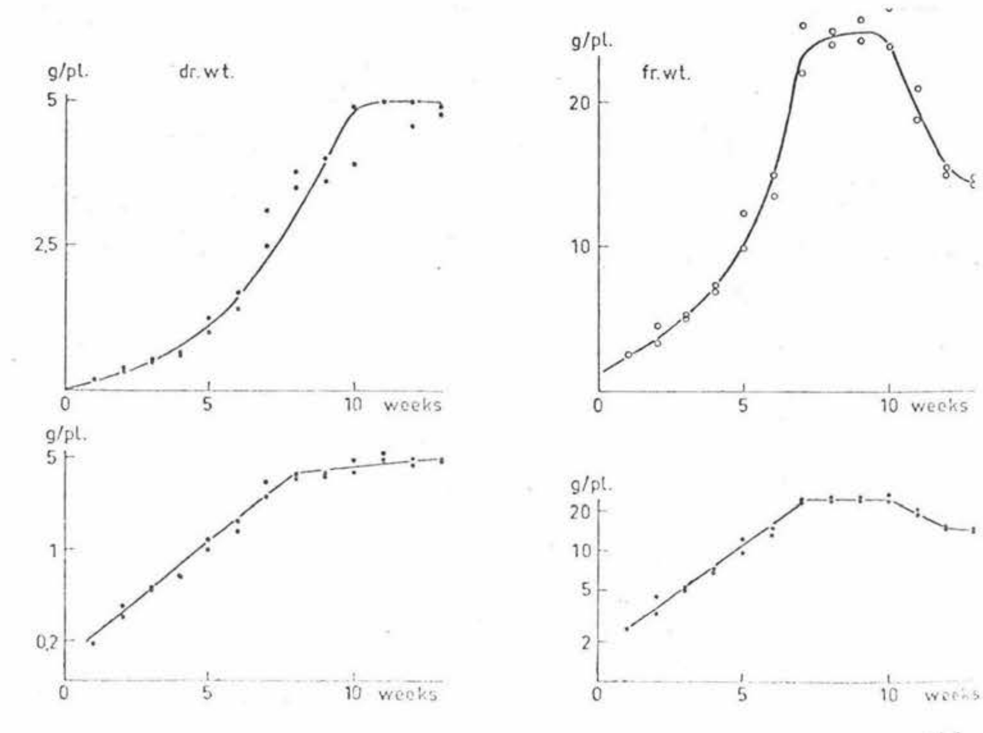
1.4.1 Introduction

When the plant as an object of study is considered one is confronted with the fact that the growth rates of the various organs and within the organs the growth rates of the different parts are well attuned to one another and this leads to the shape which is characteristic for each species, Brouwer (1962). Morphologists as well as physiologists have described these correlations. A large part of the correlation is genetically fixed and this applies especially to the interspecific differences.

However, within the genetically fixed limits external conditions may have a modifying effect and this was observed in Bensink's work (1967), that the shape of the lettuce leaf is dependent on light intensity as well as on nitrogen supply. Brouwer (1962) argues that the physiological phenomenon that forms the basis of these relationship is a growth correlation of the various organs and the correlation between the various organs can be represented by ratios. Most commonly used is the shoot/root ratio

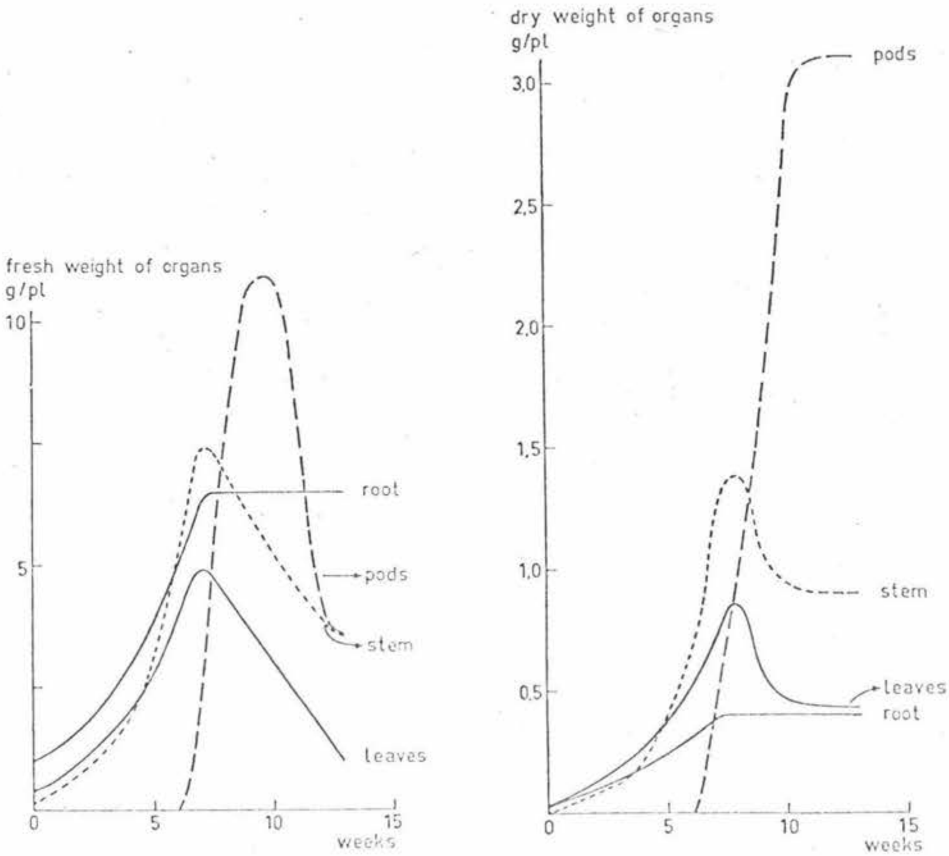
When the growth of a plant as a whole is plotted against time a S-shaped curve (Fig. 1.1) is obtained.

Fig. 1.1 Dry weight (left) and fresh weight (right) of pea plants grown in climate rooms and plotted against time after emergence (after Brouwer 1962).



During growth this applies to fresh as well as to dry weight. The 'S' shaped curve indicates that weight increase in time is more or less logarithmic. In reality a plant is composed of various organs and each separate organ has its own growth curve and these lines only partly correspond in time. In Fig. 1.2 the growth curve for peas is presented, Brouwer (1969).

Fig. 1.2 Fresh and dry weight of the various organs of pea plants plotted against time after emergence (after Brouwer 1962).



Van de Sande Bakhuyzen (1937) postulates that the distribution of dry matter is constant for long periods and these periods of constant distribution rather abruptly change into one another - each period representing a certain phase and these phases following each other. The constant distribution is not only found under controlled condition, but also in field experiments.

Brouwer (1962) suggests that a growing organ is a consumer of materials from the common store and the growth rate is a measure for the extent to which it is successful in attracting these materials. As for their supply of materials, organs growing at the same time are to be considered in competition. A constant distribution means that each of the organs is able to appropriate a certain part of these material and at the same time it means that a certain distribution pattern is affected by regulation in one or another way.

The final yield of specific organs is the result of production and distribution of dry matter in subsequent phases of plant development. Even when distribution under suitable condition is a constant function of time per phase as claimed by Van de Sande Bakhuyzen (1937) and Wittenrood (1957), distribution in the final yield may be variable owing to the variable share of each phase in total production. Moreover distribution within a phase depends on environmental factors. Various aspects of this regulation are reviewed below. Due to lack of information on cauliflower, data for other crops is presented.

1.4.2 The influence of light on distribution of material in the plant.

Light intensity and quality influence the distribution of dry matter in the plant. In etiolated shoots stem growth is maximal but leaf development is suppressed. When the shoots are illuminated, the relative distribution of matter between the stems and leaves is changed as shown by Van Dobben (1962). The vigorous growth of shoots in the absence of light produced a high shoot/root ratio. Apparently the material available is used as far as possible for stem growth and this combined with a maximum cell elongation gives the shoot a better chance to reach full daylight.

Downs, Hendricks and Borthwick (1957) have shown that light quality has a formative influence on plants and that 'far red' radiation given in the dark period may elongate shoot and leaves.

The work of Van Dobben (1962) also confirms this result. It was shown that both incandescent filament lamps and low pressure mercury lamps emit a great deal of far red. Under these lamps plants develop relatively long and weak leaves. Shoot yield is high and root yield below the yield of controls, indicating a considerably higher shoot/root ratio and when these plants are allowed to grow continuously they gain an advantage over the controls in total yield, as explained by a larger leaf area.

Van Dobben (1962) explains that the low dry matter percentage indicates that 'far red' radiation stimulates the cell elongation that contributed to the formation of a large assimilating area. The influence of light quality is especially important when the basic illumination is weak, such as in winter or with short daily illumination.

The effect can be specific and in peas it is shown by Downs, Hendricks and Borthwick (1957), that an elongation of the stem can be obtained with 'far red', but the shoot/root ratio is not effected.

Brouwer (1962) observed that increasing the light intensity tended to increase root growth relative to shoot growth. Richardson (1951), and Wassink (1955) have shown that decreasing the light intensity resulted in decreased root growth and increasing the light intensity increased the growth rate of roots. They observed that there was a relation between growth rate of the individual roots and light intensity, which bears a close resemblence to a photosynthesis curve. Carbon dioxide-free air was observed to decrease root growth and in such cases root growth was directly dependent on the photosynthetic activity of the shoots. However it was likely that in young, rapidly growing plants the carbohydrates usually limit the root growth.

In Wassink and Robertsons' experiment it was reported that defoliating had the same effect as lowering the light intensity. Experiments conducted by Brouwer (1962) have shown that partial defoliation resulted in decreased root growth and increased shoot growth.

It is well known that light intensity influences both photosynthesis and transpiration and Brouwer (1961) has shown that higher light intensities increased the suction tension in the plant and Loomis (1934) observed that this causes a reduced growth rate of the shoots. This effect may be very similar to that of increased suction tension in the root medium.

1.4.3 Influence of temperature on the distribution of dry matter.

Brouwer (1969) observed that the shoot/root ratio generally increases with temperature. This has been observed by Khalil (1958). At temperatures just above zero cereals and peas show ratios between 1 and 2. In the range 10-16°C much higher values are reached with great specific differences. Between 16°C and 25°C several species seem to show a maximum or at least no further increase. A similar condition was found to apply to growth rates. There are distinct differences between temperate zone crops and such tropical crops as maize and beans. The latter starts growing at about 10°C. At higher temperatures the shoot-root ratio and growth rate increases.

Van Dobben (1962) postulates that the yield of a plant is determined by both the growth rate and the length of the growth period. Thus the effect of the temperature on the length of the period from emergence to flowering is independent of the temperature on growth.

Brouwer (1959) studied the effect of temperature on peas and observed that the time available for production is reduced by a rise in temperature, so that the plants remain smaller when the temperature is high. At 10°C - 16°C the rates of growth and development are accelerated stronger than in the range of 16° - 25°C, but in this case the rate of development also shows the highest figures. He therefore concluded that under constant light conditions there is a general tendency for temperate zone crops to reach large proportions in cooler climates.

For beans it was observed by Brouwer (1969) the reverse relations prevail. When the temperature rises from 10-25°C growth is accelerated relatively more than development so that the plants finally become larger. It was therefore observed that beans have the faculty of compensating the acceleration of development at higher temperatures by a relatively still greater increase in daily growth rate. This phenomenon is probably typical of species originating from warm regions without its annuals in tropical regions would never reach large proportions.

1.4.4 Influence of nutrition on the distribution of dry matter.

It is thought that with low levels of nitrogen that the plants will be more deficient in the shoots than in the roots, as the shoots are further away from the region of supply, Brouwer (1962). When the supply is sub-optimal shoot growth will be checked sooner than root growth and a relatively increased share of the root weight in the total weight will be observed. The check in shoot growth resulting from a deficiency of nitrogen restricted utilisation of carbohydrates by the shoots - the carbohydrate supply to the roots increased and root growth was enhanced as sugar is frequently a limiting factor for root growth. Therefore the enhanced root growth is not directly due to lack of nitrogen but only indirectly via the sugar balance of the plant.

When the nitrogen supply is increased the shoot/root ratio increases owing to increasing shoot growth with only small differences in root growth. In other cases shoot growth increases when the nitrogen supply is increased and root growth decreases at the same time.

Other mineral elements, e.g. phosphorus, show exactly the same response. It was observed by the same authors that in all cases variations in shoot/root ratios originate from variations in the internal mineral status of the plants as induced by the treatments and therefore only indirectly depend on the presence or absence of the nutrients in the medium.

1.4.5 Influence of moisture on the distribution of dry matter.

Harris (1914) observed that by increasing the moisture content from 11% - 20% promoted both root and shoot growth, and further increase in moisture content resulted in decrease in root growth below the maximum at 20%. This is a very general phenomenon and is often attributed to a lowering of the oxygen availability. If one considers root growth in relation to the growth of the plant as a whole it can be seen that an increase in moisture decreases the relative root growth and increases the relative shoot growth.

A logical explanation advanced by Brouwer (1962) of these changes in relative growth of shoot and roots is that moisture may be a limiting factor for both roots and shoots, but it is more likely to be limiting for shoots than for roots since the shoots depend on the roots for their moisture.

