A STUDY OF THE EFFECTS OF WATER AND CUTTING ON SEED PRODUCTION OF VERANO STYLO (*Stylosanthes hamata*) AND SIRATRO (*Macroptilium atropurpureum*)

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PHANNA WAIKAKUL

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DEDICATED TO MY FATHER

ABSTRACT

Tropical pasture legume seed production in the North-east of Thailand first began in the early 1970's. *Stylosanthes hamata* cv. Verano and *Macroptilium atropurpureum* cv. Siratro were two of the forage legumes proposed to fill the requirement for improved pastures in this region of Thailand. This study was initiated to provide information on the effects of water stress, stage of plant development at the time of cutting and cutting intensity on seed production of these two tropical forage legumes, in the field at Khon Kaen, Thailand.

A second and more intensive study on the reaction of Verano stylo to water stress, and stage and intensity of cutting was carried out to provide a better understanding of possible plant adaptation and the contribution of plant components to seed yield of this species under controlled environment conditions at the D.S.I.R., Palmerston North, New Zealand.

Initially, field experiments were carried out in two different seasons, (dry season and wet season). The dry season experiment studied the effects of irrigation, non-irrigation, and cutting on seed yield. In the wet season field experiment only the effect of cutting was studied in both Verano stylo and Siratro. The results from the dry season study showed that species are responsive to irrigation. Irrigated plants produced about 25% more seed yield than non-irrigated plants in Verano stylo but only about 10% more in Siratro. The response of the plants to cutting was variable depending on the stage and intensity of cutting. Light cutting at either the vegetative or floral initiation stages gave higher seed yields than uncut plants in Verano stylo, while in Siratro all cut plants gave higher seed yields than uncut plants. Planting Verano stylo or Siratro in the wet season resulted in plants taking longer to reach the reproductive stage than in the dry season. This protracted vegetative stage resulted in bigger plants and more sites for seedheads. In stylo both cut and uncut plants gave higher seed yields than those obtained in the dry season

planting, while in Siratro plants heavily cut at the vegetative stage gave the highest seed yield. Siratro plants grown in the wet season tended to produce strong vegetative growth and good inflorescence development. However, seed yield was lower because of poor pod development and low numbers of seeds per pod.

The second experiment on Verano stylo was carried out under controlled environment conditions designed to simulate as closely as possible the different growing seasons previously used in the field. The results confirmed that water plays an important role in increasing seed yield in both cut and uncut plants, and especially in cut plants provided they received high water levels throughout the growing period. Water stress appeared to change plant structure, both vegetative and reproductive growth being greatly reduced during the stress period. Water also had an effect on the number of sites for seedhead formation and the contribution to seed yield. In plants which were water stressed from about 30 days after sowing (vegetative stage) both cut and uncut plants remained small resulting in low branch numbers, shorter branches and fewer sites for seed-head development. Water stress applied following peak flowering (55 days after sowing) also reduced seed yield, compared with the yield from plants receiving water throughout the period of seed development. The maximum yield obtained varied from 1.2-9.3 grams per plant between the three water treatments.

Studies on the contribution to seed yield from each branch order and seedhead position indicated that in both cut and uncut plants most of the seed yield came from secondary branches (60-75%). The contribution to seed yield, however, was different between water treatments. In early stressed plants seed yield was apportioned almost equally between primary and secondary branches. However in plants which had been placed under water stress at peak flowering, the seed yield obtained from primary branches was only half that produced from secondary branches. In non-stressed plants 70% of total seed yield came from seedheads produced on secondary branches and only 20% from primary branches. The position of seedhead formation on each branch was also important. The results showed that about 75-90% of total seed yield came from seedheads formed at nodal sites. The number of seedheads formed at terminal sites was low. In later stressed plants and in well watered plants the contribution of nodal sites to seed yield was higher than in early stressed plants.

The results of the field study on Verano stylo and Siratro, and the second experiment on stylo grown under controlled environment conditions were incorporated into practical recommendations which lead to conclusions on the most economically, socially and agriculturally acceptable management system for the seed production of Verano stylo and Siratro by Thai farmers.

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INTRODUCTION

Although about half of the world's grazing animals occur in the tropics the output of animal products from these areas is very much less than from other parts of the world. Tropical pastures generally have a lower nutritive value than temperate pastures. The need to correct protein deficiency is therefore seen as a major challenge for scientists since inadequate protein supply during part of the year is often a major limitation to livestock production. Animal protein needs may be met by feeding animals on pastures with a high protein content, an improved pasture legume component therefore being a logical beginning in attempts to offset grass protein deficiency. For this reason pasture improvement in the tropics is very important. The choice of methods of establishing tropical pastures is likely to be influenced by a number of factors including the selection of species and mixtures for high levels of pasture production. In improving pasture, there is also often a need for cultivars which have a versatility of use and wide environmental adaptation. Ideally, suitable species should give a dense sward structure and provide a larger intake per bite than loose and trailing species. They should also have the ability to regenerate and cover bare areas. Although the seeds of such cultivars have a wider market, problems of production may be a limitation to adequate supplies of high quality seed. For example, some improved legume cultivars produce flowers over a long period. As a result the crop ripens unevenly and the pods shatter, so that little seed is available for harvest at any one time. This leads to shortages of seed supply, and inevitably higher prices (Humphreys, 1978). Among the tropical forage legumes *Macroptilium atropurpureum* cv. Siratro spreads quickly by vegetative means and has good reseeding characteristics, while, *Stylosanthes hamata* is also an extremely free seeder (Humphreys, 1979).

The northeast region of Thailand has about 57% of Thailand's cattle and 45% of the country's buffaloes. The area has therefore a great potential for pasture improvement to service this demand. The region is a slightly elevated plateau of 17 million hectares approximately 100-300 metres above sea level. It lies between 14^{o}-19^{o}N latitude and experiences a tropical savannah climate with a pronounced seasonal distribution of rainfall. Khon Kaen, where the field experiment was conducted, receives more than 85% of its annual total of 1,255 mm rainfall in six months from mid April to mid October due to the influence of the south-west monsoon. Such a climate makes this area particularly suitable for the growth and seed production of selected tropical pasture legumes (Shelton, 1977).

Tropical pasture and legume seed production in Northeast Thailand first began in the early 1970's. Over the past decade tropical seed production has received greater attention through the demand for more seed by farmers. Through continued research and trial work at Khon Kaen University, Borabu Land Development Centre and the Department of Livestock Development Project, along with the inputs by the North-east Livestock Development Project at Tha Pra, Khon Kaen has been responsible for the rapid expansion of pasture seed production through the introduction of a village seed production programme (Hare and Waranyuwat, 1980). In 1980 over 100 tonnes of high quality seed of nearly 15 different pasture grass and legume species was produced in the North-east of Thailand. Aid from the New Zealand Government and the World Bank has made tropical pasture seed production (especially *Stylosanthes* species) possible in the region and has accomplished savings of up to 70% by overcoming the need to buy the same amount of seed from Australia (Waranyuwat, 1980).

Grazing or cutting pasture seed crops provides an additional income source for farmers and may even increase seed yield (Humphreys, 1978). Most seed growers want to get the maximum value from their seed fields by also grazing them or by conserving the residue as hay. Defoliation is also considered to be one method that can lead to increased seed yields by removing apical dominance and thereby increasing branching and providing more sites for inflorescence development. This treatment, to be successful, appears to depend upon cutting or grazing being carried out at a stage of plant growth which will permit full recovery of the vegetative framework, before flower initiation begins (Loch and Humphreys, 1970). However, further and more precise definition of this defoliation process is required to explain and exploit this potential in the field.

Many pasture seed production enterprises have failed because of an unsuitable climate or unfortunate choice of location in the district selected. Irrigation is potentially one of the most important means of raising crop production and improving the reliability of seed production. In the case of tropical legumes, for example, variation in planting time combined with irrigation could be a very important management aspect for increasing seed production.

Because of lack of information concerning the effects of defoliation and water on seed production in many tropical forage legumes, a study of the effect of these two factors on seed production in *Stylosanthes hamata* cv. Verano and *Macroptilium atropurpureum* cv. Siratro was carried out in a field trial at Khon Kaen University, Khon Kaen, Thailand beginning in August, 1979 and was followed by a controlled environment study on Verano Stylo carried out at Palmerston North, New Zealand commencing in September, 1981.

The main objectives of these studies were:

1. To examine the effects of a dry season planting (with and without irrigation) and a wet season planting on the vegetative and reproductive development and seed yield of Verano Stylo and Siratro under field conditions in Thailand.

2. To determine the effects of cutting at different stages of growth and at different intensities on the vegetative and reproductive development and seed yield of Verano Stylo and Siratro under field conditions in Thailand.

3. To study the influence of water stress applied at different stages of plant growth on the sites of inflorescence and seed formation on different branch orders and their contribution to total seed yield in Verano Stylo under controlled environment conditions.

4. To investigate the plant morphological changes which occur as a result of cutting Verano Stylo plants to different heights and at different stages of growth under water stress conditions in a controlled environment.

CHAPTER 1

LITERATURE REVIEW

1. BACKGROUND INFORMATION

1a. BACKGROUND INFORMATION OF *STYLOSANTHES HAMATA* CV. VERANO AND *MACROPTILIUM ATROPURPUREUM* CV. SIRATRO

Stylosanthes, while it is only a small genus comprising about 30 species, provides more pasture cultivars than any other tropical genus and is also useful over a much wider range of tropical conditions than many other genera. Stylosanthes contains two markedly different plant forms, annuals and perennials (Burt *et al.*, 1980).

The main centre of distribution of Stylosanthes is from 30°N to 30°S in the tropics and subtropics of South and Central America. Within this area species are found in a very wide range of climates and geographic locations. A number of well adapted cultivars have been selected from this collection including *S. hamata*, *S. scabra* and *S. humilis* for drier hotter regions, and *S. guianensis* for wetter and more subtropical conditions (Burt *et al.*, 1980).

Stylosanthes hamata cv. Verano

Verano stylo, sometimes known as Carribbean Stylo, originated in the islands of the West Indies and the adjacent coastal regions of the North and South American continents. The original collection was made in Venezuela by Mr Tom Atkinson of the NSW Department of Agriculture.

Verano stylo is a herbaceous, indeterminate perennial with a semi-erect habit and a branching pattern which is often dichotomous, with leaves trifoliate. The inflorescence is an oblong spike with 8-14 florets on a long stem. The seeds are medium to dark brown in colour and 2.0-2.5 mm long. It also has a superior competitive ability with native grasses and weeds and grows well with companion grasses (Skerman, 1977). Burt *et al.* (1980) mentioned that the growth habit of Stylosanthes is markedly different from tropical pasture legumes in other genera. The growing points of *Stylosanthes* spp. are often close to the ground, this characteristic tending to confer tolerance to grazing. *S. hamata* can be distinguished from other accessions of this species by its more profuse branching, slender stems and smaller leaves. It has also been shown to persist in other tropical regions which have a pronounced dry season, such as the north-east of Thailand. It has a high seed production capacity for a perennial legume, but may behave as an annual plant in very dry areas (Humphreys, 1974).

Wilaipon and Humphreys (1981) found that in Thailand *S. hamata* cv. Verano produced high seed yields even under grazing. Torssell *et al.* (1968) have mentioned that the ability of Townsville lucerne - a similar but annual species of *Stylosanthes* - to continue exploring a greater depth of soil enables it to grow and complete its life cycle even if the wet season is virtually over. However, the importance of drought resistance through root penetration below 150 cm soil depth and soil water availability at that depth requires further study.

The introduction of *Stylosanthes* species from South America into Australia illustrated the importance of plant introduction in improving pasture and beef production. It is suggested that beef production in Thailand would also benefit from a similar introduction programme (Topark - Ngarm, 1976).

Macroptilium atropurpureum cv. Siratro

The species is native to many countries of Central and South America and has proved to be one of the most productive and adaptable tropical legumes in many other countries such as South-east Asia and the Pacific Islands. The cultivar Siratro was bred by Dr E.M. Hutton, by crossing two Mexican introductions of *M. atropurpureum* V12. CPIS 16877 and 16979 and was released in 1960. Siratro is a deep-rooting perennial with trailing, slightly hairy stems which root readily at the nodes. Leaves are trifoliate, dark green and slightly hairy on the upper surface and silvery and very hairy on the lower surface. Flowering stalks 10-25 cm in length carry clusters of 6-12, often paired, flowers which are deep purple or almost black in colour. Pods are narrow, cylindrical, sharp pointed about 7-9 cm long and contain 12-13 ovoid but flattened, brown to black seeds. Pods shatter readily when ripe but high seed yield can be obtained. Siratro is suited to subtropical and tropical climates with an annual rainfall of 750-1750 cm and will withstand high summer temperatures. It also has a high level of drought resistance even under steady grazing pressure. Siratro can be grown on an extremely wide range of soils from light textured sandy soils to heavy clays. Seed germination is usually above 70% with a percentage of hard seeds which can remain viable in the soil for five years or more. Siratro seed should be sown with companion grasses and can also be sod-seeded into native pastures (Skerman, 1977). Its vigorous seedlings nodulate freely and establish readily even in grazed situations. The twining stems of Siratro enable it to compete with associated grasses and weeds under leniently grazed management systems. Under such situations considerable vegetative spread by both stolons and rhizomes can occur. However Siratro cannot withstand repeated heavy defoliations (Jones and Jones, 1978). Hopkinson (1977) mentioned that many Australian farmers found Siratro to be a poor pasture legume but a vigorous seed crop. The success of Siratro seed production depends on where best to grow the seed crop and how best to harvest it (Hopkinson, 1977). Climate has been a critical problem for seed production. Imrie (1973) and Whiteman (1974) found that plants failed to flower in a 16 hour photoperiod but that photoperiods below 12 hours hastened flowering.

For seed production of both Verano stylo and Siratro, Hare and Waranyuwat (1980) found that in Thailand, Stylo performs well on the free draining upland sandy loam soils that retain their moisture well into the dry season. *S. hamata* has only a moderate tolerance to salinity and generally, saline soil should be avoided. Siratro on the other hand establishes well on a wide range of soils and can also tolerate moderately saline conditions but does not tolerate flooding or waterlogging. Heavy soils will cause Siratro to produce too much vegetative growth rather than reproductive growth.

1b. BACKGROUND INFORMATION ON FIELD EXPERIMENTAL SITE

North-eastern Thailand, designated as the Korat Plateau, is described as a gently undulating, saucer-shaped plateau, tilted to the south-east and limited on the north and the east by the Mekong River. Four main levels of sedimentation are recognised in the area. These levels are the alluvial plains of the rivers and creeks, and three main stream terraces (low terrace, middle terrace and high terrace). The experiments were sited on the high terrace. The surface area of this high terrace formation is mostly composed of loamy sand; while deeper down the soil is more clayey, and generally regarded as a sandy clay loam. Soils of these sediments are red yellow latosols (Moorman *et al.*, 1964).

The field experiments were conducted at Khon Kaen University in the NE region of Thailand in Khon Kaen province, situated on a free draining upland sandy loam soil of the Yasothon series. The topsoil (A. horizon) consists of approximately 12 cm of dark reddish-brown loamy sand. It has a weak coarse crumb structure with a soft consistency. The topsoil provides a sandy mulch layer which reduces the rate of moisture loss during the dry season. The subsoil can retain moisture even in the dry season with very little runoff. This subsoil, which is up to 120 cm in depth, is very uniform and oftens contains many pores. It provides a large storage capacity of soil moisture. Field capacity is reached throughout the profile in the wet season allowing soil moisture levels higher than would be expected in the dry season (Eyles, Personal communication. Based on Soil Survey Reports of Land Development in Thailand No. 51, 1966).

Mongkolsawat and Katawetin, (1979) studied moisture distribution in the Yasothon soil series under rainfed conditions at different depths and recorded the levels of moisture content that contribute to the yield of crops planted during the dry period. They found that plants that survived during this period of planting had to be those with deep root systems or which exhibited drought tolerance. They also found that soil moisture distribution in the 25-60 cm zone was generally higher and less variable than in the upper soil layer. The period in which the moisture was available in this lower zone was from April to late October. Only plants with deep root systems could utilise moisture in these zones.

Khon Kaen is a tropical savanah with a marked seasonal distribution of rainfall. More than 85% of the rain falls in the six months from mid-April to mid-October. There are four distinct seasons controlled by the north-south movement of the intertropical Convergence Zone. The wet season occurs from May to September. Heavy rains which occur from July to August subsequently decrease. The mean maximum temperature is 32^{o}C while the mean minimum temperature is 23^{o}C. Relative humidity is generally high at about 75-80%. The second season is during October which is the transitional period of the wet season to the dry season resulting in a decreased rainfall, with a mean maximum temperature of 31^{o}C, a minimum of 21°C and a RH of about 75%. The third season is the cool season starting from November to February with a mean maximum temperature of 29°C and mean minimum of 16°C, RH about 75%. The fourth season is the hot season occurring during March and April with a mean maximum temperature of 35°C. The lowest relative humidity of the year is in March at 65% (Van den Eelarrt, 1973).

At Khon Kaen during January to June sunshine duration ranges from 7½ to 8½ hours per day. Cloudy weather during July to September reduces sunshine hours to about 4½-5. From October to December sunshine duration increases again to about 6-8 hours per day (Vorasoot and Tienroj, 1979).

Pan evaporation rate varies according to the sunshine hours in each season or each month with an average of 4-4.5 mm/day during the months from August to January. Evapotranspiration rate is about 3 mm per day in the dry season (Vorasoot and Tienroj, 1979).

2. DEFOLIATION

Defoliation means removal of plant shoots and leaves by grazing or cutting and has often been considered in terms of frequency, intensity and timing. Grazing or cutting pasture seed crops prior to closing for seed, can provide an additional source of feed for stock and income for farmers, and with some crops may even increase seed yield. However to decide the best grazing management for each seed crop, a very careful study of individual crop development is needed (Humphreys, 1978). It has also been shown (Humphreys, 1979) that both grazing and cutting can cause adverse or favourable effects on seed production according to their influence on the density of inflorescences, assimilate supply to inflorescences, time of flowering and the extent of control of competing species. Defoliation delays flowering in some species depending upon the environmental conditions occurring during the delayed flowering and maturation period. Late grazing which removes the flowering parts is usually harmful, but early grazing may stimulate branching and the generation of more sites for flower production (Humphreys, 1978). Kretschmer (1968) found in *S. humilis* that the quantity of seed produced depends upon plant vigour prior to flowering and the quantity of vegetative material present at flowering. If plants are allowed to grow for a long period without grazing and then overgrazed seed production will be very low. If grazing begins when plants are small the plant has the ability to assume prostate-growth which may produce abundant seeds even under intense grazing (Kretschmer, 1968).

The structure of the plant can also influence the degree of removal during defoliation. A flowering plant which has more elevated leaves by virtue of internodal extension is likely to suffer more from removal than a non-flowering plant where the growing point is closer to ground level. The position of the growing point is quite crucial in determining susceptibility to damage from defoliation. Plants which have elevated apices are most susceptible to grazing damage. Species which have buried buds or buds very close to ground level are generally able to maintain these buds without damage by the grazing animal. Many legumes including *Stylosanthes* spp., have few basal branches and are consequently more susceptible to defoliation damage. Most legumes' leaves are wholly available for removal (Humphreys, 1975).

Humphreys (1979) stated that defoliation can be used to manipulate the competitive relationship in favour of the sown crop species. *S. humilis* yield is increased by grazing or cutting practices which prevent taller companion species from shading them. In *S. guyanensis* cutting may be used to produce a lower and more uniform framework of branches which then gives less volume of plant material to be cut and threshed.

Humphreys (1975) mentioned that the effects of defoliation on the physical environment will alter the environment in which the sward grows. Moisture infiltration into soil is positively related to the amount of cover.

Many plants modify their habit according to defoliation frequency and will be more prostrate if grazing is heavy. Obviously, defoliation will increase light intensity in the lower levels of the sward, which may otherwise have contained deeply shaded leaves. However exposure of bare soil increases evaporation losses from the soil surface. Transpiration is positively related to leaf area, in the lower leaf area ranges, and moisture loss from plants may be reduced if the leaf canopy is diminished. Hopkinson (197[illegible]) also found similar results in his studies with *Medicago sativa* cv. Hunter River.

Many experiments have been conducted on the effects of defoliation frequency, intensity and timing. Rossiter (1961) found in Subterranean Clover that seed production of pure stands is increased by cutting or grazing at or before the flowering stage. This effect is mainly due to increased branching and inflorescence density. Kretschmer (1968) also found in *Stylosanthes humilis* that grazing when plants are small will result in the production of abundant seeds. Loch and Humphreys (1970) conducted an experiment on *S. humilis* by applying different defoliation treatments at different stages of plant growth. They found that defoliation at floral initiation, flower appearance, or advanced flowering sharply reduced seed production because defoliation reduced the fertility of bud sites. There were only minor effects on total plant growth. They also found that the main defoliation effect was to reduce the proportion of florets setting seed. More immature seeds were found on defoliated plants than on undefoliated plants.

Fisher (1973) found that defoliation of *Stylosanthes humilis* may also be used to increase seed yield. He found that a sward of *S. humilis* which commenced flowering in the middle of March (Australian autumn) if cut to 13 cm height on February 26 and March 20, or March 20 alone gave seed yields of 909 and 722 kg/ha respectively, relative to an undefoliated sward yield of 620 kg/ha. Jones (1973) found similar results with *Desmodium intortum* and stated that there is an interaction between cutting interval and cutting height on seed yield. In 1976 Loch *et al.* studied the consequence of defoliation on *S. guyanensis*. They observed that defoliated plots never grew to the maximum height reached by control plots. The results showed that plants defoliated during the vegetative growth stage showed no significant reduction in the population of growing points and floral spikes during the reproductive phase. However, if plants were defoliated at the later stages of growth, this management delayed the start and retarded reproductive development. At the time of harvest many florets were still immature. This caused a distinct fall in the percentage of successful seed production and reduced seed yield.