Moreover most of the moisture is lost from the shoots so that moisture tension is usually higher in the shoot than in the roots and it was observed that differences in root growth were fairly small compared with the differences in shoot growth.

1.4.9 Changes in pattern of distribution during life of crop.

Van Dobben (1962) observed that shoot/root ratio and growth rate change during development. In most annual plants the following pattern can be observed under optimal conditions. During germination root growth first dominates to such an extent that the shoot/root ratio is low. In the seedling stage the shoot overtakes the root and the distribution established at the end of this stage remains almost constant during subsequent vegetative development. During the transition to the generative stage the shoot/root ratio shows a sharp increase as a symptom of a new distribution pattern more favourable for the tops.

Cooper (1972) working on tomatoes observed that the control of partitioning was such that initially it increased the proportion of the dry matter going to the leaves and stem and reduced the proportion going to the cotyledons and roots. Almost immediately after flower initiation this pattern of distribution was altered, in that the proportion going to the leaves (which up to flower initiation had been increasing) ceased to increase and began to decrease slowly. Cooper (1972) also observed that flower initiation did not coincide with any change in the steadily increasing proportion going to the stem or in the decreasing proportion going to the cotyledons and roots. However leaf growth was affected.

Subsequent changes that occurred in the control of partitioning coincided with onset of rapid ovary swelling. Firstly, the proportion of dry matter going to the stem, which up to rapid ovary swelling had been increasing, began to decline. Secondly, the slow decrease in the proportion of dry matter going to the leaves became much more rapid. Rapid ovary swelling did not, however, coincide with any change in the steadily decreasing proportion going to the roots - only leaf and stem growth were affected. This was similar to Brouwer's findings (1962), where he observed that when the dry weight of pea pods began to increase rapidly, the progressive increase in the dry weights of the stem, leaves and roots ceased. Cooper (1973) data also showed that with a midwinter sowing when ovary swelling was checked then leaf growth was no longer checked suggesting competition between these two organs.

CHAPTER 2

EXPERIMENT I

2.1 Introduction

The effects of certain environmental factors on the growth and development of the cauliflower plant have been studied by a number of workers (Aamlid 1952, Parkinson 1952, Jensoma 1957, Salter 1960). Further attention however could be paid to environmental factors such as nutrition, water and light which in the field can be influenced to some extent by the grower. This experiment was designed to gain some information about the effects of nutrition water and light on the growth and development of the cauliflower plant. As the experiment was carried out during the winter months a 20 x 20 ft glasshouse was used.

2.2 Materials and Methods

The variety of cauliflower selected was Flora Blanca (Autumn) and was sown on 5.5.72 in boxes with medium containing peat and perlite mixture. When the plants were at the cotyledon stage they were pricked into black polythene bags of sizes 4" x 4" x 8" containing 1050 cc of a mixture of peat and sand in the proportion of 1:1.

The experiment comprised four treatments -

1. A control treatment (C) containing the following fertiliser per bushel -

    56 cc osmocote 14:14:14

    120 cc superphosphate

    70 cc ground Lime Stone

    34 cc Dolomite Lime

This fertiliser mix was also used for the shade and moisture stress treatments.

2. A nutrient treatment (N) containing half the above quantity of fertiliser per bushel of the control treatment.

3. Shade treatment-covered by Salon cloth supported by wire frame and allowing approximately 50% light to be transmitted.

4. A low moisture treatment (M). Plants were allowed to suffer from moisture stress by allowing the plants to wilt. They were then watered and brought back to field capacity. This resulted in normally one watering per week.

All the treatments were watered regularly at the start and the volume of water used was approximately 200 cc per plant per watering. When the plants in the moisture stress treatment were established watering was applied as described above.

When the plants were 8 weeks old a nutrient solution developed by Hewitt (1969) (Appendix 1) at the Long Aston Research Station for the nutrient culture of fruit trees was regularly applied. This has been found satisfactory for a wide range of crops.

The glasshouse was not heated and fan ventilation came into operation at 21°C. The experiment was a randomised block design comprising the four treatments in 3 replications with 58 plants per plot. The spacings between and within plants were maintained at 6" and the spacing between treatments being 1½' except in the case of the shade treatment, where the spacing was 2' between treatments.

When the control treatment had developed more than 75% curds all the treatments were harvested at this time. The edge effect was removed by discarding 34 plants from the outside of each plot and taking 24 plants (per treatment per block) for recording purposes. Out of these, ten plants were selected at random for dry matter weight determination by placing in an oven, maintained at a temperature of 38°C.

The fresh weight of leaves and curds were determined as was curd diameter, stem length and leaf number. Observations on curd quality were made and the total dry weight of plant top, leaves, stem and curd were determined from the sample of plants that were oven dried. Analysis of variance was carried out on this data and the significant differences were calculated by using Turky's procedure.

2.3 Results

2.3.1 Dry matter % in leaves $(\frac{\text{dry wt}}{\text{Fresh wt}} \times \frac{100}{1})$

Treatment means and the results of the analysis of variance carried out on this data are summarised below (Appendix 2).

C	N	M	S	sig. difference	
11.5	14.0	12.9	8.9	2.58 (p.05)	4.90 (p.01)

Shading had a significantly lower dry matter percentage of total plant dry weight in leaves than any other treatments. The low nutrition produced the highest dry matter percentage in the leaves and this was almost significantly greater than the control treatment.

2.3.2 Plant Dry weight (gms)

2.3.2.1 Total plant dry weight

Treatment means and the results of the analysis of variance carried out on this data are summarised below (Appendix 3).

C	N	M	S	sig. difference	
123.8	84.9	122.7	68.2	20.7 (p.05)	36.9 (p.01)

The shading and nutrition treatments significantly reduced the total plant dry weight in comparison to the control and moisture treatments.

2.3.2.2 Dry weight leaves (gms)

Treatment means and the results of the analysis of variance carried out on this data are summarised below (Appendix 4).

C	N	M	S	sig. difference	
85.8	62.0	81.2	49.8	21.5 (p.05)	38.4 (p.01)

The shade and nutrition treatment significantly reduced the total dry weight of leaves in relation to the control as did shade compared to the moisture treatment.

2.3.2.3 Dry weight stems (gms)

Treatment means and the results of the analysis of variance carried out on this data are summarised below (Appendix 5).

C	N	M	S	sig. difference	
22.4	12.4	18.6	15.6	6.7 (p.05)	12.0 (p.01)

The control treatment had the highest dry weight in stems in comparison to the other treatments, but there was no significant difference between the control and the moisture treatments.

2.3.2.4 Dry weight curds (gms)

Treatment means and the results of the analysis of variance carried out on this data are summarised below (Appendix 6).

C	N	M	S	N.S.
15.6	10.5	12.6	0.7	

There were no significant differences observed between the various treatments.

2.3.3 Partitioning

2.3.3.1 Percentage total plant dry weight in leaves.

Treatment means and the results of the analysis of variance carried out on this data are summarised below (Appendix 7).

C	N	M	S	N.S.
69.3	73.0	74.4	75.5	

There were no significant differences between the various treatments.

2.3.3.2 Percentage total plant dry weight in stem.

Treatment means and the results of the analysis of variance carried out on this data are summarised below (Appendix 8).

C	N	M	S	sig. difference	
18.1	14.5	15.1	23.6	4.2 (p.05)	7.5 (p.01)

The shade treatment had a significantly higher percentage total plant dry weight in the stem in relation to the other treatments.

Experiment I From left to right. Moisture stress, low nutrition, shade and control plants.

2.3.3.3 Percentage total plant dry weight in curd.

Treatment means and the results of the analysis of variance carried out on this data are summarised below (Appendix 9).

C	N	M	S	N.S.
10.8	12.4	10.5	1.1	

There were no significant differences between the various treatments. However, the shade treatment had markedly the lowest percentage of total plant dry matter in the curd.

2.3.4 Stem length (cm)

Treatment means and the results of the analysis of variance carried out on this data are summarised below (Appendix 10).

C	N	M	S	Sig. difference
3[illegible].4	2[illegible].1	[illegible].7	52.4	[illegible].2 (p.05)

The shade treatment had significantly longer stems compared to all the other treatments except the control.

2.3.5 Fresh weight curd (gms)

Treatment means and the results of the analysis of variance carried out on this data are summarised below (Appendix 11).

C	N	M	S	N.S.
12.63	8.80	10.56	0.59	

There were no significant difference between the treatments. The control gave the highest yield, while the shade treatment gave the lowest yield.

2.3.6 Curd diameter (mm)

Treatment means and the results of the analysis of variance carried out on this data are summarised below (Appendix 12).

C	N	M	S	sig. difference
75.8	58.1	66.2	7.6	31.3 (p .05)

The shade treatment had significantly smaller diameter curds compared to the other treatments.

2.3.7 Leaf number

Treatment means and the results of the analysis of variance carried out on this data are summarised below (Appendix 13).

C	N	M	S	N.S.
23.3	21.5	22.1	21.5	

There were no significant differences in leaf number between the various treatments.

2.3.8 Spread of curd initiation

Bartlett's test (Sokal and Rohlf, 1969) for homogenity of variance was carried out on the data for curd diameter and curd weights. No significant differences were observed. This indicated that the analysis of variance could be carried out on this data and that the treatments had no effect on the spread of curd initiation.

The data for the shade treatment was not included as few of these plants had initiated curds at the end of the experiment.

2.3.9 Observations on curd quality

It was observed that the control treatment produced the best quality curds, while the nutrition treatment had a high percentage of ricey and pink curds. The moisture stress treatment produced a very high percentage of browning and the shade treatment resulted in loose heads.

2.4 Discussion

2.4.1 Dry matter percentage in leaves. $(\frac{\text{Dry wt.}}{\text{Fresh wt}} \times \frac{100}{1})$

It was observed that shading results in a low percentage of dry matter in the leaves. It is considered that shading results in less photosyntheses making the plant more sappy contributing to a low percentage of dry matter.

This finding agrees with that of Evans and Hughes (1961) where they observed the consequence of shading on the dry matter percentage in both leaves and stems. Working with a plant species impatiens parviflora grown under field conditions, they observed that for stems and leaves the dry matter percentage rose in full daylight and decline under all other conditions; the decline being greater the lower the transmission of the screen.

A similar observation was recorded by Evans and Hughes (1961) for plants grown under cabinet conditions, where the dry matter percentage rose under the higher intensity and fell in the lowest. He based his observations on the general pattern of leaf development, that at low total dry weight a relatively high proportion of the total leaf tissue is meristematic. As the cells mature and expand water is taken up and the dry matter percentage falls, until the plant has received a steady state of growth where the proportion of meristematic to expand tissue is relatively constant. Meantime the cell wall thickens and other changes brought about an increase in the dry weight of individual mature cells, which tend to increase the dry matter percentage.

The low nutrition treatment produced the highest dry matter percentage in the leaves and apart from being significantly greater than the shading treatment it was almost significantly greater than the control treatment. Therefore dry matter had accumulated in the leaves. This agrees with Brouwer's (1962) finding that when nutrient supply is sub-optimal shoot growth will be checked sooner than root growth. The check in shoot growth resulting from a deficiency of nutrient restricted utilisation of carbohydrates by the shoots and hence they accumulate.

The moisture stress treatment and the control did not show significant differences between each other. According to Maximov (1929) the dry matter percentage in the leaves will depend on the type of relationship between wall expansion and cell contents, as modified by any differences in water regime.

2.4.2 Plant Dry weight (grams)

It would appear from these results that shading and low nutrition reduced plant growth (total plant dry weight) more than water deficit. This is of course relevant only to the leaves chosen of the various treatments, but this may indicate that nutrition and shading are more important in competition than water supply.

Black (1952) studied the effect of varying depths of shading on *Helianthus annus* has shown that halving the light intensity resulted in reduction of the relative growth rate of the plant and while further shading caused a progressively sharper fall the reductions in the rate of leaf growth on a weight basis follow very similar trends to those for the growth of the whole plant. He found that since shading reduces both the weight of the leaves and that of the whole plant in a similar manner, the ratio of leaf weight to total plant weight (leaf weight ratio) was little influenced by the light factor, as observed in this experiment.

	Shade	Normal light
$\frac{\text{Leaf weight gms}}{\text{Total plant weight gms}}$	$\frac{49.8}{69.2} = 0.72$	$\frac{85.8}{122.8} = 0.70$

The results of this experiment above are in agreement with that of Black (1952), where he observed that the leaf weight ratio of plants grown under natural light conditions and that under shade are almost the same. The control treatment had the highest dry weight of stem and this is perhaps to be expected as these plants also had the highest total plant dry weight. No significant differences in dry weight of curd were observed. This was due to the variation in the data collected despite the difference in the means. This could be taken as an indication of the lack of any effect of these treatments in reducing the spread of curd initiation. The shade treatment had in fact initiated very few curds when the experiment was completed.

2.4.3 Partitioning

There were no significant differences between the various treatments in the percentage total plant dry weight in leaves (2.4.2). The control and shading treatments were discussed in this regard in the previous section. It is interesting to note that the trend of the means of percentage total plant dry weight in leaves is in the reverse order to that for percentage

Experiment I   Sample of curds from control plants.

total plant dry weight in the curd. This supports the statement made in Experiment III (4.3.3.1) about competition occurring between these organs.

Shading resulted in a significantly higher percentage total plant dry weight in the stem in comparison to the other treatments and this treatment also produced the largest length of stems. This is in agreement with Van Dobben's (1962) work where he observed that light intensity influences the distribution of dry matter in the plant. In etiolated shoots stem growth is maximal, but leaf development is suppressed. The vigorous growth of shoots in the absence of light produced a high shoot/root ratio. This is shown by the shade treatment producing a significantly longer stem compared to the other treatments.

There were no significant differences between the various treatment in the percentage total plant dry weight in curd. However, the shade treatment had markedly the lowest percentage of total plant dry matter in the curd. A similar picture is also observed in the fresh weight of curd resulting in the shade treatment giving the lowest yield and significantly smaller diameter curds. There were however, no significant differences between the other treatments, even though the control treatment gave the highest yield. Although curd yields were not determined at curd maturity, these results suggest that there could well have been differences. Such differences could be explained by the statement made by Van de Sande Bakhuyzen (1937) and Wittenrood (1957) that distribution of dry matter in the final yield may be variable owing to the variable share of each phase in total production. Obviously curd initiation took place later with the shaded plants so that these plants were not as advanced with respect to curd development compared to the other treatments.

Experiment I Sample of curds from low nutrition treatment.

2.4.4 Leaf number

As the treatments had no effect on leaf number they could not have had any major direct effect on the time to curd initiation. Rather once 22 leaves were formed curds were initiated so that if differences in the time of curd initiation occurred they would be due to the treatment effects on the rate of leaf production.

2.4.5 Spread of curd initiation

No effects on the spread of curd initiation by any of the treatments was observed. It has also been suggested (2.4.4) that these treatments had no direct effect on the time of curd initiation but only indirectly by effecting the rate of leaf production but not leaf number. It is suggested that the spread of curd initiation and thus curd maturity for a particular variety cannot be influenced by nutrition, water or light providing these conditions are evenly applied to the growing crop. This is supported by the work of Salter and Fradgley ([illegible]) who found that it was factors such as seed grading and direct sowing which compacted maturity. In the first instance plant variation would be reduced and the second the effect of a transplanting check, which would vary from plant to plant would be removed. Thus both treatments would provide a more evenly growing and thus "initiating crop".

2.4.6 Curd Quality

The nutrition treatment had a high percentage of ricey and pink curds. According to Nieuwhof (1969) little is known about this particular disorder and may be related to phosphate deficiency.

The moisture stress treatment produced a high percentage of brown curds agreeing with the results obtained at the N.V.R.S. Wellesbourne and Luddington Experimental Station and reported by Anon (1962). This disorder has been established as being due to insufficient water before curding, when water loss from the plant is high.

Loose curds were pronounced in the shade treatment and this could be that growth of the plants were slow with little foliage agreeing with the observations of Nieuwhof (1969).

2.4.7 Summary

The effects of nutrition, water and light on the growth and development of the cauliflower plant are described.

The dry matter percentage of the leaves decreased under shade, while low nutrition tended to favour a high dry matter percentage in the leaves. This is explained in terms of when plants are under sub-optimal nutrient supply growth is generally retarded, resulting in restricted utilisation of carbohydrates by the shoots and therefore an increase in dry matter accumulation in the leaves.

Shading and low nutrition reduced plant growth more than water deficit at the levels applied and this may suggest that those two factors are more important in competition than water supply. Shading resulting in a higher percentage total plant dry weight in the stem in relation to the other treatments. This is generally to be expected as earlier research workers have shown that light intensity influences the distribution of dry matter in plants. The treatments did not affect the percentage total plant dry weight in the leaves.

All the treatments had no effect on leaf number and once 22 leaves were formed curds were initiated and the differences in time of curd initiation was due to the treatment effects on the rate of leaf production. No effect of the treatments were found on the spread of curd initiation and it is suggested that nutrients, water and light are unlikely to effect the spread of curd initiation of a growing crop providing they are evenly applied.

Best quality curds were obtained from the control treatments, while the other treatments produced high percentage of abnormalities.

CHAPTER 3

EXPERIMENT II

3.1 Introduction

Limited information, Aamlid (1952), Sadik (1962), Skapsi and Oyer (1964), and Salter and Ward (1972) on the cold temperature requirements for curd and flower initiation of cauliflower varieties has been published.

Sadik (1962) has shown that the response of the varieties Snowball M (Summer) and Feb-Early March (Winter) with respect to curd initiation and flowering is different. The summer variety formed curds without cold but required a cold treatment for flowering, whereas the winter variety required cold for both curd initiation and flowering.

Salter and Ward (1972) have reported that cold temperature given to young plants resulted in compactness of curd maturity with a wide range of both summer and winter varieties. With the summer varieties involved presumably low temperatures were not necessary for curd initiation.

The following experiment was designed to determine whether cold temperature was necessary for curd and flower initiation with a limited range of summer, autumn and winter varieties that are commercially available in New Zealand.

3.2 Materials and Methods

Two summer varieties, All the Year Round and Snowball M, two Autumn varieties Flora Blanca and Strain 230 and two winter varieties Y-5 Inbred and White Acre were sown in separate trays containing U.C. Compost (Appendix 14) on the 4th September 1972. The seed was obtained from Webling and Stewart Ltd, Wellington.

When the plants were at the cotyledon stage (12.9.72) they were pricked into black polythene bags containing 1060 cc of a mixture of peat and sand in the proportion of 1:1. The fertiliser mixture per bushel of compost was -

56 cc osmocote 18:2.9:7.5 (18:9:9 U.S.A.)

120 cc Superphosphate

70 cc Ground Lime Stone

34 cc Dolomite Lime

From pricking out till the end of the experiment, with the exception of the period that the cold treated plants were grown in the cold cabinets, the plants were grown in two 20' x 20' glasshouses with the heating system maintaining a minimum temperature of 16 $^{\circ}C$ and with fan ventilation operating at 22 $^{\circ}C$. Due to high solar radiation during the summer months whiting was sprayed on the glass houses on 10.12.72 to aid temperature control. The treatments applied to each of the six varieties were as follows (Table 3.1). The plants were allocated to these treatments at random.

Table 3.1 Experiment 2

	Treatments			
	Control	4/2	4/4	6/4
Time from Cotyledon expansion that cold treatment was applied (weeks)	0	4	4	6
Length of treatment (weeks)	0	2	4	4
Number of plants per treatment at start of experiment	30	7	13	13

The cold treated plants were grown in four cabinets (1.04 mx 1.04 mx 1.36m) and were maintained at a mean temperature of 5.6°C. While the plants were in the cabinets they were subjected to 12 hours of light intensity of approximately 2500 lux obtained by using one MLMG 400w lamp per cabinet.

The number of plants for the cold treatment (Table 3.1) were limited by the space available in the cabinets (1.08 sq. metres floor area). The control plants and the cold treated plants before and after treatment were grown in the glasshouse (minimum temp. 16°C).

The plants were watered as required and regular application of Hewitt's (1966) nutrient solution (Appendix 1) was applied. Regular pest and disease control measures were carried out (Appendix 15).

The plants of the varieties AYR, Snowball M and Flora Blanca were destructively harvested when they had flowered or when it was apparent that they would not form curds or would not form flowers. The remaining plants of the varieties No:230, White Acre and Y-5 were harvested on 21.3.73. This was done as time was not available to allow them to continue growth.

Where applicable the following information was recorded for each treatment of each variety.

1. Leaf number was recorded at harvest.
2. Curd initiation - the appearance of curds established that initiation had occurred. Where curds were not visible at harvest then the plants were examined under a binocular microscope to determine whether curds had been initiated or not. The use of the binocular microscope was also necessary at times to determine leaf number. On reaching a diameter of

1-1½ cms curds were described as visible and the date recorded. The data was used as a measure of the spread of curd initiation and hence spread of curd maturity (Salter 1969). The term compactness is used in relation to this assessment.

3. Flower initiation. The appearance of flowers established that initiation had taken place. The degree of flowering was recorded under three grades. PF = profuse flowering, F = flowering, WF = weak flowering.

3.3 Results

3.3.1 Leaf number

Table 3.2 Mean leaf number of various varieties.

Treatment	Variety					
	AYR	S.Ball M	F. Blanca	Strain 330	White Acre	Y-5
4/2	36.7	30.7	24.9	72.0	72.0	67.8
4/4	26.3	27.9	25.8	67.6	70.3	65.0
6/4	34.9	35.6	23.7	5[illegible].9	66.7	54.1
Control	48.7	47.1	47.1(28.9)+	70.1	80.7	70.3

\+ Flowering plants

* Leaf number determined prior to curd maturity, as these plants were harvested destructively on 21 March 1973.

At harvest leaf numbers were recorded separately for plants that had curds not yet at maturity, that had rotted, that had flowered or had resumed vegetative growth. These observations were only possible with the variety AYR, Snowball M and Flora Blanca. There was no difference in leaf number between these different sorts of plants except with the control plants of Flora Blanca. Here the plants that flowered had a mean leaf number of 28.9, whereas the other plants had a mean leaf number of 47.1.

3.3.2 Effect of temperature on curd initiation and compactness.

Table 3.3 Percentage of curds becoming visible per week*

Variety AYR

Treatment	Week				
	10th	11th	12th	13th	14th
4/2	-	14.3	14.3	14.2	[illegible]
4/4	-	76.9	-	23.1	-
[illegible]/4	-	-	53.8	38.5	-
Control	-	15.5	40.0	32.2	14.6

* Weeks from pricking out

curd initiation - As the control treatments formed curds cold treatment was not required for curd initiation.

compactness - The 4/4 treatment produced the higher percentage of curds in the 1-1½ cms range in any one week.

Table 3.4 Percentage of curds becoming visible per week

Variety Snowball M

Treatment	Week			
	9th	10th	11th	12th
4/2	85.7	-	14.3	-
4/4	86.9	-	13.1	-
6/4	-	-	30.7	69.3
Control	80.0	-	-	12.5

curd initiation - No cold treatment was required for the variety Snowball M for curd initiation.

compactness - Cold treatment had no noticeable effect on compactness.

Table 3.5 Percentage of curds becoming visible per week

Variety Flora Blanca

Treatment	Week					
	9th	10th	11th	12th	13th	14th
4/2	28.5	-	43.2	-	-	28.3
4/4	-	-	38.6	-	23.1	38.5
6/4	-	-	38.4	61.6	-	-
Control	39.5	-	3.6	30.0	4.9	8.9

curd initiation - No cold treatment was required for curd initiation in the variety Flora Blanca.

compactness - Treatment 6/4 favoured compactness.

Experiment II Control plants versus 4/4 treatment of variety All Year Round.

Table 3.6 Percentage curds initiated at harvest (21st March 1973)

Treatment	Variety		
	Strain 230	White Acre	Y-5
4/2	0.0	0.0	0.0
4/4	100.0	0.0	0.0
6/4	100.0	100.0	69.2
Control	0.0	0.0	0.0

Cold treatment was required for these three varieties to initiate curds. The 6/4 treatment was the only treatment effective with the two winter varieties. With the above varieties it was not possible to determine the effect of temperature on compactness as at harvest, few curds were visible. With the variety 230 (Autumn) it appeared the 6/4 treatment favoured earlier curd appearance compared to the 4/4 treatment, as 10 of the 13 plants from treatment 6/4 had visible curds by 21.3.73, whereas the 4/4 treatment showed no visible curds.

3.3.3 Effect of temperature on Flowering.

Table 3.7 Percentage of plants that flowered.

Treatment	No. of plants	Variety					
		AYR	S.Ball	F.Blanca	Str.230	White Acre	Y-5
4/2	7	28.6	14.3	28.6	0.0	0.0	0.0
4/4	13	100.0	69.3	7.7	0.0	0.0	0.0
6/4	13	100.0	86.6	77.0	0.0	37.7	0.0
Control	30	0.0	0.0	60.0	0.0	0.0	0.0

Table 3.8 Degree of Flowering

Treatment	Variety					
	AYR	S.Ball	F.Blanca	Str.230	White Acre	Y-5
4/2	F	F	F	-	-	-
4/4	PF	PF	F	-	-	-
8/4	PF	PF	PF	-	F	-
Control	-	-	WF	-	-	-

WF = weak flowering : F = flowering : PF = profuse flowering

The data in tables 3.7 and 3.8 indicates that cold treatment was necessary for flowering with the two summer varieties, AYR and Snowball M. With AYR the 4/4 and 8/4 treatments appeared satisfactory, whereas with Snowball M the 8/4 treatment appeared best.

Flora Blanca (Autumn) flowered best with the 8/4 treatment and weak flowering occurred on some of the control plants.

With the variety White Acre (Winter) 5 out of 13 plants flowered in the 8/4 treatment suggesting therefore a longer duration of cold may have been necessary to induce complete flowering. With the other treatments the cold duration was not sufficient to cause flowering of this variety. Strain 230 (Autumn) and Y-5 (Winter) did not show any signs of flowering.