Wilaipon and Humphreys (1976) found in their studies on *S. hamata* that severe grazing and mowing at an early stage resulted in a seed yield of 355 kg/ha, compared to a seed yield from undefoliated plants of only 221 kg/ha. Wilaipon *et al.* (1979), in their further studies with *S. hamata* cv. Verano on the effects of removing apices, laminae, and shoots on seed production and growth, observed that by defoliating plants at different stages during early or advanced floral initiation there were significant effects on seed yield. Defoliation both delayed flowering and the time of seed maturation. From these studies they concluded that there are three possible explanations for the effects of defoliation on seed production of *S. hamata* cv. Verano i.e. movement of stored assimilates from stem and older leaves to inflorescences may have been stimulated by the removal of competing young leaves; reduced competition from young leaves may have increased the proportion of buds forming inflorescences which grew and formed seeds; or removal of the upper leaf canopy in these wellgrown swards may have increased light penetration and illumination to the green inflorescences.

Humphreys (1979) found, in extremely wellgrown swards of *S. hamata* which had formed a closed canopy, that removal of 60% of the lamina at the advanced flowering stage increased final seed yield from 141 gm/m^2 in the undefoliated control to 170 gm/m^2. This increase was associated with the greater differentiation of late-formed inflorescences on the lower secondary branches and better development of the hookless lower articulated pods. This effect was also shown in a similar experiment with *S. hamata* by Girig (1977).

Hopkinson and Loch (1977) recommended that *S. guyanensis* should be defoliated not later than four weeks before floral initiation and not more than about 40% of top growth should be removed to allow a maximum shoot density to be developed by the floral initiation stage.

Humphreys (1981) suggested that defoliated plants show an increased capacity to compensate for the production of inflorescence density on the primary branch through increased secondary and tertiary branching and total inflorescence in defoliated swards. Recovery from grazing was more rapid in treatments where axillary buds were left intact. For example, *S. humilis* develops a low branching habit under repeated defoliation which still enables inflorescences to form under repeated grazing or cutting. In 1980 Wilaipon and Humphreys carried out another experiment in Thailand on the influence of grazing on the seed production of *S. hamata* cv. Verano. They reported that grazing in the period two to three months after the opening rains (July-August) may not affect seed production, but grazing later is likely to reduce seed yield. Humphreys (1981) also found that defoliation can reduce floret differentiation and cause poorer seed set and decreased seed size of *S. hamata*. The severity of these effects depends upon the timing of defoliation. *S. humilis* and *S. hamata* are also able to compensate seed yield in some circumstances where reproductive material is removed. Humphreys (1981) has stated that defoliation, by improving the light environment to green inflorescences and associated leaves, may increase seed yield.

With many pasture legumes frequent cutting or grazing can also lead to an overall reduction in dry matter yield (Humphreys, 1981). Topark Ngarm (1977) found that in *S. hamata* under a four week cutting regime dry matter yield was significantly lower than under a six week cutting frequency.

Whether this effect was due to depletion of carbohydrate reserves or to a reduction in residual leaf area is not known but it is suggested that *S. hamata* is more reliant for regrowth on the leaf area remaining after defoliation rather than on its carbohydrate status. Regrowth after defoliation may be influenced by reserve substrate levels in the residual tissue, the residual leaf area, or the number of sites from which growth can take place (Shaw and Bryan, 1976). Compared with the reasonable volume of research work on the effects of defoliation or cutting on seed production in *Stylosanthes* spp. little work seems to have been carried out on Siratro. Light conditions within the sward are strongly influenced by the spatial arrangement of leaves. Some distinction between old and young leaves may be necessary since old leaves are less photosynthetically active than young leaves (Humphreys, 1975). Hopkinson (1977) found in an experiment with lucerne that partial defoliation always induced rejuvenation of photosynthetic rate in the remaining leaves. Humphreys (1975) mentioned that the accumulation of non-structural carbohydrate was also affected by defoliation. However, if a sward is defoliated often enough and severely enough, death will result. A certain minimum level of residual energy and sufficient levels of labile carbohydrate must be available after defoliation to ensure survival. After defoliation there is a fall in the TAC level in the root and stem bases.

Robertson (1975) reported that in Thailand Siratro is a promising pasture legume for marginal forest areas where grazing is not heavy. Stobbs (1977) also found that light to moderate grazing during establishment can be quite beneficial to the growth and competitive ability of Siratro. Similarly in terms of seed yield Tothill and Jones (1977) showed that heavy grazing will reduce seed yield in a drier environment. Jones and Jones (1978) found that increasing the frequency of cutting of Siratro consistently reduces seed yield. They also found that the rate of regrowth after cutting reflects the amount of effective residual photosynthetic material and the number of buds left behind on the indeterm-inate trailing stems. Repeated severe defoliation reduces the opportunity to build up a framework of stem and so yield is severely depressed.

Humphreys (1975) and Humphreys and Robinson (1966) suggested that root growth is most sensitive to heavy defoliation, followed by stem and inflorescence growth. Leaf growth is the least affected. From his literature review he found that with defoliation of *M. atropurpureum* substantially increased the distribution of nitrogen to shoot material and reduced the proportion in the roots.

Humphreys (1979) mentioned that tropical twining legumes like Siratro produce an excessive amount of leafy material which is difficult to handle in the harvester and shades developing pods. Such a situation can be avoided by earlier grazing. He suggested that in *Macroptilium atropurpureum* cv. Siratro, which has an indeterminate habit of growth, better synchronisation of flowering may be possible when further research has shown how the manipulation of defoliation, watering and fertiliser practice may lead to a more uniform shoot population which produces flowers at the same time. Besides the effects of defoliation on growth and seed production, there were also some experiments carried out to study the effect of grazing and cutting on legume nodulation. Whiteman and Lulham (1970) and Whiteman (1970) found that grazing and cutting cause a great reduction in nodule weight and yield in *Phaseolus atropurpureus* and *Desmodium uncinatum* . The evidence showed that changes in nodule weight induced by defoliation were related to a loss of parts of the original nodule population and initiation of new nodules. This indicates that defoliation-induced changes in nodulation in tropical legumes causes a reduction in legume N-fixation.

Gutteridge (1982) has found in Verano stylo that if grazing occurs once moisture stress becomes limiting restoration of floral sites is reduced and seed yield declines. In his studies in Thailand, he found that if the wet season was protracted, flowering could proceed after grazing had ceased. In such cases seed yields were satisfactory. Siratro on the other hand produced higher floral densities in drier years compared to wetter years. However, even in dry years Siratro appeared better able to utilise the period after grazing ceased for flowering and seed formation because of its greater tolerance to moisture stress.

Shelton (1976) found that the shortage of dry season feed constitutes one of the major problems for improved beef production in North-east Thailand. Several species of the genus Stylosanthes have been found to be well adapted in this region. While production from pastures in the wet season is good, dry season growth is negligible and cattle rapidly lose weight during the latter part of the dry season. It is unlikely that farmers can be educated to specifically reserve areas for dry season feeding.

Shelton and Wilaipon (1977) discussed ways of improving animal feed supply during the dry season in North-east Thailand, when cattle and buffalo are largely dependent on nutritionally poor rice stubble, by sowing a legume forage following the paddy rice harvest. Such a system would also be beneficial due to the accumulation of nitrogen which would be available for utilisation. Gutteridge (1978) suggested a method of improving the nutritive value of rice stubble as a dry season feed by growing a forage legume on the paddy walls during the rice growing season and allowing it to be grazed in conjunction with the rice stubble once the rice is harvested. Since grazing is restricted in paddy areas from the time of transplanting until the rice is harvested this period allows the legume time to establish and make substantial growth before it is first grazed. He suggested (Gutteridge, 1979), in an evaluation of forage legumes suitable for use on paddy walls, that Verano stylo appears to be of particular value as its yield is high, all plant material can be eaten by livestock and it sets seed before grazing and therefore regenerates easily in the following wet season. A similar finding has been noted by Wilaipon (1978).

3. WATER

3a. WATER RELATIONS IN PLANT GROWTH AND DEVELOPMENT

One of the most limiting factors for crop production is water (Hasiao *et al.*, 1976). It is an essential component of plant life, and comprises approximately 85 to 90% of total fresh weight in physiologically active herbaceous plants. When the water content in most species falls much below this level many physiological activities are impaired (Turner and Kramer, 1980). Slatyer (1967) has pointed out that water is a constituent of protoplasm, participates in many chemical reactions, maintains cell turgidity and provides a medium for the movement of dissolved substances in the xylem and phloem. In most regions of the world, water is usually the determining factor in maintaining high productivity of crop plants throughout the growing season. The natural rainfall distribution limits the amount of growth or number of crops that can be grown in a year (Simpson, 1981) and the efficient and economic use of water in agricultural practice is becoming a major factor in agricultural management. When available soil moisture declines internal water deficits develop in the plant and physiological processes decline. At the other extreme, surplus water or flooding can cause various degrees of anoxia in the root environment (Humphreys, 1981). In most crops, especially forage crops, flooding damage to plants is positively related to the duration of flood and the depth of submergence. Flooding restricts oxygen availability to the roots which reduces root respiration and the availability of energy for normal plant processes such as nutrient uptake. *Stylosanthes* spp. have a high drought tolerance but low tolerance to flood or waterlogging (Hare, 1980; Humphreys, 1981).

Most of the world pastures depend largely on rainfall for their source of water. Therefore, where rainfall is irregular water deficits develop which can severely limit productivity and persistence (Turner and Begg, 1978). Water stress is the state where the water supply is inadequate and inhibits plant growth (Crafts, 1968). When plants are subjected to stress survival mechanisms are activated. In some plants water stress may induce a state of dormancy or accelerate reproductive processes (Dougherty, 1973).

As available soil moisture declines internal water deficits develop in the plant leading to loss of turgor. This continues until the plant reaches a state of permanent wilting when sufficient moisture can no longer be extracted from the soil to maintain turgor. In the field, water deficits usually build up more slowly, and roots exploit a greater volume of water, and photosynthesis continues at its full potential up to water deficits as low as -19 bars compared with a figure in controlled environment rooms of only -12 bars. Further leaf appearance and expansion ceases and with continued water deficits leaves begin to die (Ludlow, 1976). Water stress reduces crop growth rate, the length of the growing season and total yield (Dougherty, 1973). Although plants that survive throughout water deficits are often called drought resistant plants they may in fact be exhibiting two other characteristics, drought tolerance or drought avoidance (Levitt, 1980).

Drought tolerance defines the ability of plant cells to survive periods of water deficit. This ability is best developed in young meristematic tissues. Survival of meristematic tissues can be related to the redistribution of water and nutrients to maintain turgor in the meristem (Gwynne, 1960). Many plants have developed mechanisms to reduce or avoid water loss during dry periods. Avoidance of water stress can also be achieved by plants completing their life cycle before a serious plant water deficit develops (Ludlow, 1976). Jones *et al.* (1981) found that some plants have the ability to endure periods of rainfall deficit while maintaining a high internal plant water status. These mechanisms do not avoid drought but avoid tissue dehydration. In order to do this plants must either restrict their water loss or maintain their water supply. For maintaining the water supply, Fischer and Turner (1978) mentioned that roots must go deeper when low root densities prevail, or root density must be increased. The site of water loss is also the site of carbon uptake by the plant so that a reduction in water loss results in a reduction in assimilation. In maintaining the internal water balance of the plant the stomata must close firmly and water loss through the cuticle must be low (Turner and Jones, 1980).

3b. MORPHOLOGICAL EFFECTS OF WATER DEFICITS

The growth and development of a plant depends on continuing division, differentiation and enlargement of cells (Slatyer, 1963). Cell division is generally regarded as less sensitive to water deficits than cell enlargement (Salter and Goode, 1967; Slatyer, 1967). Perry and Larson (1974) showed in *Medicago sativa* that the reduction of soil water to 50% of field capacity reduced both the number of primary shoots and the regrowth of shoots after defoliation. Turner and Begg (1978) found that in pasture plants morphological responses are more sensitive to water deficit than physiological processes. Dougherty (1973) mentioned that water stress generally reduces the size of individual plant organs. The actual reduction in size depends on the intensity and duration of the stress as well as the developmental stage of the plant at the time of stress. Water cannot affect the size of organs which have already reached their final size except by senescence and death.

3c. EFFECT OF WATER ON DIFFERENT STAGES OF GROWTH

Salter and Goode (1967) mentioned the three stages of growth that might be affected by water; the period from sowing until the start of flowering, the period during flowering and the period during seed development until harvest. They cited work by Frohlich and Henkel on peas which showed that a plentiful supply of water during the early period of growth produced high vegetative yield but not high pod yield, and also found by Salter (1962). Humphreys (1979) mentioned that Siratro produced high seed yields under alternate wet and dry conditions. Fisher and Campbell (1977) found in *Stylosanthes humilis* that stress during the vegetative stage reduced growth.

Shaw and Laing (1966) have shown in soybean that stress during the flowering period results in a significant reduction in the number of pods. This effect on pod number is due to flower abortion during the main flowering period and pod abortion during the period of pod growth after flowering. Water stress also interferes with the pod filling process.

Water stress has two primary effects on reproductive development. It generally advances the rate of conversion from the vegetative to the reproductive state and it reduces the size and number of reproductive organs on each plant (Dougherty, 1973). There is evidence that the time of floral initiation is very sensitive to water deficit but that fruit and seed development are less markedly affected (Begg and Turner, 1976). They also found that peas are sensitive to stress at flowering, but that pod development is more sensitive than vegetative growth. Water deficits can also influence the length of the reproductive growth and development period in indeterminate crops.

There are numerous reports which show that water deficits limit yield and irrigation increases yield. The degree of yield reduction by a water deficit depends on the degree, duration and timing of the deficit and on the proportion of total yield that comprises the economic yield of the crop (Begg and Turner, 1976). Anderson and White (1974) found that in green peas, lack of irrigation reduced total yield by 47% but the yield of seed peas by only 36%. These results show that water deficits occurring at critical stages of plant development of a determinate crop will reduce the economic yield less than total above-ground dry matter yield.

The importance of a water deficit on yield also depends on whether the economic yield is based on the fresh or dry weight component of yield. In fruit and vegetables which are sold on the basis of fresh weight or size, a water deficit will have a greater effect since the size and weight at this stage depends more on the plant water potential than on photosynthesis (Davenport *et al.*, 1977).

Water deficits influence not only economic yield but also quality such as decreases in the quality of malting barley and sunflower oil (Begg and Turner, 1976).

Kettan and Flemming (1956) found in snap beans that irrigation during flowering resulted in higher yields and larger pods, while Andrew *et al.* (1977) found that if water stress occurred throughout the flowering period seed yields were reduced by 80% in subterranean clover.

Fisher and Campbell (1977) found in their drought treatments on *Stylosanthes humilis* that water stress during flowering significantly reduced seed yield. A similar effect was found in Siratro (*Macroptilium atropurpureum*) by Hopkinson (1977). Humphreys (1979) also comments that short periods of drought stress early in the flowering period, followed by good moisture availability during late flowering, gives more flowers. This system works well for Siratro and Stylo because seed is easier to harvest if irrigation is withheld during seed maturation.

3d. PLANT ADAPTATION TO WATER STRESS

Plants require adaptation in structure and function to survive water stress. Such an adaptation can be described as heritable modifications in structure or function that increase the probability of an organism surviving and reproducing in a particular environment. The ability of a crop variety or species to grow satisfactorily in areas subjected to periodic water deficits has been termed drought resistance (Kramer, 1980). Plants have developed both morphological and physiological mechanisms to enable them to withstand and adapt to water deficits (Dougherty, 1973).

Leaves and roots are considered to be the most morphologically adaptable plant organs in their reaction to water stress (Levitt, 1980).

According to Begg and Turner (1976), since cell expansion and cell division are sensitive to water stress both will have a marked effect on leaf area. Since the rate of evapotranspiration is determined by leaf area, any reduction of leaf expansion can provide a mechanism for reducing water loss from the soil and delaying development of more severe stress. Leaf shedding or accelerated leaf death is also an adaptive mechanism for reducing water use.

Mechanisms of greater benefit to forage species are the movement of leaves resulting in their orientation parallel to the incident radiation. The flagging or rolling of leaves when wilted are additional adaptive mechanisms. In grasses, leaf rolling is a common response to moisture stress. *Stylosanthes humilis* exhibits both diaphotonastic and parahelionastic movement depending on the degree of water stress (Begg and Torssell, 1974, 1978). Leaf movement has also been identified in stressed bean (Dubetz, 1969). Turner and Begg (1978) also found other mechanisms that reduce the radiation load such as increased leaf hairiness and wax bloom. They also mentioned that in pasture plants morphological responses are more sensitive to water deficits than physiological processes.

Adaptation to drought has developed in roots as in leaves and stems. Since water is the major limiting factor for plant growth in arid areas it can be expected that root systems develop in a way that ensures optimum water absorption (Kummerow, 1980).

Fischer and Turner (1978) found that under water stress conditions plant roots must go deeper to maintain water uptake. A deep root system would seem best in a climatic region in which the soil is recharged with water to considerable depths during the winter and rains during the growing season are infrequent (Wieb, 1980). Jordan and Miller (1980) also mentioned that a crop planted near the end of the wet period must be capable of achieving final production on stored soil moisture only. Torssell *et al.* (1968) found in Townsville lucerne that the plant has the ability to continue exploring a greater depth of soil enabling it to grow and complete its life cycle even if the wet season is finished. Hurd (1968, 1976), also found that deeper rooting varieties yielded better under drought stress. Andrew and Jones (1978) cited work by McCown who found that Stylosanthes species (*S. hamata*, *S. scabra* and *S. viscosa*) growing on sandy red earth soils in the Northern Territory of Australia can extract water from a soil depth of at least 300 cm by the end of the dry season. Henzell (1976) found that legumes show a number of adaptive features that enable them to survive water deficits caused by lack of rainfall and are intensified by competition. Many legumes are capable of drawing water from considerable depths. He found the *M. sativa* for example can obtain water from a soil depth of 6 metres. Taylor (1980) also found that the roots of cotton and soybean cultivars can extend as deep as the soil profile is wetted.

Passioura (1976) stated that one major effect of water deficits is in the increased development of the root system which enables the plant to explore a greater soil volume for water. By comparison shoot growth is greatly restricted under similar conditions.

t'Mannetje *et al.* (1980) and Burt *et al.* (1980) found that the perennial legumes such as *Medicago sativa*, *Stylosanthes scabra* and *Macroptilium atropurpureum* are drought resistant plants which adapt by developing a deep root system which enables them to obtain water from lower down in the soil profile.

3e. PHYSIOLOGICAL ADAPTATION TO WATER STRESS

The main physiological effects of a water deficit on crop plant growth and development are in stomatal behaviour, photosynthesis, respiration, translocation and the partitioning of assimilates. Recent discoveries have found that endogenous levels of abscisic acid and proline increase several-fold when plants are subjected to stress and that abscissic acid closes stomata and reduces transpiration (Begg and Turner, 1976).

As soil moisture declines and internal water stress develops, the stomata begin to close and transpiration decreases. Stomata respond directly to humidity in a feed-forward manner, local water deficits develop in the stomatal apparatus inducing stomatal closure before deficits occur in the remainder of the leaf. For the adaptation of the stomata to water stress, the stomatal responses are modified to suit the new situation of water stress which is adjusted to humidity, and leaf water potential. These adjustments are variable among species. The capacity for stomatal adjustment seems to be associated more with the environment to which plants have adapted than with any taxonomic or morphological characters (Ludlow, 1980). Turner and Jones (1980) also found that stomatal closure in response to stress is a powerful mechanism for regulating water loss and reducing the development of further stress. Levitt (1972) found that stomata open during daylight only for a short time in the early morning and they are able to close very rapidly in order to conserve their internal water supply. Turner (1974) found that stomatal closure can also be very different in growth cabinets compared with field studies. In particular, differences in irradiance and the unrestricted soil volume in the field into which the roots may grow can be important. Ludlaw and Ng (1976) have shown that stomatal closure causing net photosynthesis to cease occurs at leaf water potentials of -12 bars in controlled environments. In the field however where water deficits usually build up more slowly, and where roots exploit a greater soil volume for water, photosynthesis continues at the potential rate at least to a leaf water potential below -19 bars. Humphreys (1981) found that Siratro is a successful drought-avoiding plant in which leaf water potential rarely decreases to -20 bars. This 'feedback' mechanism of Siratro is a superior tool to the usual mechanism of stomatal closure in response to decreasing leaf water potential. Stomatal closure is a primary cause of depressed photosynthesis under water limiting conditions. Begg and Turner (1976) found that the initial reduction in photosynthesis due to an increase in moisture stress in both soil and plant is caused through the closure of the stomata and reduced CO_2 content in the plant. Whiteman (1974) also found that moisture stress reduces growth by reducing photosynthesis rate and also reduces the rate of leaf area development.