3.4 Discussion

3.4.1 Leaf number

With the Summer varieties AYR and Snowball M, where all the treatments formed curds (Tables 3.3 and 3.4), application of cold resulted in a lower leaf number (Table 3.2), compared to the control. With these varieties

Experiment II Weak (4/2 treatment) versus profuse flowering (4/4 treatment) variety All Year Round.

the treatments reduced leaf number in the following order, the treatments giving the greatest reduction coming first 4/4 > 6/4, 4/2. This may indicate that of the treatments chosen 4/4 coincided closest with the time of curd initiation.

With the autumn variety Flora Blanca, where all the treatments formed curds (table 3.5), the treatments reduced leaf number in the order of 6/4 > 4/2, 4/4 > control. A similar argument as that for the two summer varieties suggests that the 6/4 treatment coincided closest to the time of curd initiation.

With the other Autumn variety 230 the effect of the cold treatments on leaf number was 6/4 > 4/4 > 4/2. As treatments 6/4 and 4/4 initiated curds (table 3.6) this leaf number represents the number of leaves below the curd. With the 4/2 and control treatments the leaf number referred to plants which had not yet formed curds.

In the case of the two winter varieties, White Acre and Y-5 treatment 6/4 reduced leaf number more than 4/4 > 4/2 > control. This suggested that the 6/4 treatment coincided closest with the time of curd initiation. This is supported by the fact that this was the only treatment that initiated curds with these two varieties (table 3.6). The effect of the other cold treatments on leaf number were therefore an effect on the rate of leaf initiation.

These results indicate that with the treatments used, the treatment coinciding closest with the time of curd initiation in the varieties AYR and Snowball M was the 4/4 treatment and for the varieties Flora Blanca, Strain 230, White Acre and Y-5 it was the 6/4 treatment. The application of cold at these times reduced the number of leaves below the curds in all but the winter varieties. With these varieties curds were not formed in any of the other treatments.

These findings agree with that of Sadik (1967), who observed that the number of leaves initiated was dependent on the cultivar, age of the seedlings and the duration of cold treatment.

3.4.2 Curd initiation

The tables 3.3 and 3.4 suggest that curd initiation in the summer varieties AYR and Snowball M takes place without a cold treatment. This is an agreement with Sadik's (1962) finding for the summer variety Snowball M. This is a phenomenon to be expected of summer varieties as otherwise they would never form curds.

The 4/4 treatment compacted the maturity of AYR (table 3.3) suggesting therefore that this coincided with the stage when curd initiation took place. A similar conclusion was reached in 3.4.1. No indication of the time of curd initiation of the variety Snowball M could be gained from the data on compactness (table 3.4). The 6/4 treatment seemed to delay the appearance of curds with the variety Snowball M. This could have been due to cold being applied outside the curd initiation period so that its effect was to slow down growth. Support to this suggestion is given by the data on leaf number (table 3.2). Here the 6/4 treatment produced more leaves than the 4/4 treatment.

The two Autumn varieties Flora Blanca and Strain 230 reacted differently as regards their cold requirements for curd initiation. Flora Blanca did not require cold for curd initiation (table 3.5). With this variety compactness of maturity seemed to be favoured by the treatment 6/4 indicating that curd initiation was occurring at this time. A similar conclusion was reached in 3.4.1.

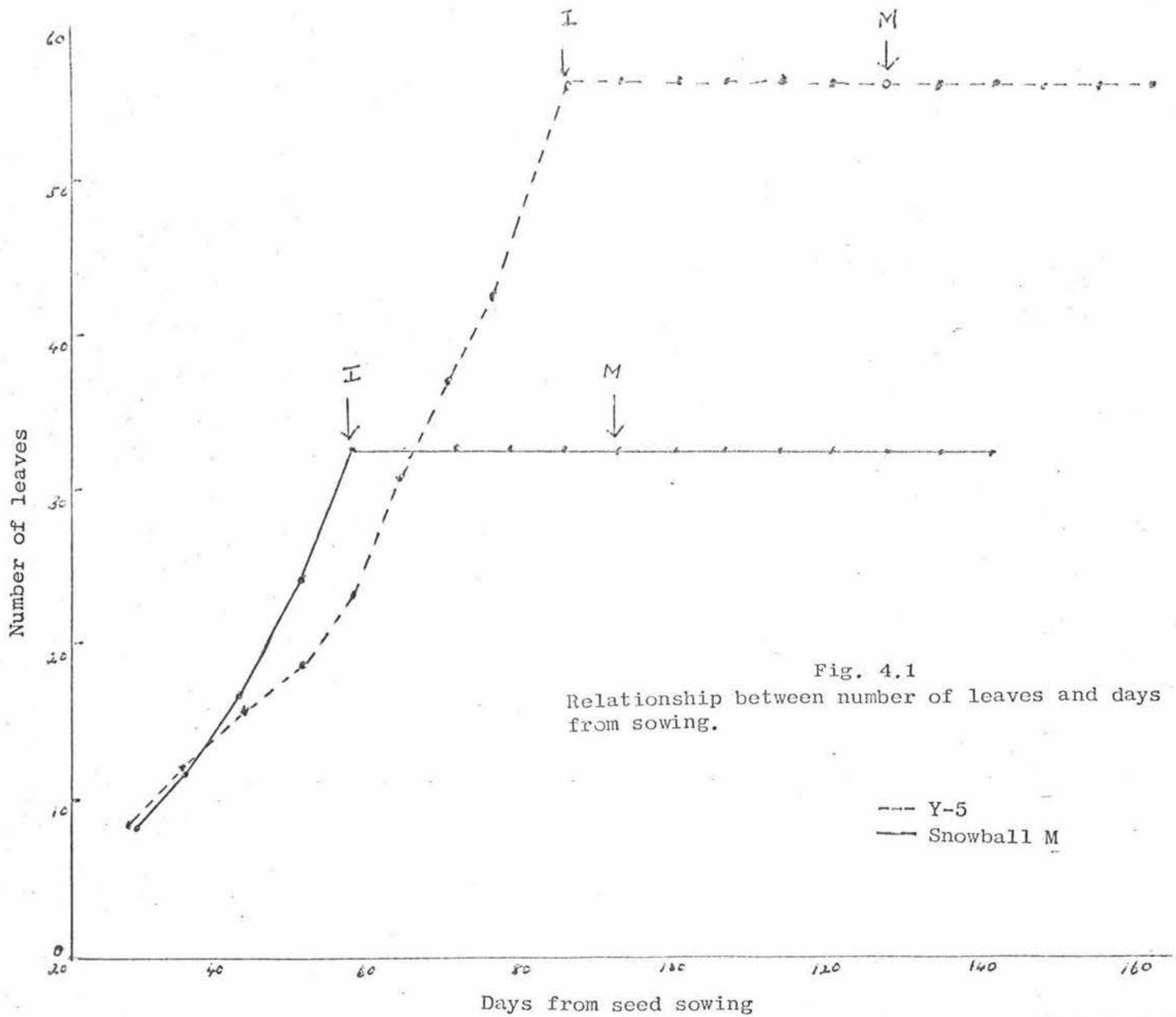


Fig. 4.1
Relationship between number of leaves and days from sowing.

With the variety 230 (table 3.6) cold treatment was essential for curd initiation. Only treatments 4/4 and 6/4 produced curds, with the treatment 6/4 producing 77% of visible curds compared to no visible curds (to naked eye) on the 4/4 treatment.

This would suggest that the 6/4 treatment was closest to the time of curd initiation. This conclusion was reached in 3.4.1.

The results presented in table 3.6 clearly show that cold treatment is essential for both the winter varieties, White Acre and Y-5 for curd initiation as suggested by Sadik (1962). The 6/4 treatment was the only effective treatment with both the winter varieties. However, the effect of 6/4 treatment on Y-5 did not seem to have its full effect. It may have been due to the duration of cold treatment being not long enough to fully supply the cold stimulus. This agrees with Haine's (1950) statement that for winter cauliflower curd initiation was induced by exposure to cool conditions for a longer period in late than in early heading varieties.

These results indicate a pattern where the most effect cold temperature for curd initiation becomes later and thus the plants older as one moves from the warm season varieties (Summer) through to the cool season varieties (Winter). The data on leaf number discussed in 3.4.1 indicated similar times of flower initiation for each variety. Curd initiation must therefore occur later as one goes from summer to autumn varieties.

3.4.3 Curd compactness

It was not possible to study the effect of compactness with the varieties 230, White Acre and Y-5 as they were of necessity harvested prior to a sufficient number of curds being visible.

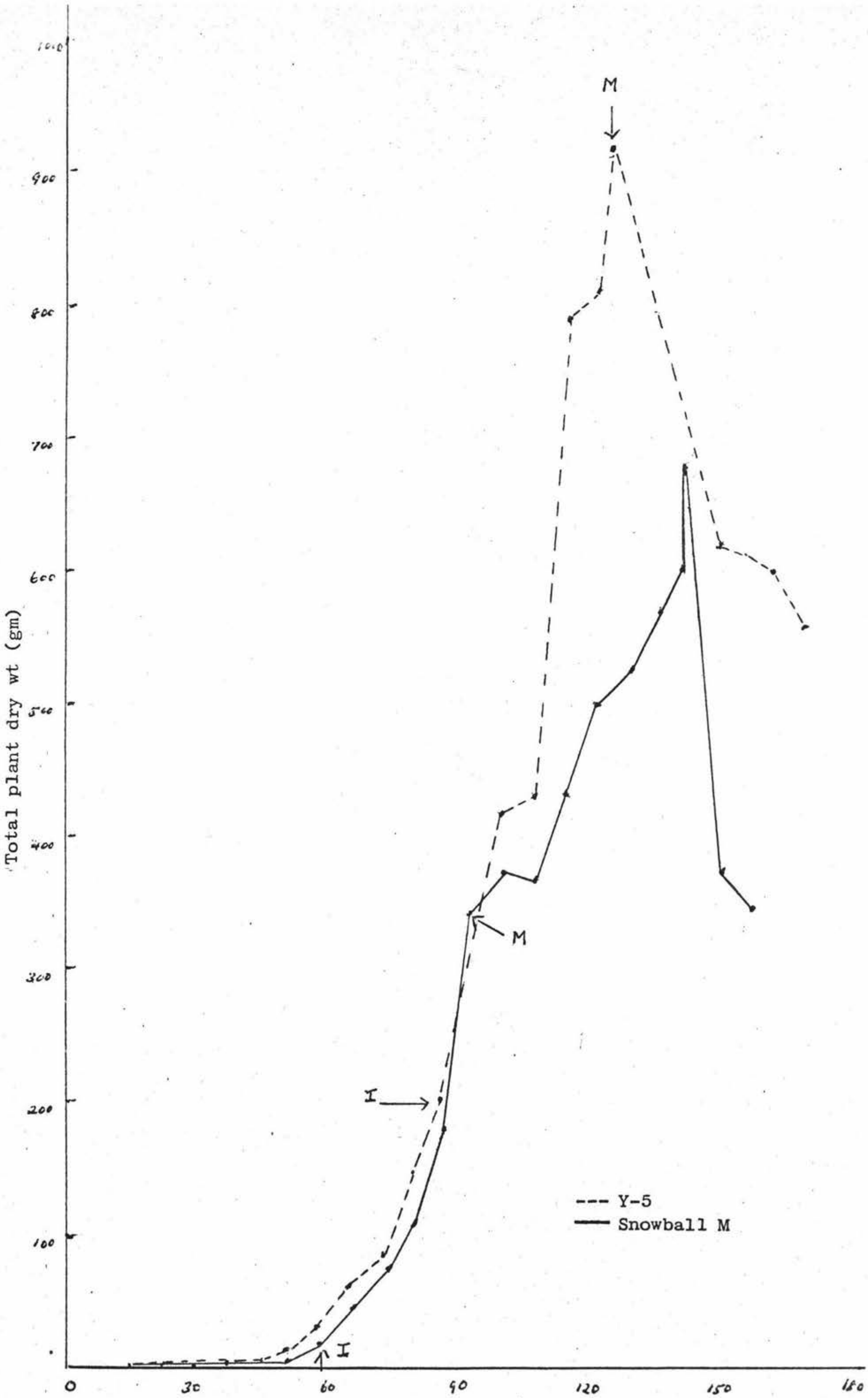


Fig. 4.2 Total plant dry wt present at each harvest.

With the variety AYR (Summer) and Flora Blanca (Autumn) cold treatment appeared to favour compactness (tables 3.3 and 3.6). No effect was observed with Snowball M (Summer) (table 3.4) and this may have been due to the cold treatment not being applied at the correct stage and/or the correct duration.

These results support the contention of Salter and Ward (1972) that for Summer, Autumn and Winter varieties compactness could be induced by application of cold at the correct stage of development. It would appear that the cold treatment must coincide with the time of curd initiation and presumably brings about its effect by causing initiation to occur over a limited period of time even with varieties where cold is not required for curd initiation.

3.4.4 Flowering (Tables 3.7 and 3.8)

With the summer varieties (AYR and Snowball M) the 4/4 and 6/4 treatments resulted in 100% of the plants flowering. Both these treatments had a positive effect on the degree of flowering in relation to the 4/2 treatment, where flowering was less pronounced and occurred on only 28.6% of AYR and 14.3% of Snowball M plants.

These results therefore suggest that exposure to low temperature is a prerequisite for flowering in summer varieties even though cold is not required for curd initiation in accordance with Sadik (1962) findings.

With the Autumn variety Flora Blanca the 6/4 treatment resulted in 77% of the plants flowering and was associated with a higher degree of flowering plants in comparison to the other treatments. It was also observed that there were 60% weak flowering plants in the control, where the temperature in the glasshouse was maintained at a minimum of 16°C.

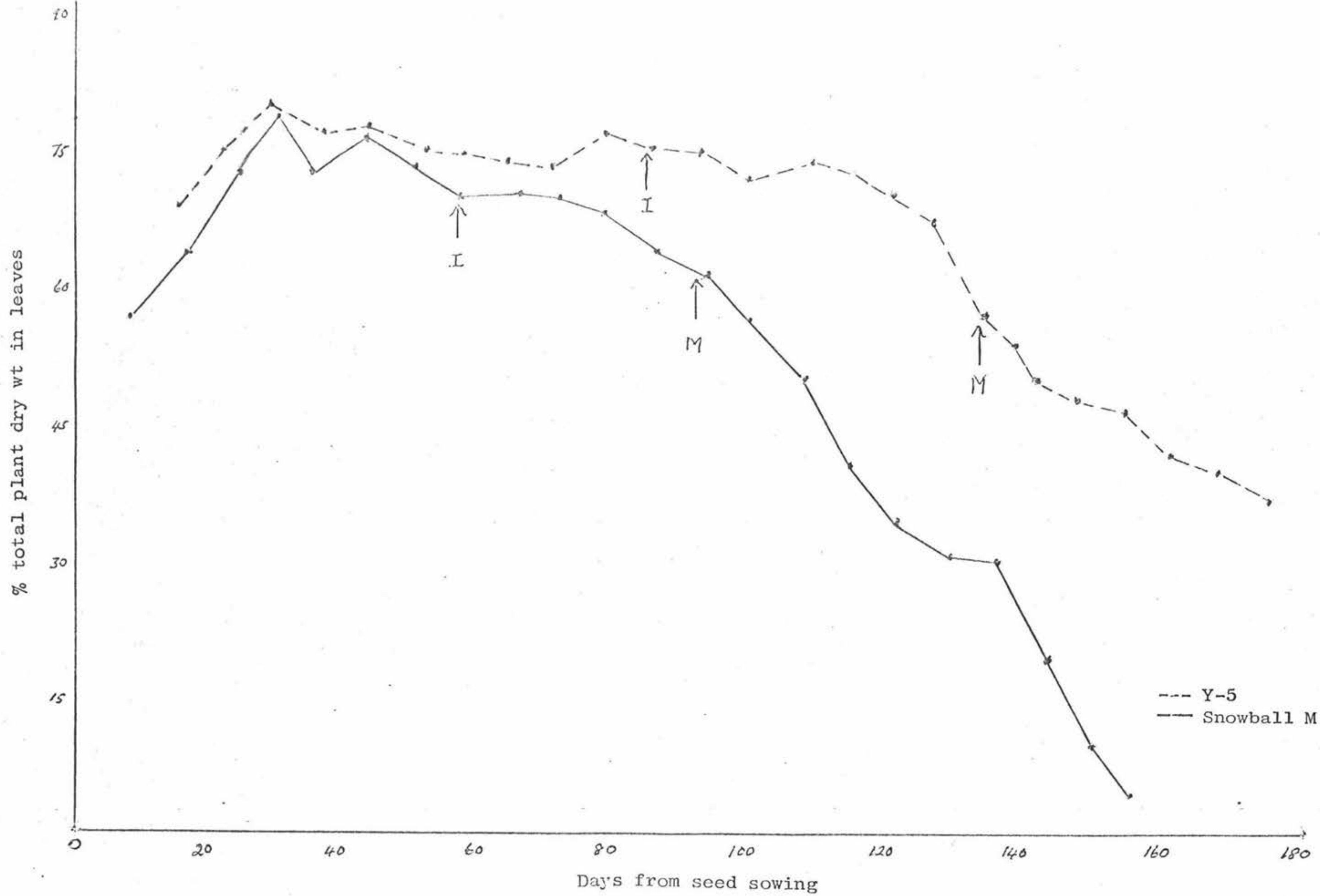


Fig. 4.3

% total plant dry wt in leaves at each harvest.

Field observations on this particular variety on its vegetative and reproductive characteristics under commercial cultivation, showed that it appears to be genetically variable with respect to its time of maturity. The data on leaf number (3.2) indicates that these two different sorts of control plants produced different numbers of leaves.

This finding is similar to the observation by Fontes, Ozbun and Sadik (1967) that with broccoli there was a considerable variation within a particular cultivar for the need of cold to develop an inflorescence. Some plants required cold, while others did not require cold for floral induction.

With the other Autumn variety 330 and the Winter variety Y-5, no flowering was observed in any of the cold treatments, but with the winter variety White Acre a low percentage of plants was observed to be flowering in the 5/4 treatment.

Two reasons could be advanced for the above behaviour. Either sufficient time was not allowed for the plants to flower, as it is established that cold was required for curd initiation, and it could be assumed that flowering would then be a natural phenomenon to follow, or that a longer duration of cold treatment may be necessary for flowering than for curd initiation.

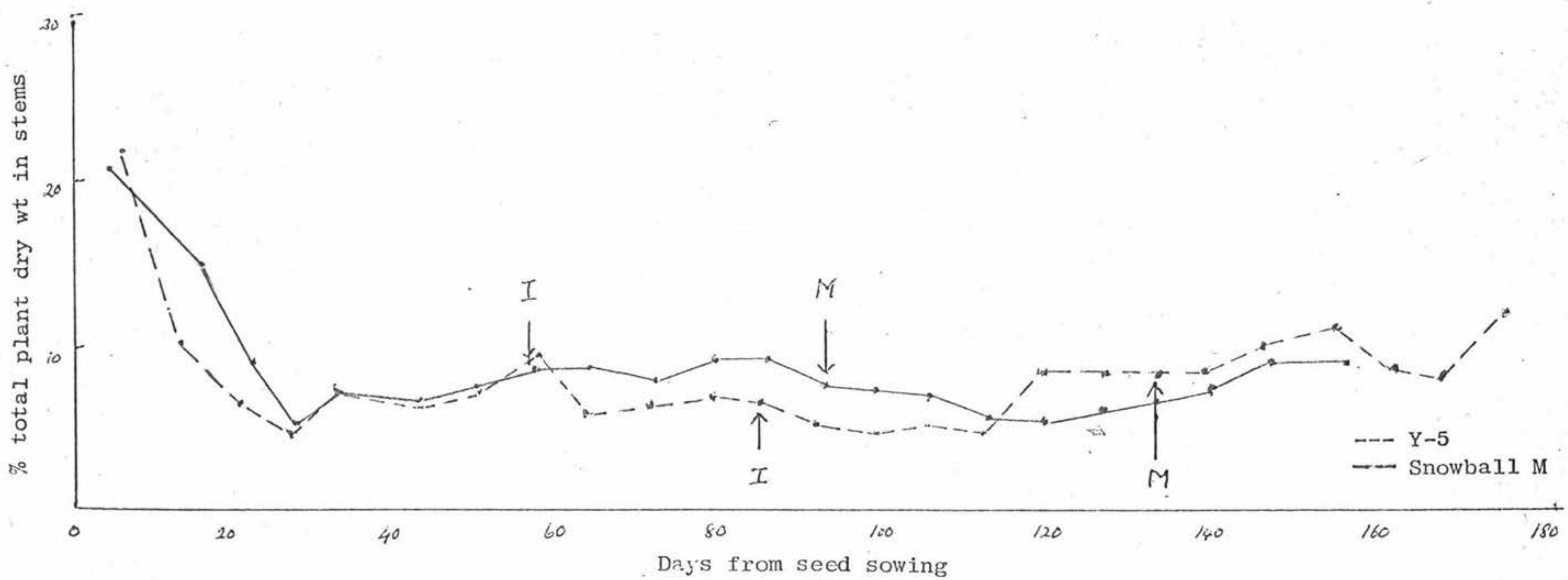


Fig. 4.4

% total plant dry wt in stem at each harvest

CHAPTER 4

EXPERIMENT III

4.1 Introduction

A study of the partitioning of dry matter with two varieties of cauliflower was undertaken. This was done as no data of this nature has been reported. Due to the time factor it was not possible to collect this data from a number of successional sowings.

4.2 Materials and Methods

An area of 203 sq. metres was selected and was disced and harrowed to fine tilth. Lime and a general fertiliser mix (see Appendix 16) were applied and worked into the soil during the above cultivations.

Seeds of the cultivars Snowball M(a summer variety) and Y-5 (a winter variety were sown on 4 December 1972 using a single row Stanhay drill with a spacing of 76.2 cms between rows and 5.0 cms in the row. The rows were 24.4 metres long, there being 5 rows of Snowball M and 8 rows of Y-5. After germination plants were thinned to 61 cms apart in the row. At the start 20 plants per variety were harvested each week, divided into roots, stems and leaves (including cotyledons and petioles), their fresh weight recorded and oven dried to 100^{o}C and weighed. All tissues below the cotyledons were regarded as belonging to the root system.

On 11 January 1973, when the plants were larger the number of plants harvested was reduced to ten per week and from 8 March 1973 onwards it was

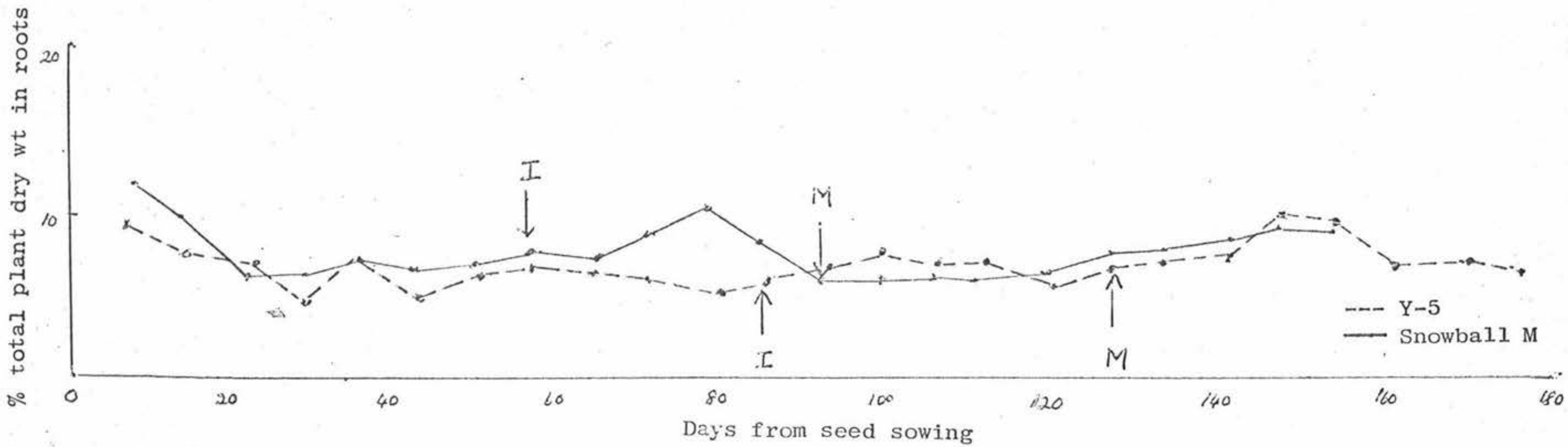


Fig. 4.5
% total plant dry wt in roots at each harvest.

reduced to five per week. Plants were selected at random for any particular harvest. Routine pest and disease control (Appendix 17) was resorted to and the experiment was irrigated whenever necessary.

For each variety the times of curd initiation and curd maturity were determined as follows.

a) Time of curd initiation (I)

The time of curd initiation was determined from the data presented in fig. 4.1. This data was collected by examining the stem apices of the weekly samples under a binocular microscope when the leaf number was determined. The time of curd initiation was taken as that point where no further increases in leaf number occurred.

The time of curd initiation for Snowball was 56 days and for Y-5 84 days after sowing.

b) Curd maturity (M)

This was defined as the time when the maximum leaf weight was present with progressive senescense of the leaves occurring thereafter (Salter, 1960). No measure was made of the spread of curd maturity.

The time of curd maturity for Snowball was 93 days and for Y-5 126 days after sowing. With Snowball M the last harvest was on 10.5.73, while with Y-5 it was on 31.5.73.

The data collected was examined with respect to partitioning of dry matter between the various plant parts and also for any relationships between these parts. One example of the method used to calculate the correlation coefficients is presented in Appendix 18.