3f. WATER RELATIONS IN TROPICAL FORAGE CROPS

Much evidence suggests that in pasture plants the morphological responses such as leaf area development, tillering and root growth are more sensitive to water deficits than physiological processes (Turner and Begg, 1978). Some of the leguminous forage crops have very deep root systems. Many legumes can recover quickly after drought because they have an indeterminate branching pattern and the meristem can survive longer. This indeterminate branching pattern together with the protected apex, provides a useful strategy for plant survival in climates with uncertain rainfall. If a plant is rewetted after a period of drought the terminal meristem can start to grow again forming new leaves and flowers and eventually more seeds (Elston and Bunting, 1979). Torssell (1976) found that in *S. humilis* the plant is capable of avoiding and tolerating short term stress during the growing season. It germinates rapidly, grows quickly, and both flowers and seeds before the water supply is exhausted. Ludlow (1980) has found that Siratro has a low water stress tolerance and that the plant depends mainly on water stress avoidance for survival. Siratro shows various mechanisms of water stress avoidance by increased rooting capacity, deep rooting which allows the extraction of water to a greater depth, sensitive stomatal control, leaf movement and leaf area reduction. Gutteridge (1982) found from his studies at Khon Kaen in Thailand that under field conditions Siratro roots appear to penetrate to great depths which he traced to 180,200 and 210 cm by the end of the dry season. However he found it difficult to trace Verano stylo roots because of their more fibrous character, but he did detect Verano roots at a depth greater than 75 cm. Hopkinson (1977) found that in Siratro moisture stress may suppress vegetative growth but favour the subsequent expansion of floral buds and the distribution of assimilates to developing inflorescences. The plants show dominantly vegetative buds in the summer wet season and predominantly floral buds in the dry season. Fisher and Campbell (1977) found that in *S. humilis* swards flower appearance develops as a result of moisture stress. Humphreys (1981) found that stressed legumes react by exhibiting premature senescence, shedding and delayed initiation of nodules. Peake *et al.* (1975) also found that Siratro responds to water stress by premature senescence of most of its leaves. Fisher and Ludlow (1976) found that Siratro grown under water stress has smaller, thicker and more rigid leaves than the normal leaves of plants growing under non-stressed conditions.

Drought tolerance in tropical pasture plants has attracted little research interest (Humphreys, 1981). Levitt (1972) showed that the maintenance of Relative Water Content (RWC) at low Leaf Water Potential (LWP) indicates drought tolerance. In Siratro rapid loss in RWC as LWP decreases to -10 bars indicates poor drought tolerance. Subsequently however there may be a slowly increasing resistance to loss of water, which suggests a progressive adaptation of surviving leaves to water stress. Turner and Begg (1978) conclude that at the cellular level an explanation of these types of relationships between LWP and RWC in tropical species is not yet available. They also suggest that acclimatisation to water stress by tropical pasture plants occurs to some extent. For example there may be an increased allocation of carbon to root growth to help maintain water uptake. Ludlow (1980) suggested that plants may acclimatise to water stress by improving turgor and hence metabolic activity for expansion growth.

4. SEED CROP DEVELOPMENT

Seed production is the final stage of a sequence of plant processes, some of which can be more easily controlled by the grower than others. The potential yield of the crop is limited by the density of flowers produced. This depends on the degree of plant branching to form shoots which is very sensitive to moisture and nutrient supply. Subsequently the proportion of the surviving shoots which are fertile, and the extent of inflorescence differentiation to form flowers are major determinants of seed yield (Humphreys, 1978).

Pasture development in tropical regions is dependent upon adequate supplies of reliable seed. Many tropical forage species are relatively wild plants. Too often plant breeders and agronomists have concentrated on improving vegetative growth and forage nutritive value and have given comparatively little attention to the ease of seed production. Seed recovery of many tropical pasture seed crops is also very low, since flowering proceeds over a long period. In addition, seeds of many crops fall to the ground soon after they ripen. Thus only a small proportion of the seed produced may be recoverable by harvest at any one time (Humphreys, 1979).

Many of the problems of seed production from tropical pasture species are due to inherent characteristics of the species that create difficulties in harvesting with resultant low yield of harvested seed (Jones and Roe, 1976). Hopkinson and Loch (1973) found that some perennial tropical legumes are determinate in habit and flower production is relatively concentrated e.g. *Desmodium sandwicense*, *D. intortum* and *Glycine wightii*. Conversely *Macroptilium atropurpureum* cv. Siratro flowers throughout much of the year in the subtropics. Its indeterminate growth habit results in a succession of flower heads along the stolons which ripen sequentially or shed their flowers under the shade of dense new vegetative growth. Seed production is prolonged and therefore little seed is ripe at any one time (Hopkinson and Loch, 1973).

This effect has also been described by Humphreys (1978) who found that many tropical pasture seed crops have poor synchronisation of maturity and that inflorescences may be produced almost continuously during the growing season in swards of *Macroptilium atropurpureum* cv. Siratro and *Lotononis bainesii*.

The low numbers of seed heads produced is also one of the main problems. The variable of inflorescence density of tropical legumes is also the main problem which varies widely from 36/m^2 (Edey and Byth, 1970) to 300/m^2 (Hopkinson and Loch, 1973) for Siratro, and 20-65/m^2 (Nicholls *et al.*, 1973) to $1021/m^2$ (Gibson and Humphreys, 1973) for *Desmodium uncinatum* cv. Silverleaf.

Tropical forage legumes are also very susceptible to weather conditions during seed set. Flower opening in many plants requires sunshine, low seed set occurring as a result of dull weather (Humphreys, 1978).

The weather the crop receives is a primary determinant of yield and unlike the nutrient and moisture supply, may only be marginally modified by the grower. Humphreys (1978) mentioned that the ideal seed production climate must have suitable radiation, temperature and rainfall for vegetative growth of the particular crop, a favourable photoperiod for floral induction, and dry, relatively still weather during seed maturation. Many tropical forage plants e.g. *Macroptilium atropurpureum* are in a climatically inductive flowering condition for most of the year.

The effect of temperature on the growth of tropical pasture species may be analysed in relation to effects on the rate of increase in dry matter, leaf area, tiller development, shoot development, and the rate of appearance of new leaves (Whiteman, 1974).

High temperatures in the range 38°-45°C can be expected to reduce the growth rate of legumes, although *S. humilis* and *S. hamata* have been shown to be better adapted to these conditions than most other sown species (Whiteman, 1974).

Ludlow and Wilson (1970) found that rate of leaf area development in both grasses and legumes is markedly affected by temperature. Temperature conditions may affect vegetative growth of the crop, floral initiation, growth and differentiation of the inflorescence, blooming, pollen germination, seed setting and seed maturation (Humphreys, 1978). Cameron (1967b) suggested that a night temperature of 28°C was adverse in *Stylosanthes humilis*, the effect being greater at a critical day length.

A regime of $35^{o}/30^{o}C$ day/night temperature prevents flowering in *Stylosanthes guyanensis* and *S. hamata* (t'Mannetje 1965). Downes *et al.* (1967) also found similar results in six strains of *S. humilis*. Skerman and Humphreys (1973) found that both the number of inflorescences and the number of florets differentiated on individual inflorescences in *S. humilis* cv. Greenvale was positively related to temperature. The speed of inflorescence development is increased by warm days and in one field experiment the duration of the period from floral initiation to flower appearance was shortened by 3.3 days in *S. guyanensis* for each $1^{o}C$ rise in maximum day temperature (Bryant and Humphreys, 1976). McWilliam (1978) mentioned that tropical legumes have a slightly lower optimum temperature than tropical grasses. The optimum temperature for the induction of flowering in pasture plants varies depending on the photoperiod response. However once induction has occurred, increased temperature hastens the onset of flowering in both short- and long-day plants e.g. *Macroptilium atropurpureum*. He also found in Siratro that increasing day/night temperatures from $24^{o}C/19^{o}C$ to $30^{o}C/25^{o}C$ advanced the onset of flowering by 17 days.

Floret numbers per inflorescence reach a maximum at $27^{o}C/20^{o}C$ in *Stylosanthes hamata* cv. Verano. The percentage of florets forming seeds is reduced as temperature decreases. Cool temperatures also restrict the formation of impermeable layers in seeds of *Stylosanthes hamata*. One month after harvest percent hardseededness of hooked seeds was 99, 99, 97 and 30 in plants flowering in temperatures of $35^{o}C/28^{o}C$, $31^{o}C/24^{o}C$, $27^{o}C/20^{o}C$ and $20^{o}C/16^{o}C$ respectively (Argel and Humphreys, 1977). This suggests that high temperatures and possible speed of dehydration are major determinants of the level of hardseededness in this species.

Whiteman (1974) found that when temperature was reduced from $32^{o}/24^{o}C$ to $26^{o}/15^{o}C$ growth was reduced about 35% in *M. atropurpureum*, *G. wightii*, *S. humilis* and *S. guyanensis*.

In a wide range of pasture plants the change from vegetative growth to reproductive development is induced by changes in day length. This response is perceived in the leaves of the plants, which transmit a floral stimulus to the vegetative meristem to cause a change to reproductive development (Whiteman, 1974). Garner and Allard (1923) divided plants into three groups, short-day, long-day and day-neutral. For the tropical forage legume t'Mannetje (1965) also grouped the genus Stylosanthes into three: *S. humilis*, and *S. guyanensis* responded as short-day plants with *S. hamata* and *S. montividensis* as long-day plants. The response of plants to photoperiod often determines whether they will flower at a given latitude and at what time of the year. A knowledge of this response is therefore of great importance for seed production (Whiteman, 1974). Cameron (1967a) found that *S. humilis* cv. Gordon is a qualitative short-day plant. By planting in the growth cabinet using different day lengths all selections of *S. humilis* flowered at a similar node number irrespective of photoperiod. In his subsequent experiment he found that this flowering response seemed to be closely related to changes in daylength but bore little relation to temperature changes (Cameron, 1967b). Bryant and Humphreys (1976) found that a number of selections of *S. guyanensis* showed a short-day flowering response, which was not related to latitude or altitude of selection origin.

Imrie (1973) found that Siratro reacts as a short-day plant with a critical maximum day length above 12 hours. Low temperature, although it tends to delay flowering, does not alter the basic short-day response.

Whiteman (1974) found that Siratro plants, if given a night-light break treatment, remained vegetative up to 180 days, suggesting that it is a quantitative short-day species. For many cultivars day length decides whether flowering will occur or not and also determines the strength of the flowering response (Humphreys, 1978). The main effect of day length is on flowering. Since Humphreys (1978) concluded that many tropical forage plants are in climatically inductive flowering conditions for most of the year, climatic variation may inhibit quantitative flowering but plants will produce flowers whenever shoots are large and old enough.

There is indirect evidence of variation in juvenility in *Stylosanthes* spp. which suggests that *S. humilis* may flower at the six node stage or earlier (Skerman and Humphreys, 1975). *S. hamata* however does not seem to show a juvenile stage and has been shown to flower within 1 month of sowing (Cameron and t'Mannetje, 1977). The rate of inflorescence appearance seems to be limited by the number of bud sites available for inflorescence occupation and is not well correlated with temperature (Skerman, 1973). This suggests that the agronomic value of a legume depends strongly on its growth, most of which is made before the plant is fully committed to its reproductive cycle (Cameron and t'Mannetje, 1977).

5. CROP HUSBANDRY FOR SEED PRODUCTION

The area chosen for seed production would ideally be in climatic zones where a dry season coincides with seed ripening. Most tropical forage legume species are apomictic or self-pollinating and therefore do not require isolation (Jones and Roe, 1976). Thorough seed bed preparation to kill existing vegetation is essential. The area will require harrowing and possibly rolling to prepare a fine, firm seed bed before planting. Some levelling of the site may be necessary, especially if suction harvesting is contemplated or the crop needs to be irrigated (Jones and Roe, 1976; Humphreys, 1979; Hare, 1980). Humphreys (1979) found that if ground seed recovery is to be employed, such as is used in harvesting *S. humilis* or *M. atropurpureum*, level land is an advantage. Most pasture seed crops are high value crops, which benefit from being grown on good agricultural soil. The fertiliser practice which gives good vegetative growth of tropical pastures will usually give high seed yields. Although the normal fertiliser requirement is for phosphorus, potassium and sulphur, Humphreys (1979) has suggested that special attention may need to be given to boron and copper levels, because he believes these nutrients have a role in promoting seed production.

There have been many experiments to study the effect of nutrients on the growth and yield of tropical forage legumes. Moore (1965) studied the influence of fertilisation and cutting on tropical grass-legume pastures. The experiment involved NPK fertilisation, and height and frequency of cutting. He found that nitrogen fertiliser application to sown pastures is unlikely to be an economic practice. Yield response resulting from superphosphate application was about 30%, although there was no response to potassium. Shaw *et al.* (1966) and Jones (1968) studied the effect of superphosphate and potassium fertiliser on the growth of *Stylosanthes humilis.* The results showed that superphosphate increased dry matter yield. Andrew and Robins (1969) studied the effects of potassium on the growth of some tropical legumes. The results showed that the optimum level of potassium chloride added for most species will increase yield and maximum growth. They also found in a subsequent experiment that phosphorus also affected growth of *Phaseolus atropurpureus* and *Stylosanthes humilis.* Wood and Dance (1970) also showed that Townsville stylo responded to applied superphosphate but not to nitrogen. Shelton and Humphreys (1971) have suggested similar effects and shown in seed production studies with *Stylosanthes humilis* that phosphate increased yields of plant top by 54% and seed yield by 20%. Robinson and Jones (1972) found that phosphorus and sulphur deficiency caused about 3 weeks delay in flowering of Townsville stylo and White (1972) recorded a similar response in *Stylosanthes humilis*, *Phaseolus atropurpureus* and *Desmodium intortum.*

Weed-free sites should be chosen for seed production. Weeds which compete with the growing crop reduce its seed yield, the worst weeds being those which produce seed that cannot be easily separated from harvested crop seed (Humphreys, 1979; Hare, 1980). Hand removal is a recommended weed control method for tropical legumes since it may be more effective and selective than chemical measures in countries where rural labour is abundant (Humphreys, 1979). Rotary cutting before the weeds flower may also be a good method of reducing their competitive position. If chemical control is needed pre-plant herbicides should be applied. Fisher and Ive (1970) used dalapon, chlorthal and trifluralin applied to *Stylosanthes humilis* before or after planting irrigation. *S. humilis* emergence was unaffected by herbicide applied 14 days before irrigation and growth was improved. Humphreys (1979) concluded that the recommendations for weed control in established crops can be formulated more precisely than pre-plant recommendations. Care should be taken by the seed production agronomist and weed scientist to determine the tolerances of tropical cultivars.

In general, legumes are more prone to insect and disease problems than grasses. Insects attacking the leaves, flower and pods can completely destroy legume seed crops (Jones and Roe, 1976). In addition some crops, such as Siratro, can be badly affected by *Rhizoctonia solani* in the very humid tropics. In controlling pests and diseases genetic resistance to or tolerance of disease and pest attack is ideally the first factor sought. In practice however, there are advantages in sowing disease-free and insect-free seed. Chemical treatment of the growing crop should take into account the role of beneficial insects such as bees for pollination. To prevent reduction in beneficial insect populations insecticides may be applied at night or in the late afternoon when bee activity is minimal (Humphreys, 1979).

Particularly in dry season plantings irrigation may make production possible. Normal irrigation practices during establishment and during the period of vegetative growth terminating at floral initiation seem particularly beneficial. *Macroptilium atropurpureum* cv. Siratro however has been shown to produce more seed under a restricted intermittent watering regime suggesting that while irrigation is beneficial, excessive and frequent watering may be detrimental to seed production. Water stress in fact has been found to favour flower development of Siratro (Humphreys, 1979).

Hopkinson (1977) noted that if the water regime of Siratro plants was maintained near field capacity, the primary axillary buds may remain either vegetative or be only minimally reproductive.

Harvested seed yields of tropical pasture species are generally low. Most tropical legumes have a progressive development of vegetative growth along with reproductive growth so seeds will not all ripen at the same time. This inherent characteristic of the species creates difficulties in harvesting with resultant low yields of harvested seed (Jones and Roe, 1976; Humphreys, 1978).

It is very important to harvest a crop at the correct time in order to obtain maximum yields of high quality seed and to minimise seed losses through shedding. Humphreys (1979) stated that judging the correct harvesting time for tropical pasture seed crops is very difficult. Even estimating the time when maximum yield of viable seed occurs is not entirely satisfactory. Griffiths *et al.* (1967) considered criteria based on seed size, moisture content, endosperm consistency, viability, biochemical changes and abscission, for judging the correct time for harvest of temperate pasture species. Humphreys (1979) mentioned that the desirable harvest time for *Macroptilium atropurpureum* occurs when the upper surface of the majority of the pods show some brown colouration. The most obvious biochemical changes during maturity occur in the pigments of the seed coat or testa and its outer coverings. Schwass (1973) stated that the optimum time to harvest a crop is largely a matter of experience. The timing of harvest is likely to be most accurately determined by measurement of changes in seed moisture content. However, information about the correct time of harvesting tropical forage legumes is still comparatively limited.

The use of successive hand harvesting methods which involve picking the ripe or nearly ripe pods of legumes tends to overcome both the problems of spread of flowering and shedding. Such a technique has the added advantage of producing high quality seed that requires a minimum of post-harvest handling and also gives a more accurate seed yield of the particular cultivar (de Boer *et al.*, 1976). Combination forage harvester and rotating cylinder harvesters can also be used successfully. This process yields best results when as many seeds as possible remain in the seed head. Harvesting by this method therefore needs to be carried out as soon as the seeds are mature but before they begin to drop (Humphreys, 1979).

In Siratro and Stylo crops, suction harvesting can be used with considerable success because large amounts of fallen seed can accumulate on the soil surface. Hopkinson and Loch (1973) studied the improvement of seed recovery and yield in Siratro using a suction harvesting system. They found that the method was successful simply because greater quantities of seed are likely to be found on the ground than in the standing crop for most of the lifetime of a stand of Siratro. Combine harvesting of Siratro has served as the standard method of seed harvesting. However, results indicate that at best, the operation recovers only about 20% of the available seed. Results also show a reduction of hardseededness in crops harvested by combine. Hopkinson and Vicary (1974) found that suction harvesting increased yield substantially, but that there is a high recovery cost in using such a method because of the need for extensive cleaning of the seed after harvest. Loch *et al.* (1976) studied the effect of preharvest desiccant spraying on seed harvesting of *S. guyanensis*. They found that pre-harvest desiccation made combine harvesting easier. Wickham (pers. comm.) studied the effectiveness of harvesting pasture seed crops in Thailand using two types of seed harvesting and cleaning methods in *S. humilis* and *S. hamata* i.e. hand harvesting compared with combine harvester and rotating cylinder. She found that hand harvested seed had a purity of up to 99%. However, the combination forage harvester and rotating cylinder method yielded best results when harvesting was timed to coincide with the point when as many seeds as possible remained in the seed head. By comparing hand and machine harvesting seed yield obtained from hand harvesting was 600 kg/ha and vacuum harvesting was 280 kg/ha (Hare and Waranyuwat, 1980).

The important thing in using machinery for harvesting seeds of tropical pasture species is the high degree of operator skill required to achieve the highest possible seed recovery. Machines often need modification because they have not been designed specifically for use with tropical species.

CHAPTER 2

FIELD TRIALS

EFFECTS OF IRRIGATION AND CUTTING ON SEED PRODUCTION OF *STYLOSANTHES HAMATA* CV VERANO AND *MACROPTILIUM ATROPURPUREUM* CV SIRATRO

MATERIALS AND METHODS

Two tropical forage legumes, namely *Stylosanthes hamata* cv Verano and *Macroptilium atropurpureum* cv Siratro were used in this experiment. A supply of certified seed of these two species and a quantity of cowpea-type rhizobium inoculum were obtained from Australia. Field plantings were made in the dry season (August, 1979) and in the wet season (May, 1980).

A. EXPERIMENTAL SITE AND LAND PREPARATION

This experiment was conducted at the Khon Kaen University Experimental Farm, in the North-east region of Thailand. The site was a free-draining upland sandy loam soil of the Yasothon series. One hectare (7 rai) of land was thoroughly cultivated, and a good seed bed prepared (Plate 1).

B. PLOTS SIZE AND EXPERIMENTAL DESIGN

The area of the plots sown with each species was different, depending on the spacing between plants. For Verano it was 1.5 m x 11.5 m plots with 25 cm x 25 cm spacing between plants, compared with 3.0 m x 23.0 m plots with 50 cm x 50 cm spacing between plants for Siratro. The layout of the experiment included 2 irrigation treatments as split blocks with 5 cutting treatments allocated at random within blocks and 3 block replicates. The spacing between plots was 2 m with a 15 m space between irrigated and non-irrigated blocks in the dry season planting. There was no applied water treatment in the wet season planting (Figure 1).

Plate 1   Well prepared seed bed.