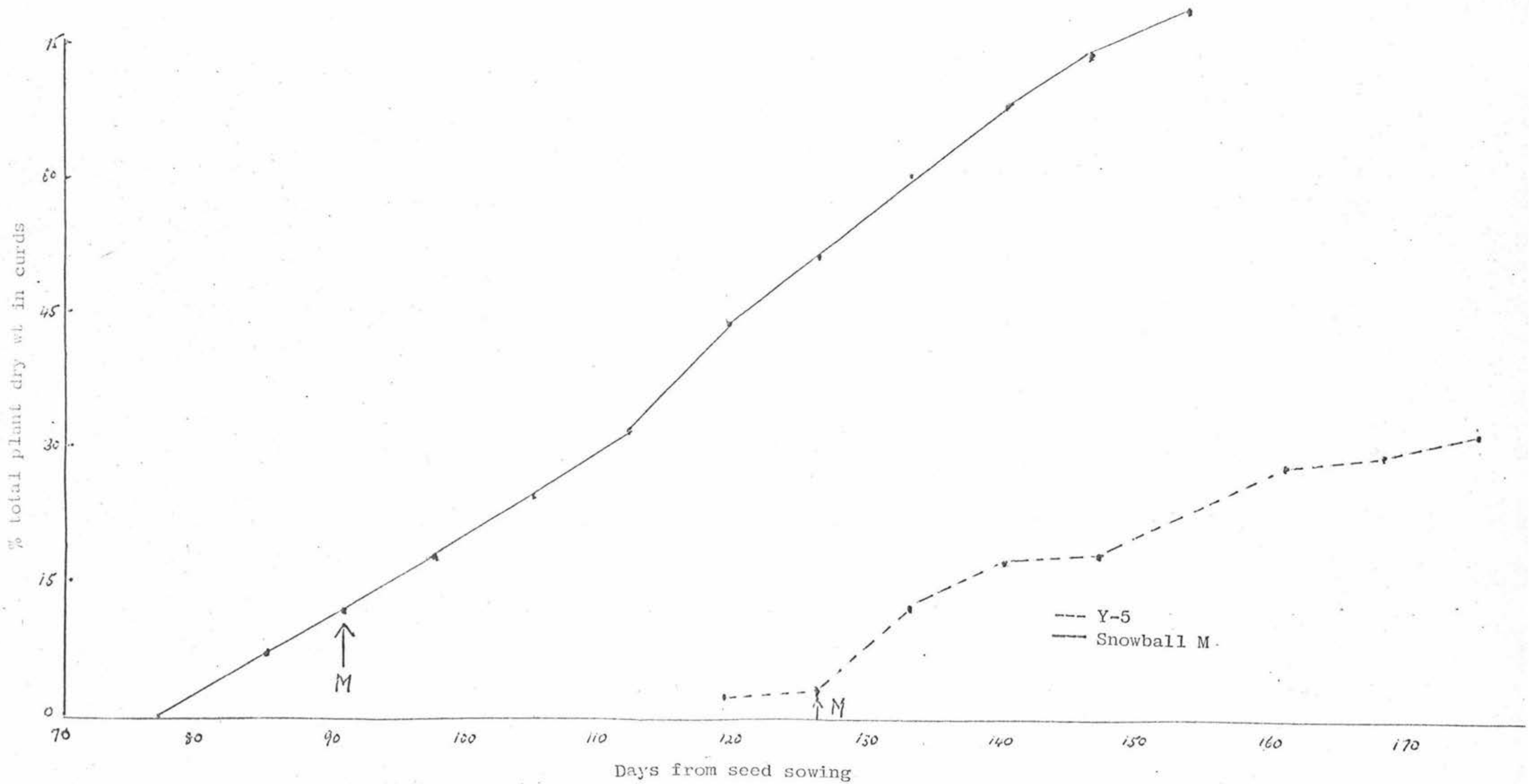


Fig. 4.6 % total plant dry wt in curds at each harvest.

4.3 Results and discussion

4.3.1 Growth of the whole plant (Fig. 4.2)

With Snowball M the total plant dry weight increased to a maximum 134 days after seed sowing. This was 41 days after curd maturity (4.2), which coincided with the point when total leaf dry weight began to decline. This was because no new leaves had been formed after curd initiation and the increase in dry weight of leaves had been due to leaf expansion. The continued increase in total plant dry weight was due to the elongation of the peduncles (E) of the curd.

With Y-5 variety the total plant dry weight increased until the time of curd maturity, when the decrease in total leaf dry weight coincided with the decrease in total plant dry weight.

As was to be expected the summer variety initiated curds (I) earlier than the winter variety resulting in earlier curd maturity (M).

4.3.2 Partitioning of total plant dry weight at each harvest.

With both varieties from the first harvest (one week from emergence) until the 28th day from seed sowing, the percentage total plant dry weight in the leaves (Fig. 4.3) went up, while that in the stem (Fig. 4.4) and roots (Fig. 4.5) went down.

From this point onwards the percentage total plant dry weight in the leaves (Fig. 4.3) was reasonably constant until curd initiation (I), when it then began to fall. With the variety Snowball M this fall was particularly marked after curd maturity (M). This may have been due to the curd elongation which took place after this point. From the 28th day the percentage of total plant dry weight in the stem (Fig. 4.4) appeared

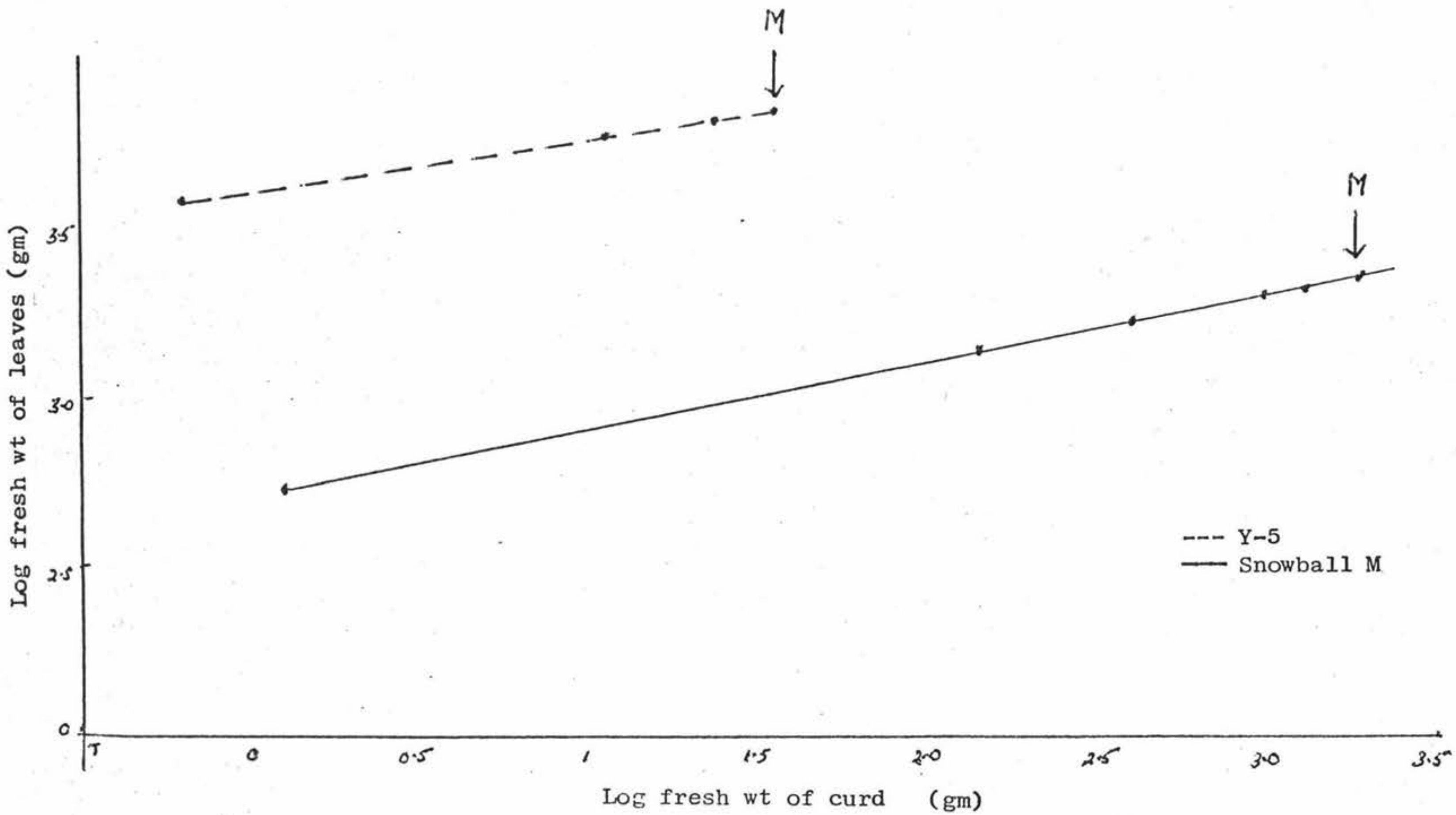


Fig. 4.7 Allometric relationship between leaf growth and curd growth.

to increase slightly with both varieties. This increase was most marked up till the time of curd initiation. This is perhaps to be expected as at curd initiation further stem growth would be restricted.

After the initial fall in percentage total plant dry weight in the roots (Fig. 4.5) the proportion remained fairly constant with both the varieties until the end of the experiment. Cooper (1972), observed a similar response with the tomato where the percentage of the absolute growth rate found in the roots fell as time progressed and there was a tendency with each of his sowings for the fall to flatten out as the time from sowing increased.

Curd development (Fig. 4.6) started at different dates for each variety. The percentage total plant dry weight in the curds increased with both varieties until the end of the experiment. Snowball M appeared to divert proportionately more assimilaty to the curd than did Y-5. This as already suggested was due to elongation of the peduncles.

4.3.3 Relationship between individual plant parts

4.3.3.1 Leaves and curds

When the fresh weight of leaves and fresh weight of curds were plotted logarithmically against each other from curd initiation to curd maturity a linear relationship was apparent, (Fig. 4.7). This suggests an allometric relationship between the growth of these organs as previously reported by Salter (1960). After curd maturity this relationship no longer occurred as the leaves began to senesce.

There was a significant negative correlation between the percentage total dry weight of plant in leaves and the curd for both varieties (Fig. 4.8).

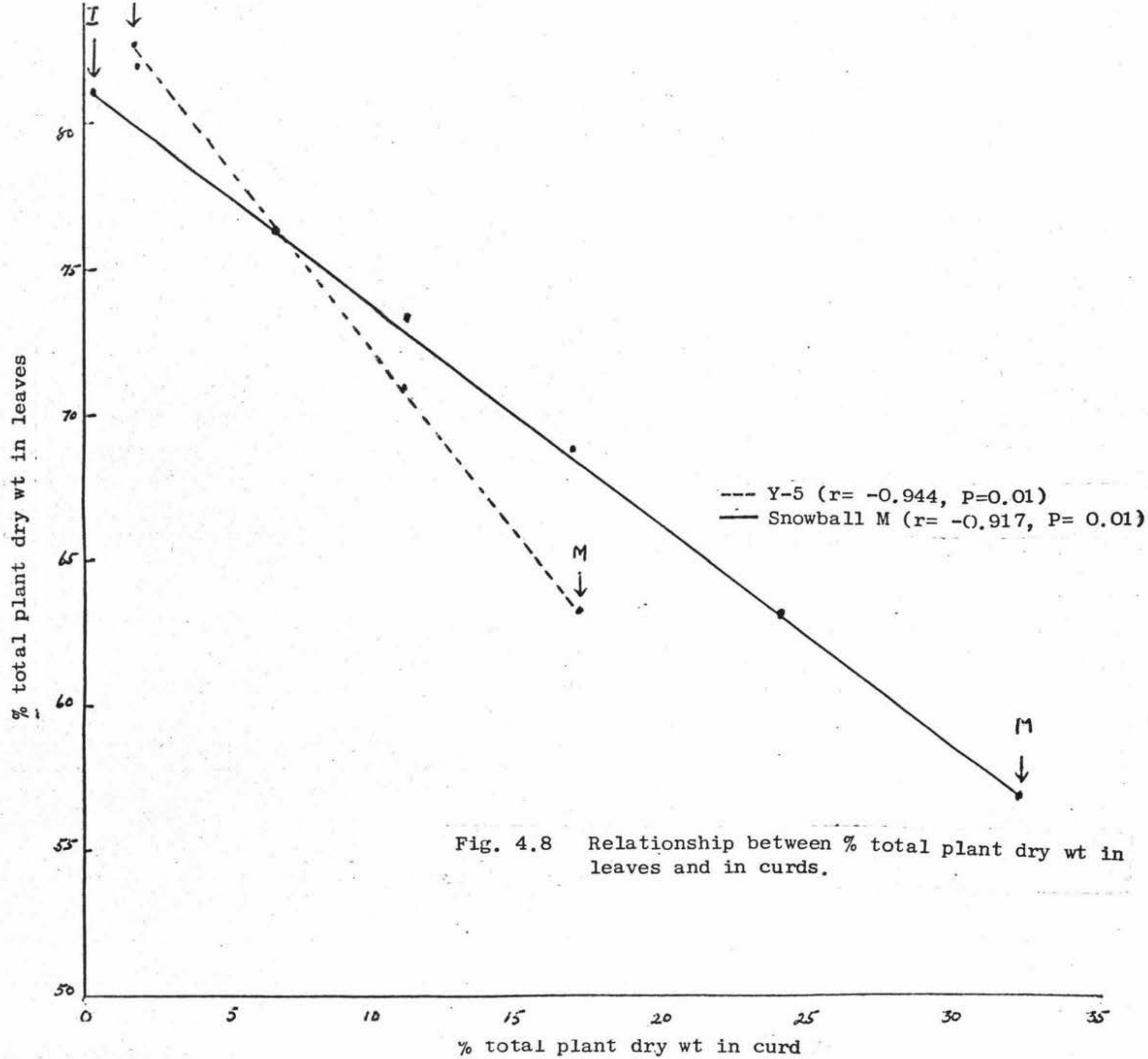


Fig. 4.8 Relationship between % total plant dry wt in leaves and in curds.