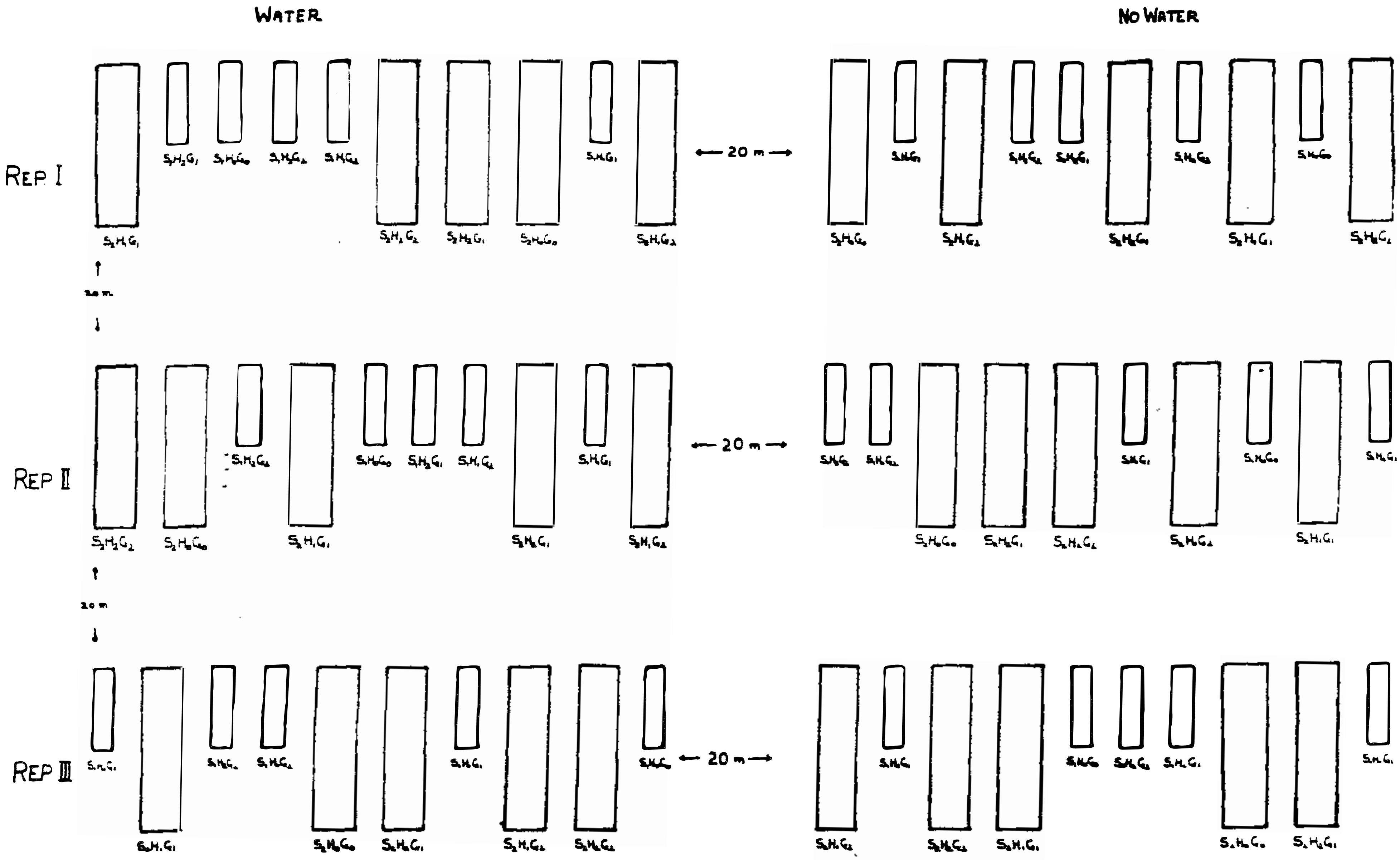
S_1 = Verano stylo

S_2 = Siratro

H_0G_0 = Co; H_1G_1 = ¼VG; H_2G_1 = ½VG

H_1G_2 = ¼FI; H_2G_2 = ½FI

Figure 1 EXPERIMENTAL LAYOUT FOR CUTTING AND IRRIGATION OF THE FIELD TRIAL IN THE DRY SEASON



C. SEED PREPARATION

Both forage legumes contain hard seeds so scarification of seed was necessary. Verano seeds were scarified by rubbing them on No. 2 sandpaper and then soaking in hot water at 80°C for 10 minutes before sowing. Siratro seeds were also scarified by using No. 2 sandpaper until some of the seed coat was rubbed off. The seeds of both species were then inoculated using cowpea-type rhizobium before sowing.

D. FERTILISER

Double superphosphate and gypsum at the rate of 110 kg/ha and potassium chloride at the rate of 50 kg/ha were used at each planting of both Verano and Siratro. The fertilisers were evenly broadcast over each plot and subsequently harrowed in to ensure an adequate mix of fertiliser and soil.

E. SOWING

For the dry season planting on 20 August, 1979, Verano seeds were sown by hand at a spacing of 25 cm x 25 cm using 3-5 seeds/hole. Seeds were sown about 2 cm deep. Siratro seeds were sown at a spacing of 50 cm x 50 cm using 3-5 seeds/hole. Depth of sowing was about 3 cm.

For the wet season planting in May, 1980 Siratro seeds were again sown as stated above. With Verano, in order to obtain a more even and uniform stand, seeds were sown in 4 cm diameter plastic bags and transferred to the plots as 3 week-old seedlings at a spacing of 25 cm x 25 cm (Plate 2).

F. SEEDLING EMERGENCE

Most Siratro seedlings emerged about 4-5 days after sowing. When the seedlings were about 10 cm above ground level with 2-3 true leaves they were thinned to one plant per hole. Verano seedlings emerged about 3 weeks after sowing. When the seedlings were about 5 cm above ground level with 2-3 true leaves they were also thinned to one plant per hole.

Plate 2 Sowing the seeds.

G. WEEDING

Weeds were removed from the site during the growing season by hand-weeding within the plots, and by a tractor-mounted rotary hoe between plots.

H. INSECT CONTROL

The plots were sprayed at approximately 7 day intervals during the growing season to control insects. If there was any sign of insects appearing in the plots the insecticide was applied more often at about 3-4 day intervals. Azodrin was used to control *Aphis* spp. and Blister beetle (*Miloidae* spp.) in both species. Ripcord was used to control Pod Borer (*Bruchus* spp.) which attacks the pod from flowering to seed maturity.

I. CUTTING TREATMENTS

There were 5 cutting treatments according to stage of growth and cutting height, viz.

Stage of Growth

1. Vegetative cut - when Verano had 5-6 primary branches (approximately 55 days after sowing)
   - when Siratro had 5-6 true leaves (approximately 45 days after sowing)

2. Floral Initiation cut - when 30-50% of Verano plants showed floral bud formation (approximately 67 days after sowing)
   - when 30-50% of Siratro plants showed floral bud formation (approximately 56 days after sowing)

<u>Cutting Height</u>

1. Both Verano and Siratro plants were cut to remove ¼ of the plants' canopy height
2. Both Verano and Siratro plants were cut to remove ½ of the plants' canopy height

<u>Control</u> Uncut (Co)

The 5 cutting treatments applied to each species can therefore be listed as follows:

1. Control uncut (Co) Plates 3 a,b, and 4 a,b.
2. Plants cut at vegetative growth stage to remove ¼ of plants' canopy height (¼VG) Plates 3a, 4a.
3. Plants cut at vegetative growth stage to remove ½ of plants' canopy height (½VG) Plates 3a, 4a.
4. Plants cut at floral initiation growth stage to remove ¼ of plants' canopy height (¼FI) Plates 3b, 4b.
5. Plants cut at floral initiation growth stage to remove ½ of plants' canopy height (½FI) Plates 3b, 4b.

Scissors were used to cut the plants following lifting of the entire plant canopy. After cutting, plants in all plots were allowed to seed and were harvested at different harvesting times.

J. IRRIGATION

Immediately after sowing 30 two-gallon tins were buried to ground level at different sites in the experimental field, each with a ruler glued to the inside of the tin to allow measurement of water level. The tins were then filled with water to the top of the ruler. The water level was read daily to determine the need for irrigation treatments. When the water level had decreased to the appropriate level, equal to 11 mm of standard pan evaporation, irrigation water was applied to the irrigated plots using overhead sprinklers and thereby refilling the tins and returning the soil to the calculated field capacity. This level of 11 mm evaporation

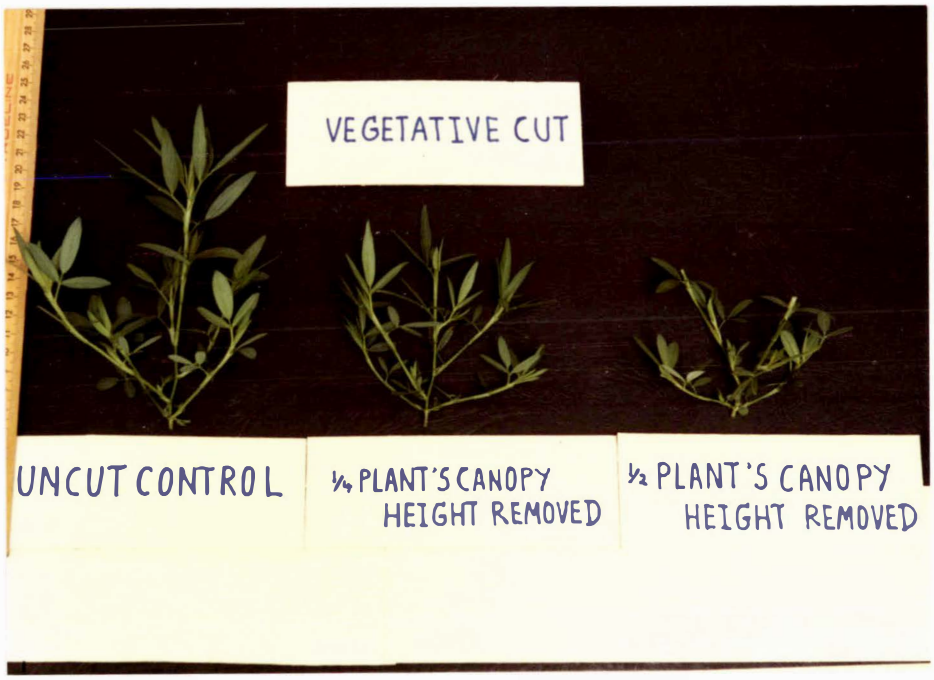
Plate 3 Cutting treatments

a. Cutting treatment at vegetative growth stage (Co, ¼VG, ½VG).

b. Cutting treatment at floral initiation growth stage.

b.1 Uncut (Co) and ¼ canopy removed (¼FI)

b.2 Uncut (Co) and ½ canopy removed (½FI)


VEGETATIVE CUT
UNCUT CONTROL
¼ PLANT'S CANOPY HEIGHT REMOVED
½ PLANT'S CANOPY HEIGHT REMOVED

a


FLORAL INITIATION CUT
UNCUT CONTROL
¼ PLANT'S CANOPY HEIGHT REMOVED

b1


FLORAL INITIATION CUT
UNCUT CONTROL
½ PLANT'S CANOPY HEIGHT REMOVED

b2

Plate 4a Cutting treatment at vegetative growth stage of Siratro (i=uncut, ii=¼VG, iii=½VG).

Plate 4b Cutting treatments at floral initiation stage of Siratro (i=uncut, ii=¼FI, iii=½FI).

was calculated in an attempt to maintain adequate soil moisture for growth i.e. to ensure that plants did not suffer from soil moisture stress. However, both non-irrigated and irrigated plots received water until the plants were well established, about 30 days after sowing, before starting the irrigation or non-irrigation treatments. In the irrigated treatments the duration of irrigation depended upon the time taken for water from the sprinklers to refill the tins. This usually took 3-4 hours every 4 days - until 14 days after peak flowering when irrigation ceased. Non-irrigated plants received no natural rainfall or irrigation water from approximately 30 days from sowing until approximately 54 days after peak flowering (i.e. 90 days for Verano stylo and 105 days for Siratro), when rainfall occurred.

K. HARVESTING

Six plants from each plot were removed at each harvest. There were eight harvests taken as follows:

Harvest 1 - at vegetative stage cut

Harvest 2 - at floral initiation stage cut

Harvest 3 - at peak flowering stage

Harvest 4 - at 7 days after peak flowering

Harvest 5 - at 14 days after peak flowering

Harvest 6 - at 26 days after peak flowering

Harvest 7 - at 40 days after peak flowering

Harvest 8 - at 54 days after peak flowering (for Siratro only)

One plant from each plot was used for photographs and the other five plants were used to study plant and seed yield components, leaf area and plant dry weight.

L. PLANT MEASUREMENTS

At each harvest, plants were dissected into leaf lamina and stem for leaf area and dry weight measurements. Other variables measured were:

Number of branches
Number of inflorescences and seedheads
Number of pods per plant
Number of seeds per seedhead or per pod

Dry weight and leaf area

The plants were divided into leaf and non-leaf portions. Approximately 50 leaves were randomly sampled to determine the leaf area and the leaves were subsequently oven dried at approximately 90^{o}C overnight and dry weight taken. The remaining leaf and non-leaf portions were oven dried for subsequent dry weight and leaf area determinations on a whole plant basis.

M. LABORATORY STUDIES

The seeds obtained from each treatment at each harvest after peak flowering were used to determine 100 seed weight, moisture content percentage and for germination testing.

Moisture tests

Each lot of 2-3 gm of seeds was weighed before being placed in metal cans and dried in an air oven at 103^{o}C for 17 hours. The dried samples were placed in a dessicator and reweighed when they were cool. The moisture content of the sample was calculated from the formula:

$$\text{Moisture content (\%)} = \frac{\text{Wet weight} - \text{Dry weight}}{\text{Wet weight}} \times 100$$

There were 2 replications for each lot of seed from each treatment, the amount of seeds used depending on the amount of seed obtained from each harvest (2-3 gm).

Germination tests

When the number of freshly harvest seeds obtained from each harvest was sufficient for a full germination test, 4 lots of 25 seeds were germinated on blotting paper at 25°C for Siratro seeds and at 35°C (day) and 15°C (night) for Verano seeds. Seedlings were counted after 3, 7 and 10 days. The percentage of normal and abnormal seedlings, hard seeds, fresh ungerminated seeds and dead seeds were also recorded.

Seed weight

The seeds obtained from each treatment at each harvest after peak flowering were counted in 3 lots of 100 seeds. These seeds were weighed to obtain mean 100 seed weight. The seeds were also dried in an air oven at 103°C for 17 hours to determine 100 seed dry weight.

N. STATISTICAL ANALYSIS

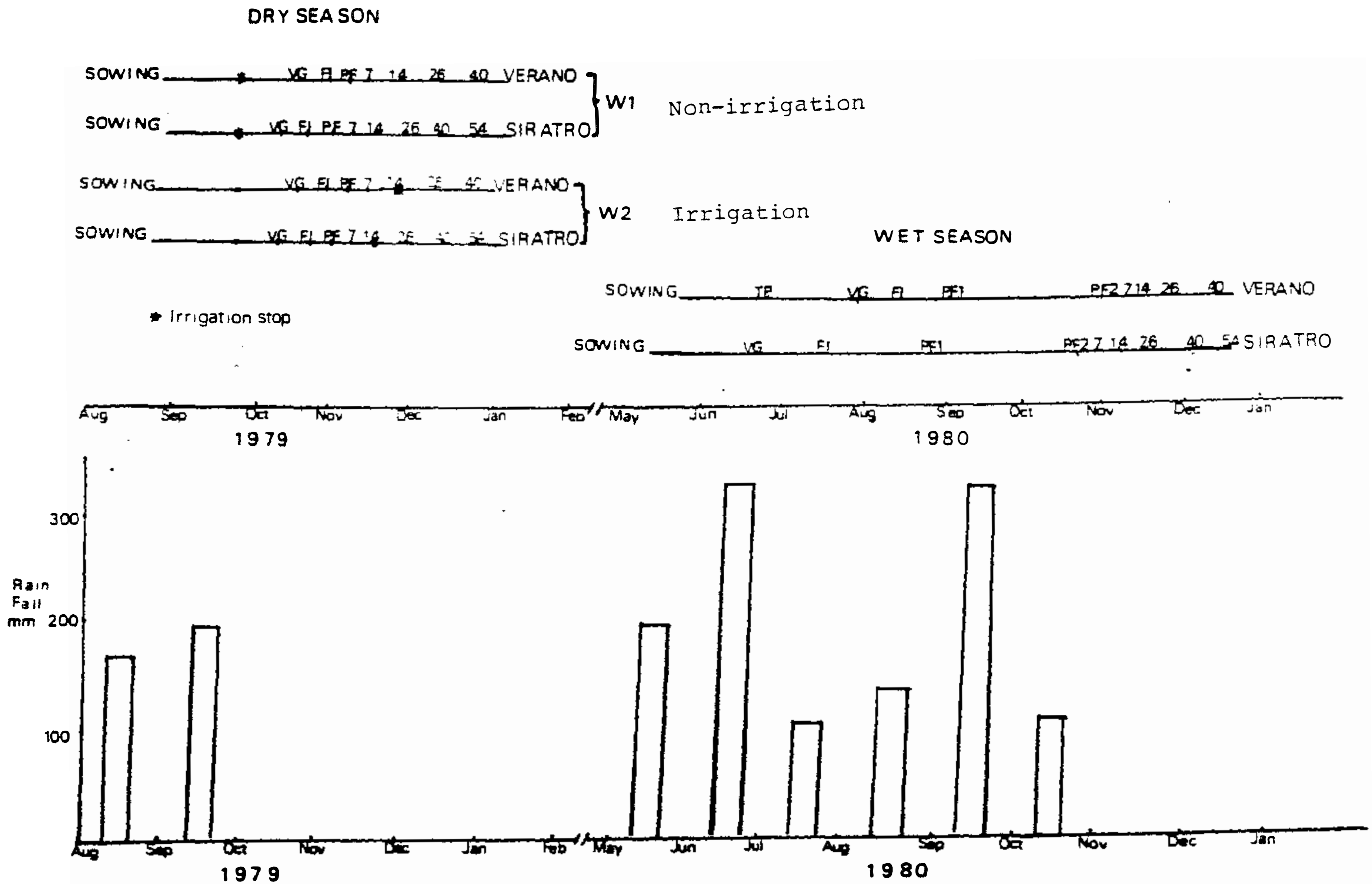
A computer programme using split plot analysis with two main plots (irrigation) and five cuttings as the subplot with three replications was employed to analyse the dry season planting data and randomize complete block design for the wet season planting. The least significant difference at 5% level was used to identify statistical differences among the results.

RESULTS

The results of these field studies are presented in two parts A and B reflecting the two seasons of planting (dry season and wet season). Each part is divided into two sections according to the two legume species (Verano stylo and Siratro). Each section of part A, which is the dry season planting, is divided into 3 subsections according to the effects of water (irrigation), cutting and the interaction between water and cutting. Part B, which is the wet season planting, deals only with the effects of cutting. This is then followed by the major treatment effects on seed quality characteristics for both species, including moisture content, germination and hardseededness.

Time of sowing, cutting and irrigation schedules, floral initiation time, peak flowering time and harvesting schedules are presented in Figure 2.

Figure 2 TIME OF SOWING, CUTTING TREATMENTS, IRRIGATION PERIOD, FLORAL INITIATION, PEAK FLOWERING TIME SCHEDULE AND RAINFALL OF THE FIELD TRIALS



PART A. DRY SEASON PLANTING

The dry season plants were sown in late August, 1979. All plants were irrigated during the period of plant establishment (0-30 days after sowing). Subsequently half of the plants of each species received no further watering, either by irrigation or rainfall until the end of the experiment. This treatment was designated W1 in each species. The remaining plants continued to receive irrigation as required for a further 64 days until 14 days after peak flowering in both Verano stylo and Siratro respectively. Irrigation was then discontinued. Plants then received no water during the next 40 days of seed development until the end of the experiment in January, 1980. This treatment was designated W2 in each species. The dry season experiment therefore lasted for a period of approximately 120 days for Verano stylo and 134 days for Siratro.

SECTION 1 EFFECT OF IRRIGATION AND CUTTING ON VEGETATIVE AND REPRODUCTIVE DEVELOPMENT IN *STYLOSANTHES HAMATA* CV VERANO

1.1 EFFECT OF IRRIGATION ON GROWTH AND YIELD

1.1.1 Plant Growth and Yield

<u>Dry Matter Yield</u>

There was a highly significant difference in plant dry weight between plants grown in non-irrigated plots (W1) and irrigated plants (W2) (Table A.1). However the difference in plant dry matter yield was not very great, the irrigated plants producing only 10-15% higher dry matter yield than non-irrigated plants. This poor response in plant dry weight to irrigation during the dry season is somewhat surprising. Plants in irrigated plots received irrigation water every 3-4 days for 64 days longer than the non-irrigated plants which received water only during establishment for the first 30 days after sowing.

Table A.1 DRY MATTER YIELD PER PLANT FROM NON-IRRIGATED (W1) AND IRRIGATED (W2) PLANTS AT SUCCESSIVE HARVESTS IN VERANO STYLO IN THE DRY SEASON PLANTING (g/pl)

Irrigation Treatment	Harvesting Times						
	VG	FI	PF	7DAPF	14DAPF	26DAPF	40DAPF
W1	0.29	1.29	6.53	8.23	14.31	16.29	15.05
W2	0.31	1.46	6.95	9.40	15.91	17.57	16.31
LSD5%		0.10	0.17	0.22	0.33	0.05	1.53

Apparently the period of irrigation was insufficient for Stylosanthes plants to show any great response in plant dry matter yield over the so-called non-irrigated plants. However, the difference between irrigated and non-irrigated plants was both noticable and significant.

Branch Number

Water had only a minor effect on total branch numbers per plant in irrigated and non-irrigated plants grown during the dry season. Certainly any stimulating of branching due to irrigation was not apparent until after peak flowering. Subsequently, at 26 and 40 days after peak flowering, irrigated plants, showed a significant increase in branch numbers (Table A.2). However, at these latter two harvests the stimulation in total branches due to irrigation was only 5.7% and 9.4% respectively. These results show that under dry season conditions branching was relatively insensitive to irrigation in *Stylosanthes hamata* cv Verano.