This suggests that these two organs are in competition for assimilates. A similar relationship is apparent for leaves and fruit in the tomato from the data presented by Cooper (1972).

Thus to increase the individual curd weight in the cauliflower plant it is necessary to increase leaf area as suggested by Salter (1959) and indicated by Fig. 4.7. Attempts to increase the percentage of total dry matter in the curd will not increase yield as this will be at the expense of leaf growth (Fig. 4.8). The percentage total plant dry weight in the curd is equivalent to the harvest index referred to by Donald (1962).

4.3.3.2 Leaf and Stem

Here plant development was divided into different stages as suggested by Van de Sande Bakhuyzen (1937). In this instance they were from seed sowing to curd initiation, from curd initiation to maturity and from maturity to the end of the experiment with Snowball M (Fig. 4.9). Whereas with Y-5 the first stage was the same and the second went from curd initiation to the end of the experiment (Fig. 4.9).

With both varieties during the first stage there was a highly significant negative correlation between percentage total plant dry weight found in the stem and leaves. This indicates that these two tissues are in competition for assimilates up till curd initiation.

After curd initiation no further relationship existed between these organs for Y-5. The lack of any relationship after curd initiation is to be expected as from this point onwards further stem growth was restricted.

With Snowball M from curd maturity until the end of the experiment a significant negative correlation again existed between these two organs with

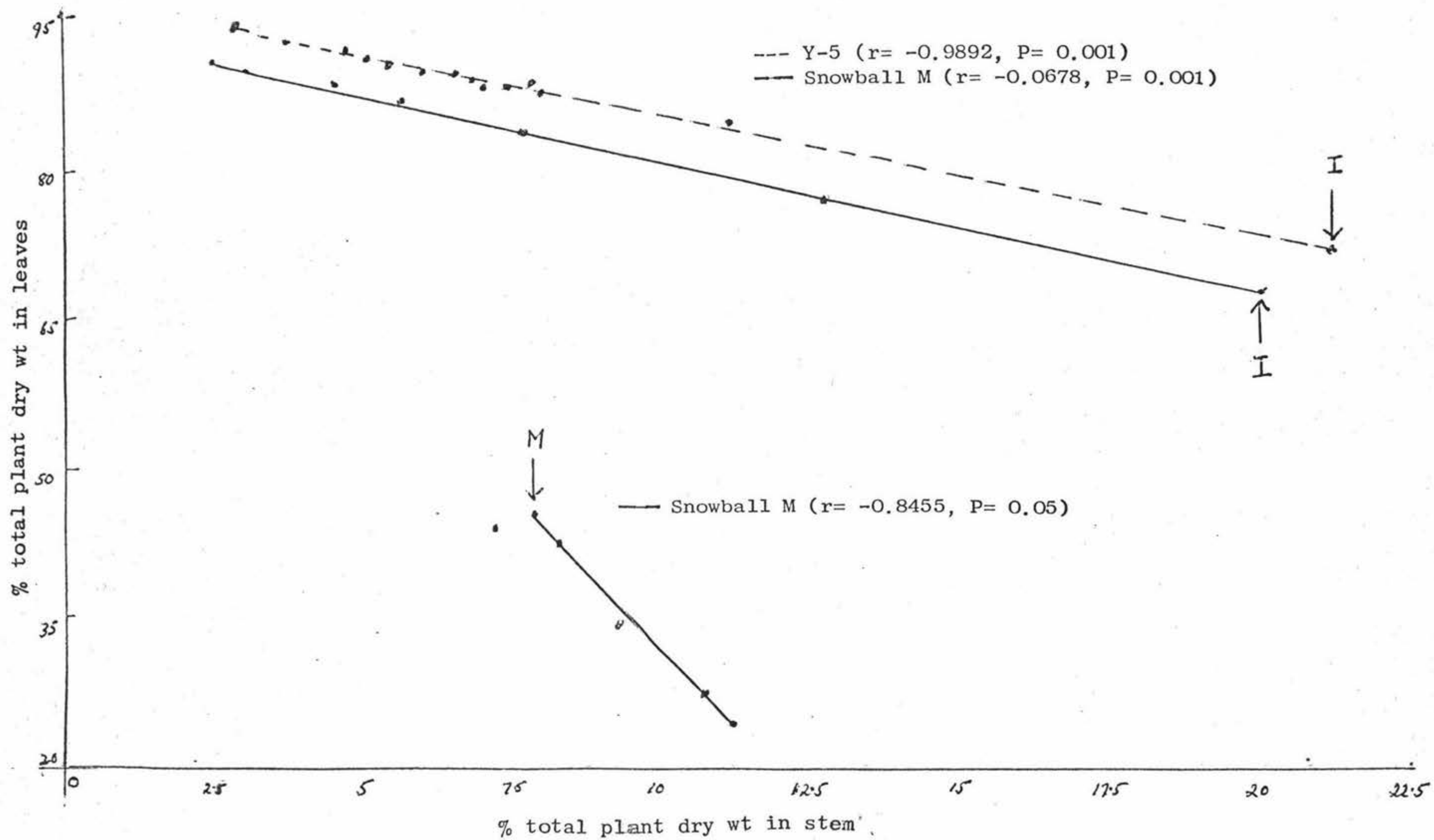


Fig. 4.9 Relationship between % total plant dry wt in leaves and stems.

respect to assimilate distribution. This may have been due to an increase in stem diameter that was noted during this stage for this variety.

4.3.3.3 Leaves and roots

With both varieties there was a significant negative correlation between the percentage total plant dry weight found in the leaves and the roots up till curd initiation (Fig. 4.10). Here again it would appear that leaf growth was in competition with another organ for assimilates. Leaf growth would therefore appear to dominate the growth of the young plant until curd initiation.

There was no relationship between these organs from curd initiation until the end of the experiment with variety Snowball M. Whereas with Y-3 a significant positive relationship existed from curd maturity till the end of the experiment (Fig. 4.10).

4.3.4 Summary

The growth of the whole plant, partitioning of the total plant dry weight at various harvests and the relationship between individual plant parts for two varieties of cauliflower are described.

For approximately a month from emergence leaf growth appeared to dominate in relation to the stem and roots, resulting in a higher percentage total plant dry weight in the leaves. At the point of curd initiation the percentage fell and this fall was marked after curd maturity in the case of Snowball M.

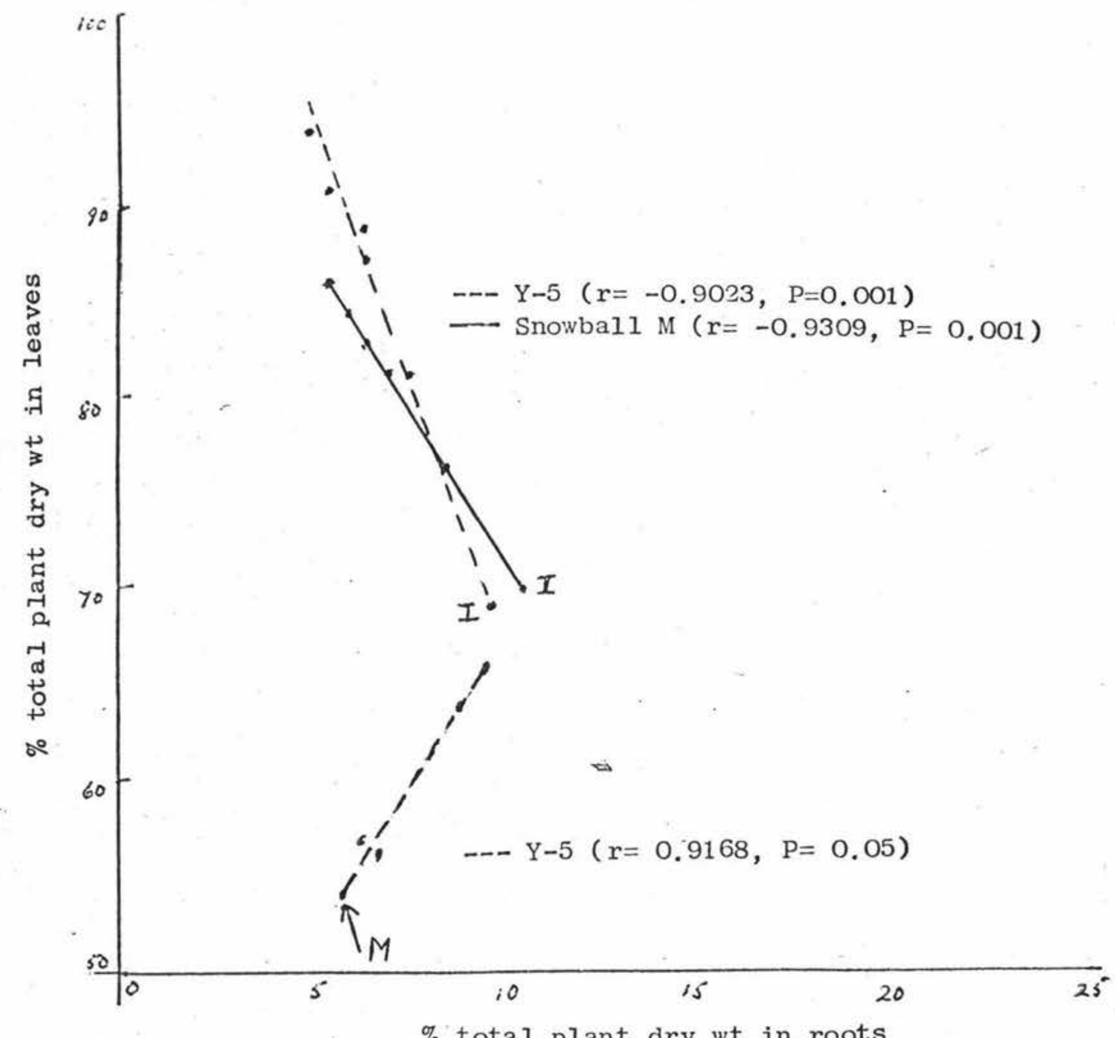


Fig. 4.10 Relationship between % total plant dry wt in leaves and in roots.

The percentage total plant dry weight in stem increased slightly with both varieties from the 28th day to curd initiation and thereafter the increase was restricted due to competition between curd and stem growth.

From emergence to the 28th day there was a gradual fall in the percentage total plant dry weight in the roots and remained fairly constant as the plants grew older.

An approximately linear relationship between growth of curd and time was shown with both type of varieties. The relationship between curd growth and leaf growth was allometric from the time of curd initiation until curd maturity. During this period these organs were shown to be in competition for assimilates. The time of curd maturity was defined as the point of maximum leaf weight.

With both varieties up till curd initiation competition for assimilates existed between stems and leaves showing a negative relationship, after this there was no competition between these two organs, except after curd maturity with Snowball M. A similar pattern was also observed between leaves and roots in the young plant and the leaf growth dominating till curd initiation. Thereafter no relationship existed between these two organs in case of Snowball, whereas with Y-5 a significant positive relationship existed from curd maturity till the end of the experiment.

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APPENDIX 1

Composition of Nutrient Solution, Hewitt (1966)

Salt	Weight in grams/100 litres nutrient solution	p.p.m.	
Major nutrients:			
KNO_3	40.4	156	57
$Ca(NO_3)_2.4H_2O$	94.4	160	113
$NaH_2PO_4.2H_2O$	20.8	31	41
$MgSO_4.7H_2O$	36.8	36	48
Minor nutrients:			
Iron Chelate	1.76		
$MnSO_4.4H_2O$	0.223	0.55 Mn	
H_3BO_3	0.186	0.33 B	
$CuSO_4.5H_2O$	0.025	0.064 Cu	
$ZnSO_4.7H_2O$	0.029	0.065 Zn	
$(NH_4)_6.Mo_7O_{24}.4H_2O$	0.0088	0.048 Mo	

APPENDIX 2

Analysis of Variance of dry matter percentage

in leaves in Experiment I.