Table A.2 TOTAL BRANCH NUMBERS PER PLANT FROM NON-IRRIGATED (W1) AND IRRIGATED (W2) PLANTS AT SUCCESSIVE HARVESTS IN VERANO STYLO IN THE DRY SEASON PLANTING

Irrigation Treatment	Harvesting Times						
	VG	FI	PF	7DAPF	14DAPF	26DAPF	40DAPF
W1	6	20.3	33.3	42.5	55.8	55.8	55.9
W2	6	20.2	34.4	45.1	55.3	59.2	61.7
LSD5%	NS	NS	NS	0.49	NS	0.86	2.0

Leaf Number

Irrigation had a marked effect in stimulating leaf production in dry season plants (Table A.3). This effect was significant as early as floral initiation and continued to increase until at least 14 days after peak flowering. At this latter stage plants receiving irrigation had a 25% greater number of leaves per plant than non-irrigated plants.

Table A.3 TOTAL LEAF NUMBERS PER PLANT FROM NON-IRRIGATED (W1) AND IRRIGATED (W2) PLANTS AT SUCCESSIVE HARVESTS IN VERANO STYLO IN THE DRY SEASON PLANTING

Irrigation Treatment	Harvesting Times			
	FI	PF	7DAPF	14DAPF
W1	73.7	252.5	368.4	520.3
W2	82.5	284.7	492.9	654.7
LSD5%	1.7	26.7	34.5	9.4

Leaf Area

The response to water in stimulating leaf numbers was reflected in differences in total leaf area per plant in non-irrigated (W1) and irrigated (W2) plants at successive harvests. The results in Table A.4 show that leaf area (cm^2) increased significantly as a response to irrigation after floral initiation. This effect continued until at least 26 days after peak flowering with irrigated plants exhibiting an approximate 1/3 increase in leaf area compared to non-irrigated plants.

Table A.4 TOTAL LEAF AREA PER PLANT FROM NON-IRRIGATED (W1) AND IRRIGATED (W2) PLANTS AT SUCCESSIVE HARVESTS IN VERANO STYLO IN THE DRY SEASON PLANTING (cm^2/pl)

	Harvesting Times				
Irrigation Treatment	FI	PF	7DAPF	14DAPF	26DAPF
W1	106.9	253.7	361.5	519.7	686.3
W2	114.6	261.0	387.2	694.9	924.7
LSD5%	NS	6.5	20.6	10.8	0.7

1.1.2 Reproductive Growth and Seed Yield

Plants in both irrigated and non-irrigated plots started to flower 67 days after sowing and reached peak flowering 80 days after sowing (Figure 3).

The indeterminate growth habit of *Stylosanthes hamata* plants makes the categorisation of reproductive development difficult. On any one plant during the reproductive phase it is normal to find fully formed inflorescences in which florets have not yet undergone anthesis or flowering, inflorescences containing florets with anthers exserted, and inflorescences containing florets which have developed pods. In order to distinguish between these situations three different terms are used in the study as follows:

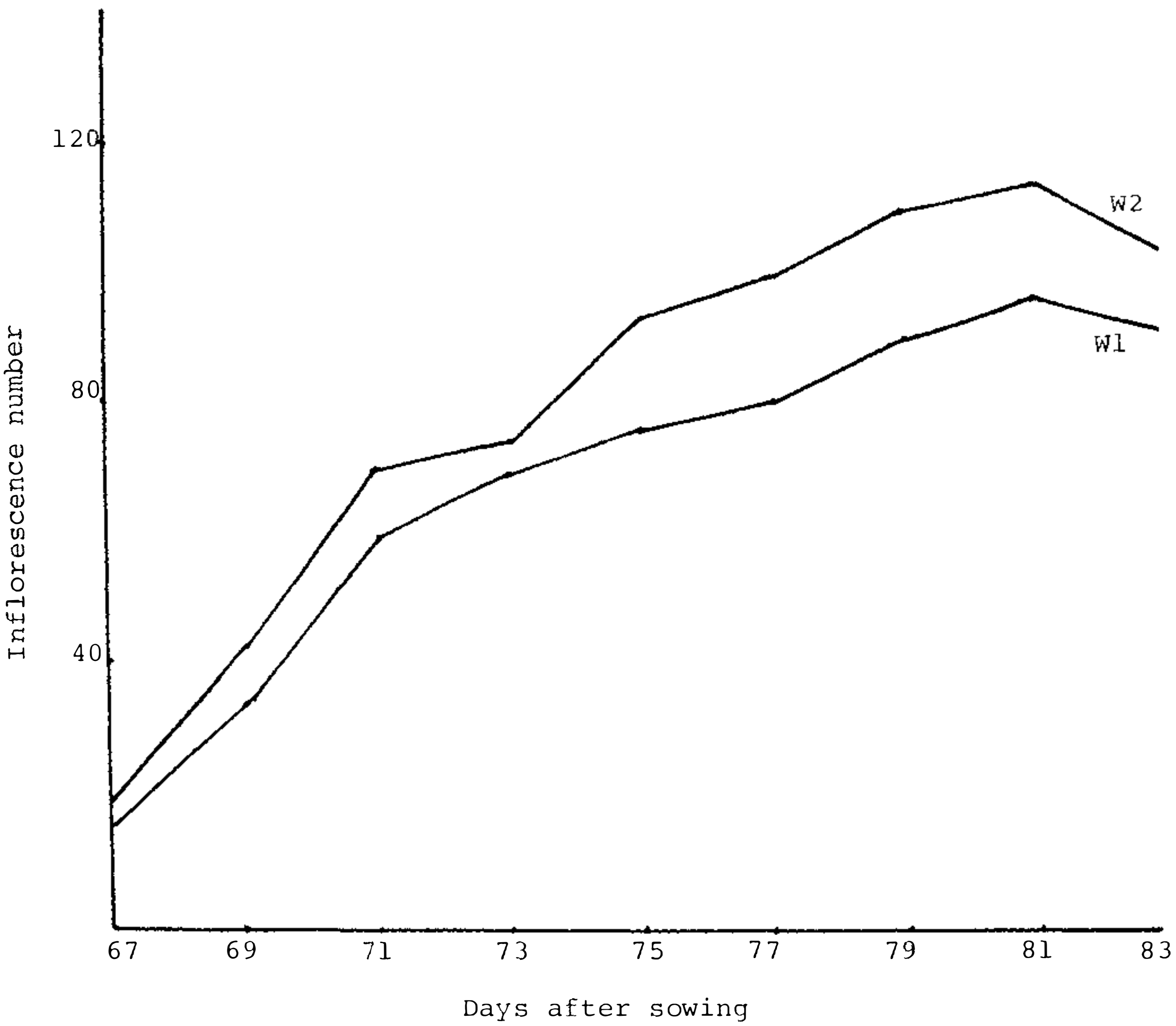


Figure 3 FLOWERING CURVES OF VERANO STYLO FROM NON-IRRIGATED (W1) AND IRRIGATED (W2) PLANTS IN THE DRY SEASON PLANTING

1. Non-flowered inflorescence = inflorescence
2. Inflorescence at anthesis = flower head
3. Inflorescence showing pod development = seed head

Seedhead Number

Irrigation had a significant effect in increasing total seedhead numbers per plant at successive harvests carried out from 7 to 40 days after peak flowering (Table A.5). In both irrigated and non-irrigated plants however, seedhead numbers increased during the first 14 days after peak flowering before declining during the later stages of seed development.

Table A.5 TOTAL SEEDHEAD NUMBERS PER PLANT FROM NON-IRRIGATED (W1) AND IRRIGATED (W2) PLANTS AT SUCCESSIVE HARVESTS IN VERANO STYLO IN THE DRY SEASON PLANTING

Irrigation Treatment	Harvesting Times			
	7DAPF	14DAPF	26DAPF	40DAPT
W1	96.3	132.7	93.5	101.6
W2	110.1	155.3	119.3	128.9
LSD5%	2.2	0.8	2.7	2.8

This is presumably as a result of loss of seedheads in Verano stylo due to shattering. Nevertheless the difference in total seedheads per plant between irrigated and non-irrigated plants was fairly constant at approximately 10-25%.

Seed Yield

Seed yield differences between irrigated and non-irrigated plants reflected the stimulation to seedhead numbers per plant from watering and were significantly different at successive harvests (Table A.6). The results show that maximum seed yield in both treatments occurred at the harvest 26 days after peak flowering. This was 12 days after the point at which maximum numbers of seed-heads per plant had been previously recorded. Presumably this time interval was sufficient to allow the production of maximum numbers of seeds per seedhead. The subsequent decline in seed yield at 40 days after peak flowering is a direct reflection of loss of seed through shattering. Nevertheless the results show that irrigated plants sown in the dry season produced 20-30% more seed than plants from non-irrigated plots.

Table A.6 TOTAL SEED YIELD PER PLANT FROM NON-IRRIGATED (W1) AND IRRIGATED (W2) PLANTS AT SUCCESSIVE HARVESTS IN VERANO STYLO IN THE DRY SEASON PLANTING (g/pl)

Irrigation Treatment	Harvesting Times			
	7DAPF	14DAPF	26DAPF	40DAPF
W1	2.19	3.27	4.21	2.83
W2	3.20	4.06	5.82	3.78
LSD5%	0.07	0.08	0.12	0.09

It was observed that at 40 days after peak flowering harvest most of the seed yield came from the lower articular or unhooked seed which developed after the upper hooked seeds within the seedhead. Hooked seeds were the first to be lost due to shattering.

1.2 EFFECT OF CUTTING ON GROWTH AND YIELD

Defoliation of *Stylosanthes hamata* cv Verano, whether by cutting or grazing is considered to be of value in dry season plantings to reduce the formation of immature seeds and empty immature pods (Hare and Waranyuwat, 1980). The cutting treatments used in the present study were chosen to assess the effects of cutting at different stages of plant growth and at different intensities on vegetative and reproductive development. Five cutting treatments were carried out, as mentioned earlier:

Co	Uncut control
¼VG	Removal of ¼ of canopy height halfway through the vegetative phase
½VG	Removal of ½ of canopy height halfway through the vegetative phase
¼FI	Removal of ¼ of canopy height at the onset of floral initiation
½FI	Removal of ½ of canopy height at the onset of floral initiation

1.2.1 Plant Growth and Yield

<u>Dry Matter Yield</u>

Cutting appeared to have only a small effect on plant dry matter yield irrespective of timing or intensity. The results presented in Table A.7 show that cutting Stylo generally reduced dry matter yield although, particularly during seed development, plants cut early and lightly (¼VG) showed similar yield to uncut plants. Plants which were cut at floral initiation showed the most severe depression in dry matter yield irrespective of cutting intensity.

Table A.7 PLANT DRY MATTER YIELD IN CUT AND UNCUT PLANTS AT SUCCESSIVE HARVESTS IN VERANO STYLO IN THE DRY SEASON PLANTING (g/pl)

Cutting Treatment	Harvesting Times						
	VG	FI	PF	7DAPF	14DAPF	26DAPF	40DAPF
Co	.35	1.80	7.17	8.68	15.78	18.0	16.87
¼VG	.30	1.70	7.42	8.08	16.03	17.48	15.98
½VG	.30	1.43	7.37	8.77	14.65	17.05	15.68
¼FI		1.25	5.57	8.88	13.17	16.37	14.73
½FI		1.00	5.20	8.65	12.92	15.73	15.03
LSD5%		0.04	0.21	0.34	0.38	0.88	0.86

Branch Number

Cutting had an interesting effect on branch numbers per plant. The results in Table A.8 show that early cutting during the vegetative stage had no immediate effect on branch numbers. However, light cutting (¼VG and ¼FI) generally stimulated branching at the time of floral initiation, although by peak flowering floral initiation cut plants produced significantly fewer branches than uncut plants or plants cut during the vegetative stage.

Table A.8 TOTAL BRANCH NUMBERS PER PLANT IN CUT AND UNCUT PLANTS AT SUCCESSIVE HARVESTS IN VERANO STYLO IN THE DRY SEASON PLANTING

	Harvesting Times						
Cutting Treatment	VG		PF	7DAPF	14DAPF	26DAPF	40DAPF
Co	6	18.8	36.7	40.2	62.5	69.7	68.3
¼VG	6	22.0	38.0	49.2	59.8	56.0	54.2
½VG	6	19.5	42.2	55.2	55.2	56.5	54.8
¼FI		23.0	29.7	47.2	47.2	54.8	58.8
½FI		17.8	27.8	58.2	58.2	55.5	57.8
LSD5%		1.5	1.0	1.4	0.8	1.2	1.2

During the early stages of seed development strong stimulation of branch numbers on all cut plants was evident. This effect however was transitory and the trend was subsequently reversed during the later stages of seed development. By 26 and 40 days after peak flowering all cut plants had significantly fewer branches than uncut plants. Such a change in relative branch production between cut and uncut plants was surprising. However it possibly reflects the influence of moisture stress during the dry season in preventing plants from forming new branches. This effect is shown by the relatively constant number of branches on all cut or uncut plants during the later stages of seed development.

Leaf Number

Cutting reduced leaf numbers at the time each cutting treatment was applied (Table A.9). However, at the stage 7 days after peak flowering, plants which had received a light cut at the vegetative stage had similar leaf numbers to uncut plants. The reduction in leaf numbers caused by cutting was not consistent. However, overall, uncut plants seemed to have generally higher leaf numbers than cut plants.

Table A.9 TOTAL LEAF NUMBERS PER PLANT IN CUT AND UNCUT PLANTS AT SUCCESSIVE HARVESTS IN VERANO STYLO IN THE DRY SEASON PLANTING

	Harvesting Times			
Cutting Treatment	FI	PF	7DAPF	14DAPF
Co	93.3	260.5	466.5	641.7
¼VG	89.1	259.2	457.2	562.7
½VG	77.1	280.3	442.0	580.0
¼FI	72.8	286.5	400.5	523.2
½FI	58.2	256.5	387.2	530.2
LSD5%	2.7	10.1	11.2	17.4

Leaf Area

Cutting reduced plant leaf area. This effect occurred irrespective of the stage of plant growth at which plants were cut or cutting intensity. However, severely cut or late cut plants seemed to be most severely affected (Table A.10). These results follow the same trend as that previously shown for leaf number.

Table A.10 TOTAL LEAF AREA IN CUT AND UNCUT PLANTS AT SUCCESSIVE HARVESTS IN VERANO STYLO IN THE DRY SEASON PLANTING (cm^2/pl)

Cutting Treatment	Harvesting Times					
	VG	FI	PF	7DAPF	14DAPF	26DAPF
Co	47.1	132.2	309.3	373.7	708.3	870.2
¼VG	41.5	125.0	253.7	371.7	635.2	788.8
½VG	43.9	108.0	283.0	382.5	615.7	750.3
¼FI		103.5	278.2	395.0	555.3	779.2
½FI		84.2	162.7	349.9	522.0	639.0
LSD5%		3.6	6.6	10.8	7.3	16.0

1.2.2 Reproductive Growth and Seed Yield

Both cut and uncut plants started to flower at the same time and reached peak flowering at 80 days after sowing. This suggests that cutting was not effective in prolonging or shortening the vegetative duration of plant growth in the dry season.

Seedhead Number

The seedhead numbers formed on both cut and uncut plants varied depending on the ability of the plants to recover from cutting (Table A.11).

Table A.11 TOTAL SEEDHEAD NUMBERS PER PLANT IN CUT AND UNCUT PLANTS AT SUCCESSIVE HARVESTS IN VERANO STYLO IN THE DRY SEASON

Cutting Treatment	Harvesting Times			
	7DAPF	14DAPF	26DAPF	40DAPF
Co	94.7	148.6	99.2	108.7
¼VG	96.2	143.7	116.5	83.5
½VG	121.2	131.7	114.7	113.8
¼FI	101.3	102.3	109.8	135.5
½FI	82.7	103.3	92.0	132.7
LSD5%	2.2	2.6	2.2	1.6

Maximum numbers of seedheads were formed at different times in different cutting treatments and tended to reflect both the time of cutting and cutting severity. Highest seedhead numbers in uncut plants and in plants cut at the vegetative stage were recorded 14 days after peak flowering. However, when cutting was delayed until floral initiation highest numbers of seedheads were not reached until 40 days after peak flowering. All the cutting treatments produced maximum numbers of seedheads which were significantly lower than the maximum seedhead numbers produced on uncut plants.

Only plants which were lightly cut during the vegetative stage (¼VG) were apparently able to recover sufficiently to ultimately produce nearly the same total seedhead numbers formed on uncut plants. All other cutting treatments produced approximately 10% fewer maximum numbers of seedheads.

Seed Yield

Seed yield depends on the number of seedheads and the number of seeds formed. In *Stylosanthes hamata* cv Verano however, cutting had no effect on the number of seeds per seedhead, a remarkably constant mean value of seeds per head occurring in all cutting treatments (15-16 seeds/seedhead) (Appendix 1). The total seed yield per plant, presented in Table A.12, is therefore different mainly as a result of the effect of cutting on the number of seedheads produced per plant. In all treatments maximum seed yield was obtained 26 days after peak flowering. At this maximum seed yield stage plants lightly cut at the vegetative stage (¼VG) or at floral initiation (¼FI) had a significantly higher seed yield than uncut plants and plants from other cutting treatments. Plants cut late and severely (½FI) gave the lowest seed yield (Table A.12).

Table A.12 TOTAL SEED YIELD PER PLANT IN CUT AND UNCUT PLANTS AT SUCCESSIVE HARVESTS IN VERANO STYLO IN THE DRY SEASON (g/pl)

Cutting Treatment	Harvesting Times 7DAPF	14DAPF	26DAPF	40DAPF	Max. Seed Yield kg/ha
Co	3.11	4.52	5.07	3.21	1267.5
¼VG	2.89	4.61	5.66	2.81	1415.0
½VG	3.85	3.15	4.89	2.91	1222.5
¼FI	2.02	2.97	5.31	4.22	1327.5
½FI	1.63	3.07	4.13	3.38	1032.5
LSD5%	0.08	0.08	0.04	0.10	

In all treatments a decline in seed yield was evident at the harvest 40 days after peak flowering. This reflected seed shattering losses. A reduction in seed yield of up to 50% occurred in the 14 days after maximum seed yield 26 days after peak flowering. Conversion of maximum seed yield per plant to maximum seed yield per hectare by use of a conversion value of 250,000 plants per hectare allowed comparative maximum yield values to be presented in Table A.12. These seed yield figures clearly show the higher yield in lightly cut treatments (¼VG, ¼FI) and the severe depression in seed yield due to late and severe cutting (½FI) compared with the seed yield obtained in the uncut control treatment.

1.3 EFFECTS OF THE INTERACTION BETWEEN IRRIGATION AND CUTTING ON GROWTH AND YIELD

In addition to their individual effects there was a strong interaction between irrigation and cutting on both vegetative and reproductive growth in *Stylosanthes hamata* cv Verano.

1.3.1 Plant Growth and Yield

Dry Matter Yield

The results in Table A.13 show that significant interactions occur between irrigation and cutting on plant dry weight in both cut and uncut plants. Irrigation of dry season plants stimulated plant dry weight. However there was a significant depression of this water effect in treatments where plants had been cut, particularly if cutting was delayed until floral initiation. In fact, late cutting virtually cancelled out the irrigation response by the time plants had reached the point of maximum seed yield 26 days after peak flowering. Dry season plants which had not received irrigation (W1) showed no significant interaction due to cutting at 26 days after peak flowering although, again, there was the suggestion that late and severe cutting (½FI) depressed plant growth. The interaction between water and late cutting was presumably due to the water demand of the plants to renew and replace dry matter following cutting. This effect was most obvious during the early stages of seed development and was seen most clearly at harvests carried out 7 and 14 days after peak flowering.

Branch Number

No effect of irrigation and cutting on total branch numbers per plant were observed until peak flowering (Table A.14). Subsequently, and particularly during the early stages of seed development, a pronounced stimulation

Table A.13 INTERACTION BETWEEN IRRIGATION AND CUTTING ON DRY MATTER YIELD PER PLANT AT SUCCESSIVE HARVESTS IN VERANO STYLO IN THE DRY SEASON PLANTING (g/pl)

Cutting Treatment	Harvesting Times											
	FI		PF		7DAPF		14DAPF		26DAPF		40DAPF	
	W1	W2	W1	W2	W1	W2	W1	W2	W1	W2	W1	W2
Co	1.33	1.67	6.70	7.63	7.77	9.60	14.3	17.3	16.7	19.3	15.7	18.0
¼VG	1.53	1.87	7.33	7.50	7.70	9.47	15.6	16.4	16.3	18.6	14.9	15.9
½VG	1.30	1.57	8.27	8.47	8.20	9.40	17.3	18.0	16.4	17.7	14.7	16.0
¼FI	1.30	1.30	5.37	5.77	8.60	9.47	12.7	13.6	16.4	16.3	14.5	14.9
½FI	1.00	1.00	5.00	5.40	7.43	9.87	11.7	14.2	15.5	15.9	15.2	16.2
Significance	**		**		**		**		**			
LSD A	.11		.30		.47		.56		1.3		NS	
5% B	.06		.29		.48		.54		1.2			

A = LSD for differences between subplot treatments for different main plot treatments.

B = LSD for differences between subplot treatments for the same main plot treatment.

Table A.14 INTERACTION BETWEEN IRRIGATION AND CUTTING ON TOTAL BRANCH NUMBERS PER PLANT AT SUCCESSIVE HARVESTS IN VERANO STYLO IN THE DRY SEASON PLANTING

Cutting Treatment	Harvesting Times											
	FI		PF		7DAPF		14DAPF		26DAPF		40DAPF	
	W1	W2	W1	W2	W1	W2	W1	W2	W1	W2	W1	W2
Co	18.7	19.0	34.3	39.0	38.0	42.3	61.6	63.3	65.7	73.7	63.0	73.7
¼VG	22.0	22.0	38.0	38.0	47.0	51.3	47.3	52.3	52.3	59.7	51.3	57.0
½VG	20.7	20.8	41.7	42.7	42.7	52.3	52.3	58.0	51.3	51.7	52.7	57.0
¼FI	22.0	24.0	28.0	31.3	42.7	41.3	44.0	50.3	54.3	55.3	56.7	61.0
½FI	18.0	18.0	27.0	28.6	41.3	41.3	56.3	60.0	55.3	55.7	56.0	59.7
Significance			**		**		**		**		**	
LSD A	NS		2.29		1.79		3.5		1.7		2.4	
5% B			1.54		1.94		1.13		1.7		1.7	

A = LSD for differences between subplot treatments for different main plot treatments.

B = LSD for differences between subplot treatments for the same main plot treatment.

of branching was seen in irrigated plants which had been cut early in their development. However, this effect was transitory. The branching capacity of uncut plants was higher than in cut plants, this ability being significantly enhanced in plants from the irrigated treatment (W2) during the later stages of seed development. It was obvious that new branch formation continued through until the point of maximum seed yield 26 days after peak flowering in uncut plants which had been irrigated. By contrast plants which had not been irrigated (W1) reached an apparent maximum branch development about 14 days after peak flowering.

By the end of the experiment 40 days after peak flowering there was an approximate 15% increase in the number of branches on uncut plants in the irrigated treatment. In cut plants however, this stimulation of branching by irrigation was much smaller. Cutting certainly reduced the impact of water on branching, an approximate 20% reduction in branch numbers occurring in cut plants which had been irrigated compared with the number of branches on uncut plants. This inability of cut plants to replace lost branches even in the irrigated treatment suggests that in the dry season the application of water was insufficient to support full growth recovery. This was possibly due to the poor water holding capacity of the soil and also to the fact that irrigation was discontinued even in the irrigation treatment (W2) 14 days after peak flowering.

Leaf Number

There was a significant increase in leaf numbers due to irrigation in both cut and uncut plants (Table A.15). This effect became increasingly apparent at harvests carried out 7 and 14 days after peak flowering. Leaf numbers were most severely reduced in plants cut late (floral initiation) irrespective of severity. This effect was also obvious during the early stages of seed development.

Table A.15 INTERACTION BETWEEN IRRIGATION AND CUTTING ON TOTAL LEAF NUMBERS PER PLANT AT SUCCESSIVE HARVESTS IN VERANO STYLO IN THE DRY SEASON

	Harvesting Times							
	FI		PF		7DAPF		14DAPF	
Cutting Treatment	W1	W2	W1	W2	W1	W2	W1	W2
Co	81.0	105.7	247.0	274.0	373.0	560.0	522.7	760.7
¼VG	86.0	92.3	239.7	278.7	382.3	532.0	496.7	628.7
½VG	75.3	79.0	273.0	287.7	386.3	497.7	476.7	723.3
¼FI	69.3	76.3	273.3	299.7	356.7	444.3	463.3	583.0
½FI	57.0	59.3	229.3	283.7	343.7	430.7	482.3	578.0
Significance	**		**		**		**	
LSD A	3.8		28.12		26.56		24.87	
5% B	3.9		14.31		15.85		24.69	

A = LSD for differences between subplot treatments for different main plot treatments.

B = LSD for differences between subplot treatments for the same main plot treatment.

Leaf Area

The effects of irrigation and cutting on branch and leaf numbers were reflected in differences in leaf area between treatments. The results in Table A.16 show the marked stimulation in leaf area caused by irrigation in both cut and uncut plants particularly at harvests carried out during seed development. However, cutting generally reduced leaf area in both irrigated and non-irrigated plants, those plants where cutting was delayed until floral initiation being most severely affected.

Table A.16 INTERACTION BETWEEN IRRIGATION AND CUTTING ON TOTAL LEAF AREA PER PLANT AT SUCCESSIVE HARVESTS IN VERANO STYLO IN THE DRY SEASON (cm^2/pl)

Cutting Treatment	Harvesting Times							
	FI		PF		7DAPF		14DAPF	
	W1	W2	W1	W2	W1	W2	W1	W2
Co	116.3	150.0	298.0	320.7	367.3	380.0	539.7	877.0
¼VG	123.0	127.0	245.0	262.3	360.3	383.0	546.0	724.3
½VG	109.0	109.0	276.7	289.3	379.0	386.0	545.3	686.0
¼FI	102.7	104.3	289.7	296.7	377.3	412.7	498.7	612.0
½FI	83.7	84.7	159.3	166.0	323.7	374.3	469.0	575.0
Significance	**		**		**		**	
LSD A	10.8		10.2		23.2		13.4	
5% B	5.2		9.4		15.3		10.3	

A = LSD for differences between subplot treatments for different main plot treatments.

B = Differences between subplot treatments for the same main plot treatment.

1.3.2 Reproductive Growth and Seed Yield

Seedhead Number

The results in Table A.17 clearly show the interaction between irrigation and cutting on seedhead numbers. All plants except those cut lightly at floral initiation (¼FI) and measured at the harvest 7 days after peak flowering had highest seedhead numbers in the presence of irrigation water (W2). Maximum seedhead numbers in uncut plants and plants lightly cut at the vegetative stage were reached 14 days after peak flowering. Late cut plants (FI) reached maximum seedhead numbers 40 days after peak flowering with or without irrigation. However, although cutting reduced the number of seedheads except the early cut plants (VG) in some cases (7 and 40 days after peak flowering). It was apparent that this depression could be partly or completely overcome provided plants received enough water (W2) to allow the replacement of the structural framework removed by cutting in time to provide sites for flowerhead development.

Table A.17 INTERACTION BETWEEN IRRIGATION AND CUTTING ON TOTAL SEEDHEAD NUMBERS PER PLANT AT SUCCESSIVE HARVESTS IN VERANO STYLO IN THE DRY SEASON

Cutting Treatment	Harvesting Times							
	7DAPF		14DAPF		26DAPF		40DAPF	
	W1	W2	W1	W2	W1	W2	W1	W2
Co	66.3	123.0	163.7	168.0	91.3	109.0	96.7	120.7
¼VG	93.0	99.3	126.3	161.0	104.3	128.7	79.0	88.0
½VG	129.3	133.0	123.0	140.3	86.0	143.3	83.3	144.3
¼FI	109.3	99.3	107.7	127.0	96.7	123.0	129.7	145.3
½FI	79.3	86.0	102.6	124.0	89.3	94.7	119.3	146.0
Significance	**		**		**		**	
LSD A	3.4		3.4		3.7		3.2	
5% B	3.2		3.8		3.2		2.2	

A = LSD for differences between subplot treatments for different main plot treatments.

B = LSD for differences between subplot treatments for the same treatment.

Seed Yield

The results (Table A.18) show that provided plants received irrigation (W2) they are generally capable of attaining high seed yield. This presumably reflects a need for plants to respond to watering by reaching maximum vegetative size and replacing the material removed by cutting in time to produce large numbers of seedheads. This effect was not apparent early (7 days after peak flowering) but was very evident at the point of maximum seed yield 26 days after peak flowering. Presumably the relatively low values at the point of maximum seed yield 26 days after peak flowering in severely cut treatments ½VG and ½FI without irrigation and ½FI with irrigation are due to an inability of plants to meet the above criteria for high seeding potential.

Table A.18 INTERACTION BETWEEN IRRIGATION AND CUTTING ON TOTAL SEED YIELD PER PLANT AT SUCCESSIVE HARVESTS IN VERANO STYLO IN THE DRY SEASON (g/pl)

Cutting Treatment	Harvesting Times							
	7DAPF		14DAPF		26DAPF		40DAPF	
	W1	W2	W1	W2	W1	W2	W1	W2
Co	1.58	4.63	4.93	5.10	4.51	5.61	2.81	3.60
¼VG	2.38	3.40	4.04	5.17	4.82	6.49	2.68	2.94
½VG	3.87	3.83	2.76	3.53	3.58	6.20	2.14	3.67
¼FI	2.56	2.48	2.86	3.09	4.54	6.08	3.72	4.72
½FI	1.60	1.65	2.76	3.39	3.56	4.70	2.82	3.94
Significance	**		**		**		**	
LSD A	.13		.13		.12		.16	
5% B	.12		.12		.06		.15	

A = LSD for differences between subplot treatments for different main plot treatments.

B = LSD for differences between subplot treatments for the same main plot treatment.

Overall, the maximum yield of cut plants receiving irrigation (except plants which were cut too late and too severely to respond) was higher than uncut plants. This was surprising considering the effect of cutting on branching and on seedhead production. The seed yield from cut plants in treatments ¼VG, ½VG and ¼FI was approximately 15% higher than from uncut plants provided plants were irrigated. Without irrigation no yield improvement occurred due to cutting except plant with the light cut (¼VG, ¼FI). The effect of irrigation was more pronounced, resulting in a seed yield increase of about 20-30% compared to no irrigation.

SECTION 2 EFFECT OF IRRIGATION AND CUTTING ON VEGETATIVE AND REPRODUCTIVE DEVELOPMENT IN *MACROPTILIUM ATROPURPUREUM* CV SIRATRO

2.1 EFFECT OF IRRIGATION ON GROWTH AND YIELD

2.1.1 Plant Growth Yield

Dry Matter Yield

There was a significant difference in plant yield dry weight between irrigated (W2) and non-irrigated plants (W1) grown in the dry season (Table A.19).

Table A.19 DRY MATTER YIELD PER PLANT AT SUCCESSIVE HARVESTS IN SIRATRO FROM NON-IRRIGATED (W1) AND IRRIGATED (W2) PLOTS IN THE DRY SEASON PLANTING (g/pl)

Irrigation Treatment	Harvesting Times							
	VG	FI	PF	7DAPF	14DAPF	26DAPF	40DAPF	54DAPF
W1	0.9	3.36	14.21	19.65	30.83	42.39	47.82	56.54
W2	1.63	3.31	16.24	25.66	36.93	48.32	52.39	58.63
LSD5%		NS	0.87	0.99	1.13	0.62	0.98	0.57

Water significantly increased dry matter yield from the peak flowering stage, although the difference in yield between irrigated and non-irrigated plants was small. During the early stages of seed development (7-14 days after peak flowering) this difference reached maximum levels (up to 20%). However this difference was progressively reduced subsequently. Plants which received no irrigation reached a maximum at the final harvest (54DAPF) of 56 gm per plant while irrigated plants reached a maximum of only 58 gm at the same stage. This difference, although statistically significant, was disappointing in terms of an overall irrigation response.

Branch Number

Water had a similar effect on total branch numbers. There was a significant stimulation of total branch numbers between irrigated (W2) and non-irrigated (W1) plants (Table A.20). Plants which received no irrigation water had a maximum branch number of 20 while plants which received irrigation reached a maximum of 23 branches per plant. Again this difference was significant but disappointingly small in terms of an irrigation response.

Table A.20 TOTAL BRANCH NUMBERS PER PLANT AT SUCCESSIVE HARVESTS IN SIRATRO FROM NON-IRRIGATED (W1) AND IRRIGATED (W2) PLOTS IN THE DRY SEASON PLANTING

Irrigation Treatment	Harvesting Times						
	FI	PF	7DAPF	14DAPF	26DAPF	40DAPF	54DAPF
W1	7.9	9.3	13.3	15.9	17.8	19.5	20.1
W2	8.7	11.3	15.3	18.5	20.8	22.6	22.9
LSD5%	0.4	1.7	1.5	1.4	1.4	2.0	2.1

Leaf Number and Leaf Area

Water also significantly increased leaf number per plant (Table A.21) as well as leaf area (Table A.22). The highly significant increase in leaf numbers and leaf area as a response to irrigation was first detected at the peak flowering stage. Plants which had received irrigation developed about 15% higher leaf area than non-irrigated plants. This increase in leaf area was directly reflected in an increase of up to 50% in leaf numbers in irrigated plants.

Table A.21 TOTAL LEAF NUMBERS PER PLANT AT SUCCESSIVE HARVESTS IN SIRATRO FROM NON-IRRIGATED (W1) AND IRRIGATED (W2) PLOTS IN THE DRY SEASON PLANTING

Irrigation Treatment	Harvesting Times			
	FI	PF	7DAPF	14DAPF
W1	61.6	162.5	177.3	198.6
W2	67.1	197.8	212.2	304.1
LSD5%	NS	15.9	5.0	0.77

Table A.22 TOTAL LEAF AREA PER PLANT AT SUCCESSIVE HARVESTS IN SIRATRO FROM NON-IRRIGATED (W1) AND IRRIGATED (W2) PLOTS IN THE DRY SEASON PLANTING (cm^2/pl)

Irrigation Treatment	Harvesting Times			
	FI	PF	7DAPF	14DAPF
W1	392.9	1722.7	1862.7	2092.0
W2	402.0	2024.9	2213.1	2275.1
LSD5%	NS	44.5	42.1	51.1

2.1.2 Reproduction Growth and Seed Yield

Pod Number

There was no significant difference in the floral initiation date between non-irrigated and irrigated plants. Both irrigated and non-irrigated plants sown in the dry season started to flower 56 days after sowing and reached peak flowering approximately 75 days after sowing (Figure 4). However, although irrigation had no effect on the duration of the vegetative and reproductive growth phases it did affect the number of pods formed per plant (Table A.23).

Table A.23 TOTAL POD NUMBERS PER PLANT AT SUCCESSIVE HARVESTS IN SIRATRO FROM NON-IRRIGATED (W1) AND IRRIGATED (W2) PLOTS IN THE DRY SEASON PLANTING

Irrigation Treatment	Harvesting Times			
	14DAPF	26DAPF	40DAPF	54DAPF
W1	30.2	32.4	36.5	44.1
W2	33.8	36.8	41.3	59.5
LSD5%	1.4	0.8	1.2	3.7

Plants receiving irrigation had higher numbers of pods per plant than non-irrigated plants. This effect was largely due to the higher inflorescence numbers present at peak flowering (W1=18, W2=29). The difference in pod numbers between the two water treatments was relatively high (over 25% by the end of the experiment) suggesting that pod numbers are relatively sensitive and responsive to added water.

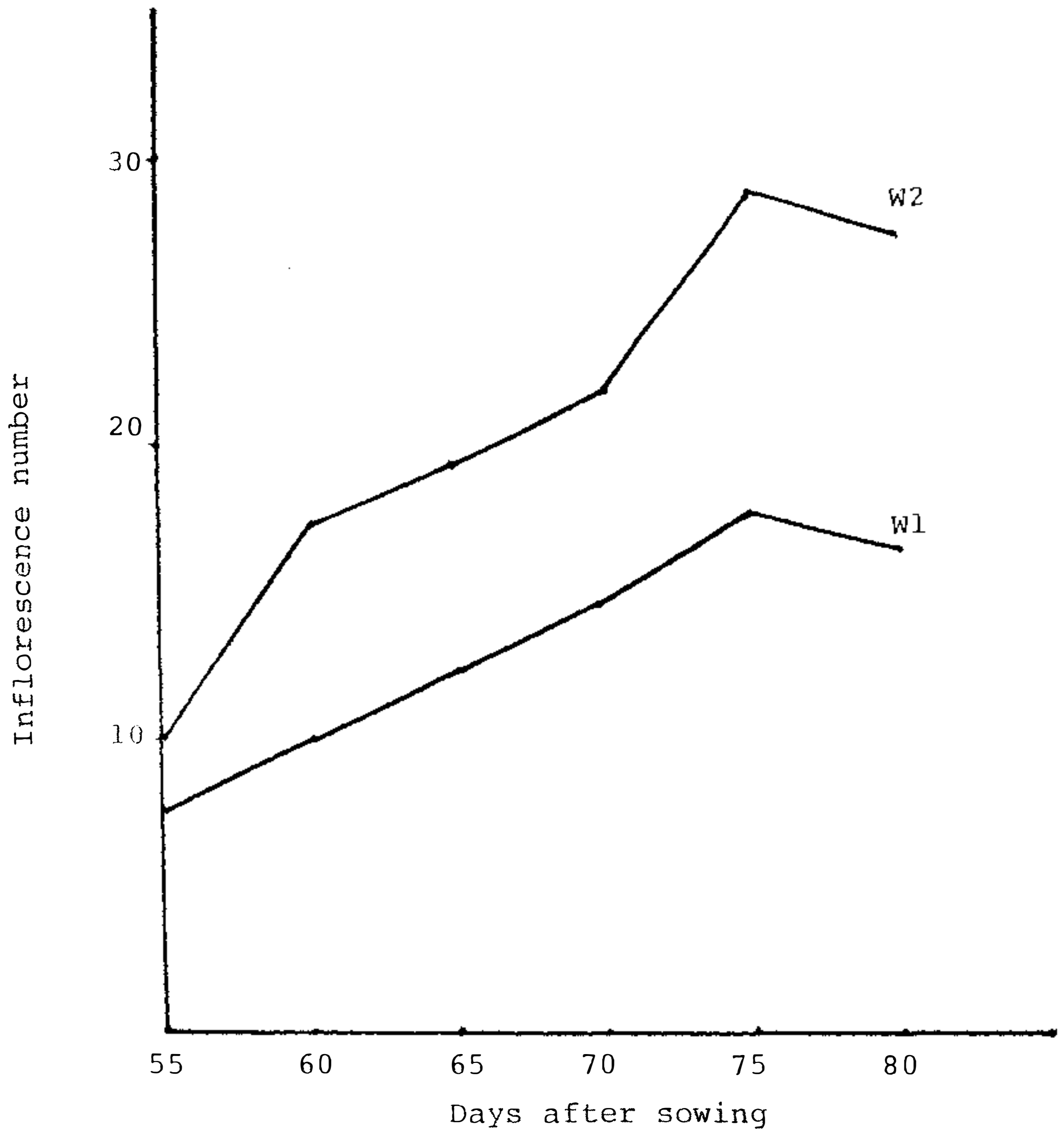


Figure 4 FLOWERING CURVES OF SIRATRO FROM NON-IRRIGATED (W1) AND IRRIGATED (W2) PLANTS IN THE DRY SEASON PLANTING

Seed Yield

There was also a significant difference in the seed yield obtained between irrigated and non-irrigated plants (Table A.24). Plants which had received irrigation reached maximum yield approximately 2 weeks after plants without irrigation.

Table A.24 TOTAL SEED YIELD PER PLANT AT SUCCESSIVE HARVESTS IN SIRATRO FROM NON-IRRIGATED (W1) AND IRRIGATED (W2) PLOTS IN THE DRY SEASON PLANTING (g/pl)

Irrigation Treatment	Harvesting Times 14DAPF	26DAPF	40DAPF	54DAPF	Max.Seed Yield Kg/ha
W1	2.61	4.27	13.87	13.80	1248.3
W2	2.35	7.94	13.61	14.64	1317.6
LSD5%	0.09	0.18	0.05	0.30	

These maximum yields when converted to kg/ha (at 90,000 plants per hectare) showed figures of 1248.3 kg/ha in non-irrigated plots (W1) and 1317.6 kg/ha in irrigated plots. This difference of only 69.3 kg/ha (approximately 5.5%) was a disappointing response to irrigation and suggests that either Siratro plants were unable to respond fully to watering or that the irrigation frequency or duration was inadequate to allow maximum response to be expressed.

2.2 EFFECT OF CUTTING ON GROWTH AND YIELD

2.2.1 Plant Growth and Yield

Dry Matter Yield

Table A.25 presents plant dry matter yields at successive harvests and shows that there was a significant difference in vegetative dry matter yields due to cutting treatments. Up to the peak flowering stage uncut plants had significantly higher vegetative yield than cut plants. However subsequently there was a stimulation to plant dry matter yield as a response to cutting.

Table A.25 DRY MATTER YIELD PER PLANT ON CUT AND UNCUT PLANTS AT SUCCESSIVE HARVESTS IN SIRATRO IN THE DRY SEASON (g/pl)

Cutting Treatment	Harvesting Times						
	FI	PF	7DAPF	14DAPF	26DAPF	40DAPF	54DAPF
Co	3.60	18.07	20.9	36.65	39.13	44.40	49.45
¼VG	3.27	16.03	22.17	41.15	44.45	46.88	55.12
½VG	2.97	14.75	25.33	30.68	46.67	44.45	61.83
¼FI	3.23	13.50	25.55	35.52	46.98	57.92	62.40
½FI	2.62	13.78	19.33	25.40	49.55	56.58	58.63
LSD5%	0.28	0.73	0.56	0.62	0.74	0.76	0.68

At the final harvest plants severely cut during the vegetative stage (½VG) and plants lightly cut at floral initiation (¼FI) gave the highest yield of 61.8 gm and 62.4 gm/plant respectively. Plants severely cut at floral initiation (½FI) and plants cut lightly at the vegetative stage (¼VG) gave yields of 58.6 and 55.1 gm/plant respectively. However at harvests carried out at 26, 40 and 54 days after peak flowering all cut plants had higher dry matter yields than uncut plants.

Branch Number

There was a significant difference in branch numbers between cut and uncut plants beginning at the peak flowering stage (Table A.26). The results show that cut plants had significantly higher branch numbers than uncut plants, plants lightly cut at the vegetative stage appearing to produce the highest branch numbers. This stimulation to branching by cutting was consistent at successive harvests after peak flowering.