Source	S.S.	d.f	M.S.	F	Result
Block	1.16	2	0.58	1.18	n.s.
Treatment	43.32	3	14.49	29.46	**
Error	2.98	6	0.49		
Total	47.46	11			

APPENDIX 3

Analysis of Variance total plant dry weight (gms) in Experiment I

Source	S.S.	d.f	M.S.	F	Result
Block	112.70	2	56.35	1.70	n.s.
Treatment	968.95	3	322.98	11.91	**
Error	162.66	6	27.11		
Total	7244.31	11	658.57		

APPENDIX 4

Analysis of Variance dry weight of leaves (gms) in Experiment I

Source	S.S.	d.f	M.S.	F	Result
Block	144.43	2	72.22	2.40	n.s.
Treatment	3451.89	3	1150.63	38.25	**
Error	180.52	6	30.08		
Total	3776.89	11	343.35		

APPENDIX 5

Analysis of Variance dry weight of stems (gms) in Experiment I

Source	S.S.	d.f	M.S.	F	Result
Block	19.01	2	9.50	3.1	n.s.
Treatment	164.75	3	82.37	27.64	**
Error	17.89	6	2.98		
Total	201.65	11	18.33		

APPENDIX 6

Analysis of Variance dry weight of curds (gms) in Experiment I

Source	S.S.	d.f	M.S.	F	Result
Block	11.93	2	5.96	0.12	n.s.
Treatment	377.73	3	125.91	2.60	n.s.
Error	290.03	6	48.34		
Total	679.69	11	61.79		

APPENDIX 7

Analysis of Variance percentage total plant dry weight in leaves in Experiment I

Source	S.S.	d.f	M.S.	F	Result
Block	38.80	2	19.40	0.60	n.s.
Treatment	61.55	3	20.52	0.63	n.s.
Error	192.89	6	32.16		
Total	299.29	11	27.20		

APPENDIX 8

Analysis of Variance percentage total plant dry weight in stems in Experiment I.

Source	S.S.	d.f	M.S.	F	Result
Block	12.06	2	6.03	5.15	n.s.
Treatment	153.31	3	51.10	[illegible]	[illegible]
Error	6.98	6	1.16		
Total	172.35	11	15.67		

APPENDIX 9

Analysis of Variance percentage total plant dry weight in curd in Experiment I.

Source	S.S.	d.f	M.S.	F	Result
Block	36.63	2	18.31	0.84	n.s.
Treatment	236.53	3	78.84	3.[illegible]	n.s.
Error	130.74	6	21.79		
Total	400.90	11	36.71		

APPENDIX 10

Analysis of Variance of stem length (cms) in Experiment I

Source	S.S.	d.f	M.S.	F	Result
Block	8.88	2	4.44	0.64	n.s.
Treatment	204.17	3	68.05	9.84	[illegible]
Error	41.46	6	6.91		
Total	254.51	11	23.13		

APPENDIX 11

Analysis of Variance fresh weight of curds (gms) in Experiment I

Source	S.S.	d.f	M.S.	F	Result
Block	4.97	2	2.48	0.06	n.s.
Treatment	247.85	3	82.62	2.30	n.s.
Error	215.99	6	35.99		
Total	468.31	11	42.57		

APPENDIX 12

Analysis of Variance of curd diameter (mm) in Experiment I

Source	S.S.	d.f	M.S.	F	Result
Block	3.3	2	1.[illegible]	0.02	n.s.
Treatment	916.2	3	305.4	4.80	
Error	394.0	6	65.6		
Total	1313.5	11	119.5		

APPENDIX 13

Analysis of Variance of Leaf Number in Experiment I

Source	S.S.	d.f	M.S.	F	Result
Block	1.41	2	0.70	0.42	n.s.
Treatment	1.50	3	0.50	0.30	n.s.
Error	9.82	6	1.63		
Total	12.73	11	1.15		

APPENDIX 14

The Composition of U.C. Compost in Experiment II

The mixture used contained 50% peat and 50% fine sand and was based on mixture IIc recommended by the University of California.

The mixture per two bushels of compost was -

2 ounces Uramite

8 grammes potassium nitrate

8 grammes potassium sulphate

4 ounces superphosphate

4 ounces dolomite lime

4 ounces ground lime stone

APPENDIX 15

Pest and disease control Experiment II

When the plants were ten weeks old, they were sprayed with DDT and Malathion to control caterpillars and aphids, and at the time of curd development, they were sprayed with Benlate to prevent fungus attack. The rates used were as follows:

1. DDT (50%) at $\frac{1}{2}$-1lb. per 100 gallons at 14-21 day intervals.
2. Malathion (Active ingredient 25% w/w Malathion) at 2 lb. per 100 gallons at weekly intervals.
3. Benlate (Benomyl fungicide 50% w/w) at 2 oz in 10-40 gallons of water per acre.

APPENDIX 16

The following amounts of base fertilisers were applied to the $^{1}/_{20}$th of an acre block in Experiment III.

Lime	-	2 cwt
Borax	-	1 lb.
Sodium molybdate	-	3 ozs
Superphosphate	-	1 cwt
Sulphate of Potash	-	40 lb.
Blood and bone	-	40 lb.
Sulphate of Ammonia	-	10 lb.

APPENDIX 17

Pest and disease control Experiment III

When the plants were four weeks old a regular spray programme to control aphids and caterpillars was adhered to. The rates used were as follows:

1. DDT (50%) at ½-1 lb per 100 gallons at 14-21 day intervals.
2. Malathion (active ingredient 25% w/w Malathion) at 2 lb. per 100 gallons at weekly intervals.

APPENDIX 18

Calculation of correlation coefficient between leaf and stem of variety Snowball M during the period from emergence till curd initiation in Experiment III.

Example -

Leaves %	Stem %	
X	Y	
69.6	20.2	
75.9	14.7	
86.4	8.1	
91.5	2.6	
85.6	3.8	
90.7	3.8	
86.7	7.6	
83.6	8.9	
ΣX 670.0	ΣY 69.7	ΣXY 5,532.3
ΣX^2 56,501.9	ΣY^2 862.35	

$$\Sigma x^2 = \left(X^2 - \frac{(\Sigma X)^2}{n} \right) = 56{,}501.9 - 56{,}112.5 = 389.4$$

$$\Sigma y^2 = \left(Y^2 - \frac{(\Sigma Y)^2}{n} \right) = 862.4 - 607.3 = 255.1$$

$$\Sigma xy = \left(\Sigma XY - \frac{(\Sigma X)(\Sigma Y)}{n} \right) = 5{,}532.3 - 5{,}837.4 = -306.1$$

$$r^2 \frac{(\Sigma xy)^2}{\Sigma x^2 y^2} = \frac{-(306.1)^2}{(389.4)(255.1)} = \frac{93{,}086}{99{,}336} = -0.9366$$

$r = -\sqrt{0.9366} = -.9678$ significant at 0.001 level.

BIBLIOGRAPHY

Aamlid, K. (1952). A study of Cauliflower (Brassica oleracea linn. var. botrytis D.C.) Ph.D. Thesis, Univ. Maryland, College Park, Maryland, U.S.A.

Anon, (1962). High water loss causes browning on cauliflowers. The Grower, 58, 867.

Bakhuzen, H.L. (1937). Studies on Wheat grown under constant conditions. Miscell. Publ. No.8 of Ford Research Inst. Stanford Univ. of California.

Black, J.N. (1955). The interaction of light and temperature in determining the growth rate of subterranean clover. Aust.J. biol. Sci., 8, 330-43.

Bensink, J. (1959). Proc. Kon. Ned. AK. Wet. C. 61, 89.

Brouwer, R. (1959). De involved van de temperatur op de ontwikkeling-scyclus van erwten. Yearbook I.B.S. 1959, 17-26.

Brouwer, R. (1962). Distribution of dry matter in the plant. Neth. J. Agric. Sci., 10, 361-376.

Brouwer, R. (1962). Nutritive influences on the distribution of dry matter in the plants. Neth. J. Agric. Sci., 10, 399-408.

Brouwer, R. (1968). Morphological and Physiological adaptations to external conditions. Acta Bot. neerl., 17, 78-80.

Carew, J. and Thompson, H.C. (1948). A study of certain factors affecting "Buttoning" of Cauliflower. Proc. Am. Soc. hort. Sci., 51, 406-414.

Cooper, A.J. (1972). Partitioning of dry matter by the tomato. J. hort. Sci., 47, 137-140.

Downs, R.J., Hendricks, S. and Borthwick, H.A. (1957). Photoreversible control of elongation of Pinto beans and other plants under normal conditions of growth. Bot. Gaz., 118, 199-208.

Evans, G.C. and Hughes, A.P. (1961). Plant growth and the aerial environment. I. Effect of artificial shading on Impatiens parviflora. New Phytol., 60, 150-180.

Fontes, M.R., Ozbun, J.L. and Sadik, S. (1967). Influence of temperature on initiation of floral primordia in green sprouting broccoli. Proc. Am. Soc. hort. Sci., 91, 315-320.

Gwarthwaite, J.M. (1967). Comparison of direct drilling and transplanting. Final Rep. Luddington. Expt. hort. Stn for 1966, 87-91.

Haine, K.E. (1959). Time of heading and quality of curd in Winter Cauliflower. J. natn. Inst. agric. Bot., 8, 667-74.

Harris, F.S. (1914). The effect of soil moisture, plant food and age on the ratio of tops to roots in plants. J. Am. Soc. Agron., 6, 65-75.

Jensma, J.R. (1957). Teelt en Veredeling van bloemkool. Meded. Inst. Vered. TuinbGewass., 96, 1-56.

Kato, T. (1964). On flower head formation and development in cauliflower. I. Ecological studies on flower head formation and development. J. Jap. Soc. hort. Sci., 33, 316-26.

Kato, T. (1965). On flower head formation and development in Cauliflower plants. II Physiological studies on flower head formation. J. Jap. Soc. hort. Sci., 34, 49-56.

Khalil, M.S.H. (1956). The interaction between growth and development of wheat as influenced by temperature, light and nitrogen. Thesis Wageningen. Agric. Univ.

Loomis, W.G. (1934). Daily growth of maize. Am. J. Bot., 21, 1-6.

Love, J. (1963). Note on the effect of sowing date and planting date on the quality and yield of some Autumn Cauliflower varieties in 1962. Rep, Efford. Lab. Stn. for 1962, 60-61.

Maximor, N.A. (1929). The plant in relation to water. Edited with notes, by R.H. Yapp, London, George Allen and Unwin, pp. 0+451.

Nieuwhof, M. (1969). Cole crops 140. World Crop Series.

Parkinson, A.H. (1952). Experiments on vegetative and reproductive growth of Cauliflower. Ann. Rep. Nat. Veg. Res. Sta., 38-51.

Richardson, S.D. (1951). Observations on the connection between root growth and shoot illumination in first year seedlings of Acer pseudoplatnaus L, and Quercus borealis maxim (MARSH). ASHE. Proc. KON. Ned. Akad, Wetensch, C54, 503-510.

Sadik, S. (1962). Morphology of the curd of Cauliflower. Am. J. Bot., 49, 290-7.

Sadik, S. (1967). Factors involved in curd and flower formation in cauliflowers. Proc. Am. Soc. hort. Sci., 90, 252-9.

Sadik, S. and Ozbun, J.L. (1968). The association of carbohydrate changes in the short tip of cauliflower with flowering. Pl. Physiol., Lancaster, 43, 1696-1698.

Salter, P.J. (1959). Effect of different soil moisture conditions during the seedlings stage in the growth of early summer cauliflower. J. hort. Sci., 34, 23-31.

Salter, P.J. (1960). The growth and development of early summer cauliflower in relation to environmental factors. J. hort. Sci., 35, 21-23.

Salter, P.J. (1961). Irrigation of early summer cauliflower. J. hort. Sci., 36, 241-253.

Salter, P.J. (1969). Studies on crop maturity in cauliflower. 1. Relationship between the times of curd initiation and curd maturity of plants within a cauliflower crop. J. hort. Sci., 44, 129-40.

Salter, P.J. and Fradgley, J.R.A. (1969a). Studies on crop maturity in cauliflower. II Effects of cultural factors on the maturity characteristics of a cauliflower crop. J. hort. Sci., 44, 141-54.

Salter, P.J. and Fradgley, J.R.A. (1969b). II Effects of cultural factors on yield and curd quality of autumn cauliflower. J. hort. Sci., 44, 265-273.

Salter, P.J. and Ward, R.J. (1969). Artificial induction of curd initiation. Rep. natn. veg. Res Stn for 1969, 74-75.

Salter, P.J. and Ward, R.J. (1972). Studies on crop maturity in cauliflower. III Effect of cold treatment and certain growth regulators on crop maturity characteristics and yield. J. hort. Sci., 47, 57-68.

Skapski, H. and Oyer, E.B. (1964). The influence of pre-transplanting variables on the growth and development of cauliflower plants. Proc. Am. Soc. hort. Sci., 374-85.

Sokal, R. and Rolf, G.J. (1969). Biometry. W.H. Freeman and Company.

Van De Sande Bakhuyzen, H.L. (1937). Studies on wheat grown under constant conditions. Miscell. Publ. No.8. of Ford Research Inst. Stanford Univ. of California.

Van Dobben, W.H. (1962). Influence of temperature and light conditions on dry matter distribution, development rate and yield in arable crops. Neth. J. Agric. Sci., 10, 361-376.

Wassink, E.C. (1955). Correlaties tussen wortelgroei en borrengrondse condities. In De plantenwortel in de landbouw, Staatsdrukkerij-en uitgeverijbedrijt, 's-Gravenhage, 119-125.

Williams, A.M. (1967). Winter Cauliflower-seedling densities. O.P. 275 (Interim Report). Rep. Rosewarne Exp. hort. Stn for 1966, 50-52.

Wittenrood, H.G. (1967). Grafische voorstelling van de ontwikkeling van een plant. Jaarboek I.B.S. 87-94.