Table A.26 TOTAL BRANCH NUMBERS PER PLANT ON CUT AND UNCUT PLANTS AT SUCCESSIVE HARVESTS IN SIRATRO IN THE DRY SEASON

Cutting Treatment	Harvesting Times						
	FI	PF	7DAPF	14DAPF	26DAPF	40DAPF	54DAPF
Co	8.0	9.5	11.7	15.3	15.5	18.0	18.7
¼VG	8.8	12.8	16.8	19.8	22.8	23.8	24.2
½VG	8.7	10.0	14.0	16.7	19.0	21.5	22.2
¼FI	8.3	9.3	13.7	17.2	19.0	20.2	20.7
½FI	7.8	9.7	15.2	17.2	20.2	21.8	22.0
LSD5%	NS	0.5	0.9	1.0	1.1	0.9	1.3

Leaf Number and Leaf Area

As would be expected cutting initially reduced leaf numbers per plant, the effect being more apparent in the later cut (FI) treatments. However all defoliation treatments showed a reasonable recovery in leaf numbers per plant by 14 days after peak flowering, with only the severely and late cut plants (½FI) still showing signs of depressed leaf numbers.

Table A.27 TOTAL LEAF NUMBER PER PLANT ON CUT AND UNCUT PLANTS AT SUCCESSIVE HARVESTS IN SIRATRO IN THE DRY SEASON

Cutting Treatment	Harvesting Times			
	FI	PF	7DAPF	14DAPF
Co	69.8	197.2	208.3	259.7
¼VG	75.5	192.7	211.7	248.3
½VG	62.0	185.3	188.3	250.8
¼FI	67.8	168.3	189.3	257.5
½FI	46.5	157.2	175.5	240.3
LSD5%	1.6	6.1	4.3	8.5

Cutting had a similar effect on leaf area, uncut plants producing highest leaf areas at all harvests after floral initiation. The results in Table A.28 reflect the influence of cutting on leaf numbers previously described. Apparently severely and late cut plants (½FI) in particular, were unable to replace leaf sufficiently after cutting and produced the lowest leaf area as a result.

Table A.28 TOTAL LEAF AREA PER PLANT ON CUT AND UNCUT PLANTS AT SUCCESSIVE HARVESTS IN SIRATRO IN THE DRY SEASON (cm^2/pl)

Cutting Treatment	Harvesting Times			
	FI	PF	7DAPF	14DAPF
Co	464.3	2120.0	2218.5	2317.2
¼VG	487.0	1973.0	2211.0	2191.5
½VG	379.0	1920.7	1968.2	2134.3
¼FI	398.7	1725.5	1952.2	2240.8
½FI	258.3	1630.[illegible]	1839.5	2033.8
LSD5%	17.5	44.4	43.8	34.8

2.2.2 Reproductive Growth and Seed Yield

Cutting had no effect on the time from floral initiation to peak flowering. Both cut and uncut plants reached peak flowering about 20 days after floral initiation was first observed.

Pod Number

The results in Table A.29 show that cutting generally stimulated pod production in Siratro. This effect was particularly the case in plants cut lightly during the vegetative stage and at a later stage in plants cut at floral initiation. Presumably plant recovery following cutting resulted in the production of more sites for pod development. It appears however, that more severe cutting at the vegetative stage (½VG) caused a depression in pod numbers particularly in relation to plants from other cutting treatments but also compared with uncut plants. This effect was particularly obvious at the final harvest 54 days after peak flowering.

Table A.29 TOTAL POD NUMBERS PER PLANT ON CUT AND UNCUT PLANTS AT SUCCESSIVE HARVESTS IN SIRATRO IN THE DRY SEASON

Cutting Treatment	Harvesting Times			
	74DAPF	26DAPF	40DAPF	54DAPF
Co	33.5	30.7	33.7	48.8
¼VG	43.3	45.7	41.8	61.2
½VG	28.3	33.3	32.2	40.8
¼FI	27.0	31.8	43.5	50.2
½FI	27.3	31.5	43.3	58.0
LSD5%	0.8	1.3	1.5	1.4

Seed Yield

Seed yield is a direct reflection of pod numbers, seed numbers per pod and seed weight. Of these three yield components only pod numbers were affected by cutting. Both seed numbers per pod and seed weight were unresponsive to cutting, averaging 16 seeds per pod and .19 mg of seed weight respectively across all cutting treatments (Appendix 2). The results in Table A.30 show that both cut and uncut Siratro plants reached maximum seed yield 54 days after peak flowering except in treatment ¼FI where yield maximum was recorded 14 days earlier. Highest yields per plant and per hectare were obtained from those cutting treatments which had been previously shown to produce highest numbers of pods (¼VG, ¼FI and ½FI) and ranged from 1400-1445 kg/ha compared with a maximum yield from uncut plants of only 1160 kg/ha. The suppression in pod numbers in plants cut severely during the vegetative stage (½VG), as described earlier, was reflected in the lowest seed yield of only 1096 kg/ha from plants in this treatment.

Table A.30 TOTAL SEED YIELD PER PLANT ON CUT AND UNCUT PLANTS AT SUCCESSIVE HARVESTS IN SIRATRO IN THE DRY SEASON (g/pl)

Cutting Treatment	Harvesting Times				
	14DAPF	26DAPF	40DAPF	54DAPF	Max.Seed Yield Kg/ha
Co	3.50	6.09	11.45	12.89	1160.1
¼VG	3.11	8.93	15.21	16.06	1445.4
½VG	1.85	4.44	12.18	12.03	1096.2
¼FI	2.34	4.79	15.93	14.56	1433.7
½FI	1.59	6.31	13.93	15.57	1401.3
LSD5%	0.09	0.15	0.31	0.21	

2.3 EFFECT OF THE INTERACTION BETWEEN IRRIGATION AND CUTTING ON GROWTH AND YIELD

2.3.1 Plant Growth and Yield

Dry Matter Yield

There was a significant interaction between irrigation and cutting (Table A.31) which reflected the varying responses to different cutting treatments by plants receiving or not receiving irrigation. For example, plants cut more severely or later generally benefitted to a greater extent from irrigation than those uncut or cut lightly and early (¼VG). This was very evident in the ½VG and ¼FI treatments.

Branch Number

The significant interactions between irrigation and cutting presented in Table A.32, generally highlighted the greater stimulus to branching by irrigation of those plants cut more severely or later. This was probably most clearly demonstrated at the final harvests (54 days after peak flowering).

Leaf Number

Once again the significant interactions between irrigation and cutting (Table A.33) reflected the importance of irrigation, in this case in terms of leaf number, to those plants subjected to late and severe cutting. In several cases (harvests) irrigation enabled complete recovery from severe and late cutting - which was not always as evident in the non-irrigated cutting treatments.

Table A.31 INTERACTION BETWEEN IRRIGATION AND CUTTING ON DRY MATTER YIELD PER PLANT AT SUCCESSIVE HARVESTS IN SIRATRO (g/pl)

Cutting Treatment	Harvesting Times													
	FI		PF		7DAPF		14DAPF		26DAPF		40DAPF		54DAPF	
	W1	W2	W1	W2	W1	W2	W1	W2	W1	W2	W1	W2	W1	W2
Co	3.57	3.63	16.1	20.0	19.4	22.4	36.9	36.4	33.9	44.4	43.3	45.5	49.3	50.6
¼VG	4.63	4.90	15.5	16.6	20.1	24.3	37.8	44.5	44.2	44.7	46.4	47.4	55.1	55.1
½VG	2.83	3.10	14.1	15.4	19.2	31.4	25.2	36.2	44.8	48.5	38.4	51.1	60.4	63.2
¼FI	3.23	3.23	12.7	14.3	22.2	28.9	33.2	37.8	44.4	49.6	55.2	60.7	60.5	64.3
½FI	2.53	2.70	12.7	14.9	17.4	21.3	20.9	29.8	44.7	54.4	55.9	57.3	57.4	59.8
Significance	**		**		**		**		**		**		**	
LSD A	0.53		1.21		1.10		1.30		1.38		1.30		0.99	
5% B	0.39		1.04		0.80		0.88		1.05		1.30		0.96	

A = LSD for differences between subplot treatments for different main plot treatments.
B = LSD for differences between subplot treatments for the same main plot treatment.

Table A.32 INTERACTION BETWEEN IRRIGATION AND CUTTING ON TOTAL BRANCH NUMBERS PER PLANT AT SUCCESSIVE HARVESTS IN SIRATRO

Cutting Treatment	Harvesting Times									
	7DAPF		14DAPF		26DAPF		40DAPF		54DAPF	
	W1	W2	W1	W2	W1	W2	W1	W2	W1	W2
Co	10.3	13.0	14.7	16.0	14.7	16.3	16.7	19.3	18.0	19.3
¼VG	16.0	17.7	18.0	21.7	21.3	24.3	23.3	24.3	23.7	24.7
½VG	13.0	15.0	15.7	17.7	18.3	19.7	20.7	22.3	21.3	23.8
¼FI	14.0	14.3	16.0	18.3	17.7	20.3	18.3	22.0	19.0	22.3
½FI	13.0	17.3	15.3	19.0	17.0	23.3	18.7	25.0	18.7	25.3
Significance	**		**		**		**		**	
LSD A	1.7		1.8		1.9		1.6		2.5	
5% B	1.2		1.3		1.5		1.2		1.8	

A = LSD for differences between subplot treatments for different main plot treatments.

B = LSD for differences between subplot treatments for the same main plot treatment.

Table A.33 INTERACTION BETWEEN IRRIGATION AND CUTTING ON TOTAL LEAF NUMBERS PER PLANT AT SUCCESSIVE HARVESTS IN SIRATRO

Cutting Treatment	Harvesting Times							
	FI		PF		7DAPF		14DAPF	
	W1	W2	W1	W2	W1	W2	W1	W2
Co	66.3	73.3	194.3	200.0	194.0	222.7	204.0	315.3
¼VG	76.0	75.0	178.3	207.0	204.7	218.7	203.0	293.7
½VG	56.7	67.3	155.7	215.3	164.7	213.0	196.3	305.3
¼FI	69.0	69.7	144.0	192.7	169.3	209.3	195.7	319.1
½FI	40.0	53.0	140.3	174.0	153.7	197.3	194.0	286.7
Significance	**		**		**		**	
LSD A	6.2		16.7		7.0		10.7	
5% B	3.1		8.6		6.16		12.02	

A = LSD for differences between subplot treatments for different main plot treatments.

B = LSD for differences between subplot treatments for the same main plot treatment.

Leaf Area

The significant interaction between irrigation and cutting (Table A.34) demonstrated again the importance of irrigation in restoring leaf area per plant following cutting. In fact during some of the earlier harvests cutting plus irrigation resulted in a significant and positive response in leaf area over the uncut control while cutting without irrigation substantially reduced leaf area per plant.

Table A.34 INTERACTION BETWEEN IRRIGATION AND CUTTING ON TOTAL LEAF AREA PER PLANT AT SUCCESSIVE HARVESTS IN SIRATRO (cm^2/pl)

Cutting Treatment	Harvesting Times FI W1	FI W2	PF W1	PF W2	7DAPF W1	7DAPF W2	14DAPF W1	14DAPF W2
Co	464.7	464.0	2046.3	2093.7	2060.7	2376.3	2172.0	2462.3
¼VG	436.3	537.7	1840.3	2150.7	2116.7	2305.3	2189.7	2193.3
½VG	328.3	429.7	1664.3	2177.0	1813.0	2123.2	1998.0	2270.7
¼FI	398.0	399.3	1512.0	1939.0	1728.0	2176.0	2076.7	2405.0
½FI	236.0	280.7	1450.7	1809.3	1954.7	2084.3	2023.7	2044.0
Significance	**		**		**		**	
LSD A	23.6		52.5		66.7		63.6	
5% B	24.8		62.8		61.98		49.3	

A = LSD for differences between subplot treatments for different main plot treatments.

B = LSD for differences between subplot treatments for the same main plot treatment.

2.3.2 Reproductive Growth and Seed Yield

Pod Number

The significant interaction recorded between irrigation and cutting, in terms of pod numbers per plant (Table A.35), shows that, even at the earliest harvest date (14 days after peak flowering), where the depressing effects of severe cutting and/or late cutting were clearly evident, the more severe, late cutting treatment (½FI) showed better signs of recovery than the less severe, late cutting treatment (¼FI) in the presence of irrigation. The cutting treatment suffering the greatest depression in pod numbers was ½VG. Plants in this treatment generally failed to recover as well as other cutting treatments relative to the uncut control. This trend occurred in some cases in the absence of irrigation and in other cases even in the presence of irrigation.

Table A.35 INTERACTION BETWEEN IRRIGATION AND CUTTING ON TOTAL POD NUMBERS PER PLANT AT SUCCESSIVE HARVESTS IN SIRATRO

	Harvesting Times							
Cutting Treatment	14DAPF		26DAPF		40DAPF		54DAPF	
	W1	W2	W1	W2	W1	W2	W1	W2
Co	30.0	37.0	28.0	33.0	33.0	34.3	38.3	59.3
¼VG	45.7	41.0	45.0	46.0	37.3	46.3	48.0	74.3
½VG	25.3	22.3	29.0	37.7	29.7	34.7	36.0	45.7
¼FI	25.7	28.3	30.0	33.7	41.3	45.7	45.0	55.3
½FI	24.3	30.3	29.7	33.3	41.3	45.3	53.0	63.0
Significance	**		**		**		**	
LSD A	1.6		1.8		2.1		3.9	
5% B	1.08		1.8		2.05		1.8	

A = LSD for differences between subplot treatments for different main plot treatments.

B = LSD for differences between subplot treatments for the same main plot treatment.

Seed Yield

Table A.36 shows a significant interaction between irrigation and cutting on seed yield per plant. In the early harvests (14 and 26 days after peak flowering) seed yield per plant was generally depressed by most of the cutting treatments. However compared to the uncut treatment in the 26 days after peak flowering harvest this depression was reduced in the severe late cutting (½FI) treatment. This effect was most obvious in irrigated treatment. By the 40 days after peak flowering harvest this extreme cutting treatment had recovered and even achieved significantly greater seed yields than uncut plants in the presence but not in the absence of irrigation. By the final harvest 54 days after peak flowering even non-irrigated and severely and late cut plants significantly outyielded the uncut control. In contrast plants in the severely and early cut treatment (½VG) generally appeared to suffer to a much greater extent in terms of seed yield both without and particularly with irrigation. Looking more broadly at the results it does appear that a light cutting particularly at the vegetative stage without irrigation and even a later stage with irrigation can result in a significant increase in seed yield compared with an uncut treatment.

Table A.36 INTERACTION BETWEEN IRRIGATION AND CUTTING ON TOTAL SEED YIELD PER PLANT AT SUCCESSIVE HARVESTS IN SIRATRO IN THE DRY SEASON PLANTING (g/pl)

Cutting Treatment	Harvesting Times 14DAPF W1	14DAPF W2	26DAPF W1	26DAPF W2	40DAPF W1	40DAPF W2	54DAPF W1	54DAPF W2
Co	3.24	3.78	3.40	8.74	12.55	10.36	11.74	14.04
¼VG	3.03	3.19	6.82	11.04	16.16	14.26	15.13	16.99
½VG	1.95	1.95	3.52	5.35	13.14	11.21	12.75	11.32
¼FI	2.65	2.03	3.40	6.19	15.43	16.38	13.20	15.92
½FI	1.18	2.00	4.22	8.40	12.40	15.83	16.18	14.95
Significance	**		**		**		**	
LSD A	.14		.25		.39		.38	
5% B	.12		.21		.44		.30	

A = LSD for differences between subplot treatments for different main plot treatments.

B = LSD for differences between subplot treatments for the same main plot treatment.

DISCUSSION

This dry season field experiment clearly indicated that *Stylosanthes hamata* cv Verano and *Macroptilium atropurpureum* cv Siratro are responsive to irrigation and to cutting.

In Verano stylo there was only a small response in plant dry weight, leaf number, leaf area and branch number to irrigation during the dry season. Nevertheless the response was significant. Irrigation also increased seed yield, with irrigated plants producing about 25% more seed yield than non-irrigated plants (W1=1052 kg/ha and W2=1455 kg/ha). Cut plants also responded to irrigation differently. Verano stylo, if irrigated every 4 days up to 2 weeks after peak flowering 94 days after sowing), actually benefitted in terms of seed yield from light or heavy cutting during the vegetative growth stage and also light cutting at floral initiation compared to uncut plants (Co=1430 kg/ha, ¼VG=1623 kg/ha, ½VG=1550 kg/ha, and ¼FI=1520 kg/ha). This was due to the high number of seedheads produced in the presence of irrigation water. However, if Verano stylo was grown without irrigation, plants could only be lightly cut from the vegetative stage up to floral initiation without reducing seed yield (Co=1128 kg/ha, ¼VG=1205 kg/ha and ¼FI=1136 kg/ha). Similar results were also found by Wilaipon *et al.* (1979) in Verano stylo. Gutteridge (1982) found that the dry season interrupted flower and seed formation and resulted in decreased seed yield in Verano stylo at Khon Kaen, Thailand. He also found that flowering and seed yield in Verano stylo were influenced principally by grazing and moisture stress. If grazing occurred after moisture became limiting, restoration of floral sites declined and reduced seed yield. It has been shown in this study that heavily cut plants without irrigation gave lower seed yields than uncut and lightly cut plants.

Siratro plant dry weight response to irrigation during the dry season was better than in Verano stylo even though the response was again not very high. Irrigated plants gave a maximum of only about 10% higher seed yield than non-irrigated plants. At some stages non-irrigated and irrigated plants gave similar seed yields. Plant dry matter yield, leaf number, leaf area and branch number were all increased by water at all harvesting times. Irrigation also delayed optimum harvesting time by about two weeks in some cutting treatments. The results show that Siratro was susceptible to both irrigation and dry conditions in this study and was capable of producing high seed yields in both cut and uncut plants. Humphreys (1979) showed that moisture supply to the seed crop can be manipulated to influence the maximum number of inflorescence sites. He also found that Siratro produced more seed under a restricted and intermittent watering management than when plants were maintained near field capacity. Gutteridge (1982) found in his study with Siratro in a dry year at Khon Kaen, that dry conditions appeared to trigger flowering with resultant higher floral density compared to a wet year. The results from this study also show that cut plants, whether irrigated or not, gave higher seed yields than uncut plants. The higher seed yield obtained following cutting was due to the production of high numbers of branches and pods. This high seed yield was also thought to be due to observed increases in the length of the primary branches left after cutting. This branch elongation was thought to produce more sites for inflorescence and pod formation. Certainly, a similar conclusion was made by Gutteridge (1982) who showed that even in a dry year Siratro appeared to be well suited to utilizing the period after grazing for flowering and seed formation because of its tolerance to moisture stress.

PART B: WET SEASON PLANTING

The wet season planting of Verano stylo and Siratro began in May, 1980. In order to obtain a more even and uniform stand Stylo seeds were sown in 4 cm diameter plastic bags during the last week of May and then transplanted into the field 3 weeks later. Siratro seeds were sown directly into the field in mid May.

Verano stylo plants reached their vegetative cutting stage of growth 45 days after transplanting (65 days after sowing). Siratro plants reached the vegetative cutting stage 50 days after sowing. Plants grown in the wet season took longer to reach the floral initiation stage than plants grown in the dry season. Siratro reached the floral initiation stage 75 days after sowing compared to 60 days after transplanting (80 days after sowing) for Verano stylo. Both Verano stylo and Siratro took a long time to reach a flowering peak, i.e. about 155 days after sowing for Verano stylo and 170 days for Siratro. By that stage the plants in both species were very large (Plates 5 and 6). The final seed harvest was carried out 40 days after peak flowering (195 days after sowing) in Verano stylo and 54 days after peak flowering (224 days after sowing) in Siratro.

SECTION 1 EFFECT OF CUTTING ON VEGETATIVE AND REPRODUCTIVE DEVELOPMENT IN *STYLOSANTHES HAMATA* CV VERANO

1.1 PLANT GROWTH AND YIELD

Dry Matter Yield

There was a significant difference in plant dry weight between cut and uncut plants recorded at successive harvests (Table B.1). At the early harvesting times uncut plants had a significantly higher yield than cut plants. However, from the peak flowering stage onwards cut plants generally produced significantly higher dry matter yields than uncut plants. Maximum dry weight was obtained 7 days after peak flowering. At this stage plants lightly cut at the vegetative stage (¼VG)

Plate 5 Well grown Verano stylo plants in the wet season.

Plate 6 Well grown Siratro plants in the wet season.

had the highest vegetative yield followed by plants cut at floral initiation (¼FI or ½FI) (Table B.1). The reduction in plant dry matter yield which occurred progressively from the maximum at 7 days after peak flowering presumably reflected plant senescence, including leaf fall.

Table B.1 PLANT DRY MATTER YIELD ON CUT AND UNCUT PLANTS AT SUCCESSIVE HARVESTS OF VERANO STYLO IN THE WET SEASON (g/plant).

Cutting Treatment	Harvesting Times						
	VG	FI	PF	7DAPF	14DAPF	26DAPF	40DAPF
Co	1.46	3.42	58.13	60.77	57.03	52.83	52.43
¼VG	1.10	2.80	64.60	66.10	59.23	55.17	54.30
½VG	1.00	3.05	63.10	63.17	53.73	54.10	54.77
¼FI		2.91	60.60	65.20	54.23	56.03	54.47
½FI		2.34	58.80	65.47	59.57	55.50	54.93
LSD5%		0.22	1.23	1.37	0.65	1.03	1.66

Branch Number

The fluctuations in numbers of branches in the different cutting treatments relative to the uncut control are difficult to interpret. However it is interesting that branching continued to occur in all but the uncut and most lightly cut treatments right up to the final harvest.

Table B.2 TOTAL BRANCH NUMBERS PER PLANT ON CUT AND UNCUT PLANTS AT SUCCESSIVE HARVESTS OF VERANO STYLO IN THE WET SEASON

Cutting Treatment	Harvesting Times					
	FI	PF	7DAPF	14DAPF	26DAPF	40DAPF
Co	27.00	54.0	74.67	84.33	95.00	92.67
¼VG	25.00	48.0	65.67	83.67	81.00	80.67
½VG	22.33	52.67	66.00	67.33	77.00	85.33
¼FI	26.67	43.67	59.33	58.67	72.00	80.00
½GI	23.33	50.33	64.00	72.00	79.00	86.67
LSD5%	.14	2.15	2.30	1.87	2.69	2.34

Leaf Number

In the wet season planting leaf numbers were recorded only 4 times (vegetative, floral initiation, peak flowering and 26 days after peak flowering). The results are presented in Table B.3.

Table B.3 TOTAL LEAF NUMBERS PER PLANT ON CUT AND UNCUT PLANTS AT SUCCESSIVE HARVESTS OF VERANO STYLO IN THE WET SEASON

Cutting Treatment	Harvesting Times			
	VG	FI	PF	26DAPF
Co	33	120.7	1043.0	3131.0
¼VG	36	91.0	1027.0	1628.3
½VG	29	81.0	1046.7	1521.0
¼FI		72.7	970.0	2212.0
½FI		59.3	938.3	1935.3
LSD5%		9.0	44.0	27.2

The results show that cutting reduced leaf numbers per plant. This effect was evident as early as halfway through the vegetative stage and continued through to floral initiation. Although the differences between treatments were less evident at peak flowering they were most striking by the final harvests, 26 days later, particularly when defoliation was early and/or severe.

Leaf Area

Leaf area per plant showed a similar trend to that previously described for leaf numbers per plant. At most harvests uncut plants had a significantly higher leaf area than cut plants (Table B.4). Only at peak flowering did plants cut at the vegetative growth stage (¼VG or ½VG) produce a similar leaf area as uncut plants.

Table B.4 TOTAL LEAF AREA PER PLANT ON CUT AND UNCUT PLANTS AT SUCCESSIVE HARVESTS OF VERANO STYLO IN THE WET SEASON (cm^2/pl)

Cutting Treatment	Harvesting Times			
	VG	FI	PF	26DAPF
Co	46.9	149.9	1431.3	4351.0
¼VG	42.8	129.1	1462.7	2320.7
½VG	31.7	115.4	1493.9	2136.7
¼FI		102.3	1361.3	3088.3
½FI		86.7	1328.3	2708.0
LSD5%		13.6	32.4	29.0

The large increase in leaf area from floral initiation to peak flowering was due to the longer time (approximately 2 months) that plants took to reach peak flowering. This allowed plants to produce large numbers of leaves.

1.2 EFFECT ON REPRODUCTIVE GROWTH AND SEED YIELD

Both cut and uncut Stylo plants started to flower 80 days after sowing and reached peak flowering at about 155 days after sowing. Unlike the dry season plants there were two main flowering periods in this wet season planting, the first occurring 115 days after sowing (about the end of August in Thailand) coincident with the first break in the wet season. When the rain started again the number of inflorescences present also began to increase reaching a more extensive peak flowering in the middle of October (about 155 days after sowing (Figure 5) (Plate 7).

Seedhead Number

There was a significant difference in seedhead numbers on cut and uncut plants at successive harvests from 7 days after peak flowering to 40 days after peak flowering.

Table B.5 TOTAL SEEDHEAD NUMBERS PER PLANT ON CUT AND UNCUT PLANTS AT SUCCESSIVE HARVESTS OF VERANO STYLO IN THE WET SEASON

Cutting Treatment	Harvesting Times			
	7DAPF	14DAPF	26DAPF	40DAPF
Co	97.3	202.7	242.3	160.3
¼VG	112.7	246.3	209.9	150.3
½VG	83.3	180.7	163.3	171.0
¼FI	85.0	141.7	168.3	124.0
½FI	97.7	189.0	192.0	163.0
LSD5%	3.7	3.4	4.4	3.9

At harvests 7 and 14 days after peak flowering plants which had received light cutting at the vegetative stage (¼VG) had significantly higher seedhead numbers than uncut plants and plants from other cutting treatments. However at

Plate 7 Close up view of Verano stylo plants at peak flowering stage.

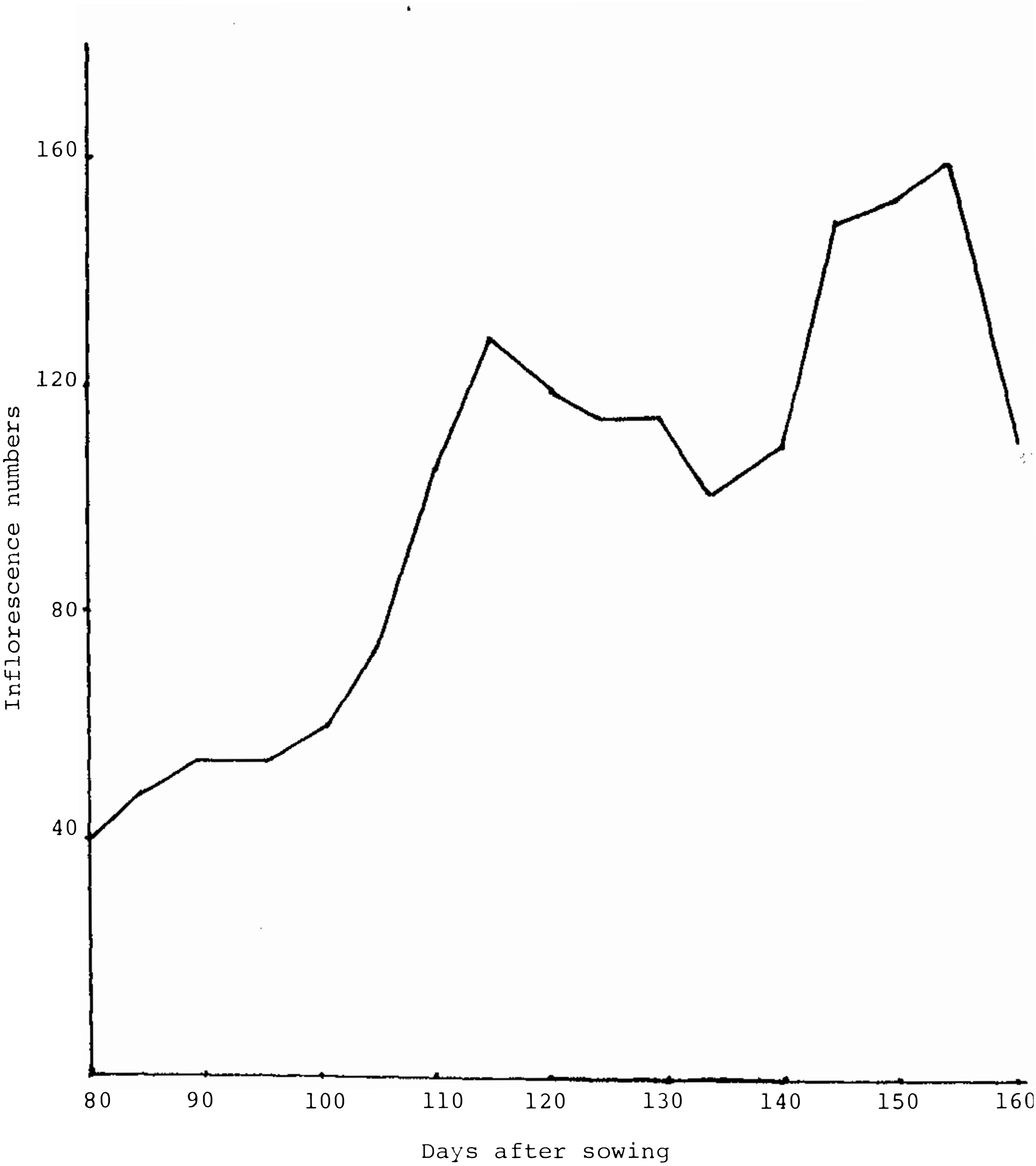


Figure 5 FLOWERING CURVE OF VERANO STYLO PLANTS IN THE WET SEASON PLANTING

subsequent harvests all cut plants showed a significant depression in seedhead numbers compared with uncut plants, except at 40 days after peak flowering when heavily cut plants at the vegetative stage (½VG) had significantly higher seedhead numbers than uncut and the other cut plants. The differences in seedhead numbers in the various cutting treatments are difficult to explain, as they show no consistent trends across successive harvests.

Seed Yield

Maximum seed yield depends strongly on the formation of large numbers of inflorescences or seedheads and the production of maximum numbers of fertile florets. In this study it was interesting that there was no cutting treatment effects on the number of seeds produced per seedhead (15-16 seeds per seedhead) or on 100 seed weight (0.29-0.30 g) (Appendix 3). This suggests that the maximum seed yield obtained at 26 days after peak flowering was mainly determined by the number of inflorescence produced.

Table B.6 TOTAL SEED YIELD PER PLANT ON CUT AND UNCUT PLANTS AT SUCCESSIVE HARVESTS OF VERANO STYLO IN THE WET SEASON (g/pl)

Cutting Treatment	Harvesting Times				
	7DAPF	14DAPF	26DAPF	40DAPF	Max.Seed Yield kg/ha
Co	3.08	5.85	10.90	4.94	2725
¼VG	3.50	7.81	9.66	5.30	2415
½VG	2.50	5.77	7.93	4.40	1983
¼FI	1.77	3.57	7.72	3.55	1930
½FI	2.64	4.86	7.88	4.26	1970
LSD5%	0.37	0.17	0.12	0.13	

In Table B.6 the results show that cutting Verano stylo plants in the wet season generally depressed seed yield. The extent of this depression generally reflected the stage of growth at the time of cutting and cutting severity. In particular, late cutting (floral initiation) and severe cutting (½ canopy removal) were particularly damaging. Early and lightly cut plants (¼VG) were least affected. In fact at 7, 14 and 40 days after peak flowering there was an apparent stimulation of seed yield in plants lightly cut during the vegetative stage (¼VG). However, maximum seed yield occurred in all treatments 26 days after peak flowering. By 40 days after peak flowering seed yield reduction due to shedding became severe. Multiplication of maximum per plant yield by a plant density of 250,000 plants/hectare allowed a conversion to maximum seed yield in kg/ha. This conversion appears in the right hand column of Table B.6. The most extreme seed yield reduction (approximately 25%) occurred between uncut plants (2725 kg/ha) and plants cut at floral initiation (¼FI-1930 kg/ha and ½FI=1970 kg/ha).

SECTION 2 EFFECT OF CUTTING ON VEGETATIVE AND REPRODUCTIVE DEVELOPMENT IN SIRATRO

2.1 PLANT GROWTH AND YIELD

Dry Matter Yield

There was a significant difference in plant dry matter yield between cut and uncut Siratro plants at successive harvests during the wet season.

The results in Table B.7 show that plants lightly cut at the vegetative stage (¼VG) generally produced a significantly higher plant dry weight than uncut plants particularly at later harvests. Even plants cut severely at the vegetative stage (½VG) were able to reach a final dry weight greater than uncut plants. However plants which were cut late, either heavily or lightly, showed a significant depression in dry matter yield.

Table B.7 DRY MATTER YIELD PER PLANTS AT SUCCESSIVE HARVESTS ON CUT AND UNCUT PLANTS OF SIRATRO IN THE WET SEASON (g/pl)

Cutting Treatment	Harvesting Times							
	VG	FI	PF	7DAPF	14DAPF	26DAPF	40DAPF	54DAPF
Co	3.77	45.63	465.5	588.6	520.2	566.6	584.9	556.7
¼VG	2.73	61.37	445.0	560.0	556.9	603.0	652.7	650.2
½VG	2.43	52.60	454.1	585.0	543.8	577.4	654.4	647.0
¼FI		46.37	406.0	451.5	484.0	485.7	510.2	513.3
½FI		41.7	422.5	441.2	453.2	467.5	483.0	487.3
LSD5%		1.63	25.77	25.26	24.01	20.45	26.06	22.07

Branch Number

Cut plants seemed to produce significantly higher branch numbers than uncut plants (Table B.8). This stimulation to branching by cutting was consistent at successive harvests. Although the effect of cutting on branching was not evident until the peak flowering stage, plants which were cut late (floral initiation) either lightly or heavily produced significantly higher branch numbers than uncut plants and other cut plants. This increase in branching due to cutting resulted in plants with up to approximately 50% more branches at 26 days after peak flowering compared with uncut plants.

Table B.8 TOTAL BRANCH NUMBERS PER PLANT AT SUCCESSIVE HARVESTS ON CUT AND UNCUT PLANTS OF SIRATRO IN THE WET SEASON

Cutting Treatment	Harvesting Times							
	VG	FI	PF	7DAPF	14DAPF	26DAPF	40DAPF	54DAPF
Co	6	9.0	9.0	13.7	15.7	18.0	19.7	21.3
¼VG	5	9.0	13.7	18.3	18.3	23.3	24.3	25.0
½VG	5	9.0	10.7	17.7	19.7	22.7	25.0	26.0
¼FI		9.0	12.3	19.0	21.0	28.0	28.7	28.7
½FI		9.0	14.0	20.0	22.7	28.3	27.7	28.7
LSD5%		NS	1.8	1.9	2.0	1.9	1.6	1.6

Leaf Number

In this wet season planting leaf numbers were only recorded at 3 harvests. The results are presented in Table B.9 and show that cutting significantly reduced leaf numbers compared with uncut plants, except that at the peak flowering stage plants cut at an early stage (¼VG or ½VG) had similar leaf numbers to uncut plants.

Table B.9 TOTAL LEAF NUMBERS PER PLANT AT SUCCESSIVE HARVESTS ON CUT AND UNCUT PLANTS OF SIRATRO IN THE WET SEASON

Cutting Treatment	Harvesting Times VG	FI	PF
Co	93	246.0	509.0
¼VG	66	161.3	508.0
½VG	60	145.3	512.3
¼FI		138.0	388.3
½FI		107.3	435.3
LSD5%		14.1	21.5

Leaf Area

The results presented in Table B.10 show that at the vegetative and floral initiation stages uncut plants had a significantly higher leaf area than cut plants. However, when cut plants reached the peak flowering stage, plants cut early (¼VG or ½VG) had a significantly higher leaf area than uncut plants. By comparison late cut plants were unable to fully recover leaf area by the peak flowering stage.

Table B.10 TOTAL LEAF AREA PER PLANT AT SUCCESSIVE HARVESTS ON CUT AND UNCUT PLANTS OF SIRATRO IN THE WET SEASON (cm^2/pl)

Cutting Treatment	Harvesting Times VG	FI	PF
Co	455.3	1897	5392
¼VG	332.3	1296	5551
½VG	292.3	982	5486
¼FI		948	4215
½FI		747	4579
LSD5%		97	75

2.2 EFFECT ON REPRODUCTIVE GROWTH AND SEED YIELD

There was no significant difference in the flowering dates between cut and uncut plants. Siratro plants started to flower about 75 days after sowing and reached peak flowering at 170 days after sowing. It appears that Siratro, like Stylo, has the capacity to exhibit two main flowering periods in a wet season sowing. The first occurs at the commencement of the mid-break of the rainy season about 115 days after sowing and the second follows the end of the rainy season, at the onset of the dry season, to reach peak flowering about 170 days after sowing (Figure 6) (Plate 8). This capacity for the production of two flowering periods in wet season sown plants was not evident in the dry season sowing even when Siratro plants received irrigation.

Pod Number

The results in Table B.11 show that at the harvests 26 to 54 days after peak flowering cut plants seemed to have higher or similar pod numbers per plant to uncut plants. This effect however, was not as obvious during the earlier stages of seed development 14 days after peak flowering. By the final harvest, plants which were heavily cut at the vegetative stage (½VG) had produced significantly more pods per plant than uncut plants or other cut plants (Table B.11).

Table B.11 TOTAL POD NUMBERS PER PLANT ON CUT AND UNCUT PLANTS AT SUCCESSIVE HARVESTS OF SIRATRO IN THE WET SEASON

Cutting Treatment	Harvesting Times			
	14DAPF	26DAPF	40DAPF	54DAPF
Co	38.0	37.3	49.0	75.3
¼VG	35.7	47.3	57.3	73.7
½VG	30.0	49.3	53.3	87.0
¼FI	23.3	41.0	54.7	73.0
½FI	27.3	44.3	49.3	77.0
LSD5%	2.69	2.8	2.9	3.5

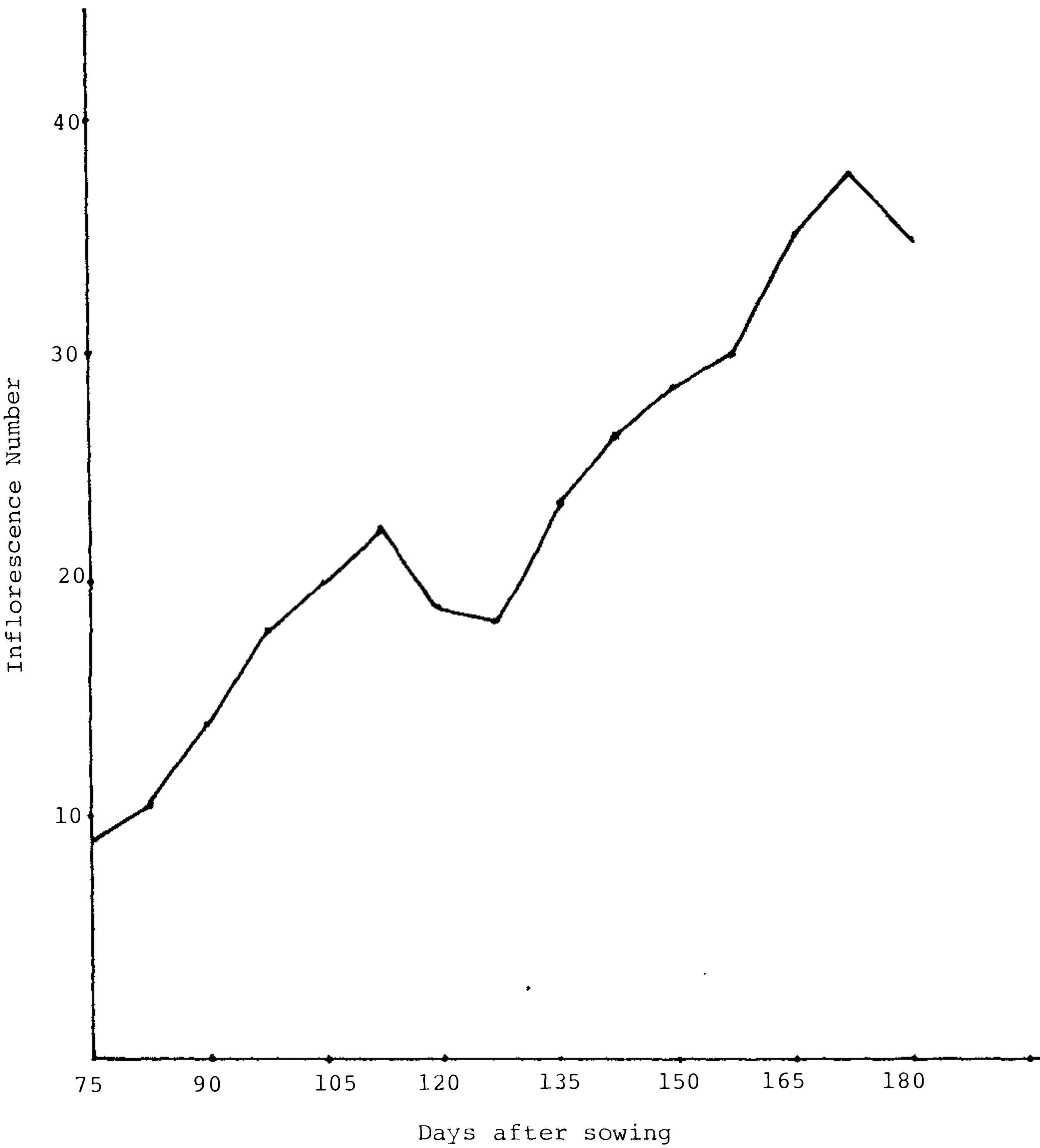


Figure 6 FLOWERING CURVE OF SIRATRO PLANTS IN THE WET SEASON PLANTI

Plate 8 Closed up view of Siratro plants at peak flowering stage in the wet season.

Seed Yield

Seed yield in Siratro depends on the number of inflorescences, number of pods and number of seeds per pod.

Cut and uncut plants reached maximum seed yield at different times. The results in Table B.12 show that Siratro plants which had been heavily cut at the vegetative stage had the highest yield of 12.77 g/pl at 54 days after peak flowering. Uncut plants, and those plants heavily cut at floral initiation (½FI) also had their maximum seed yield at this stage (10.29 g and 10.19 g per plant respectively). It appears that heavily cut plants develop reproductive growth better and somewhat later than lightly cut plants in the wet season. Also, pod number was the major determinant of seed yield since cutting had no effect on number of seeds per pod (15-16) or 100 seed weight (1.8-1.9 g) (Appendix 4). Certainly a maximum seed yield of 12.77 g/pl which is equivalent to a yield of 1149 kg/ha at a plant density of 90,000 plants per hectare is considered to be good by commercial standards. This stimulation of pod production by severe cutting carried out during the vegetative stage, suggests that useful forage can be obtained from Siratro seed crops without any reduction, and often an increase, in seed yield.

Table B.12 TOTAL SEED YIELD PER PLANT AT SUCCESSIVE HARVESTS ON CUT AND UNCUT PLANTS OF SIRATRO IN THE WET SEASON (g/pl)

	Harvesting Times				
Cutting Treatment	14DAPF	26DAPF	40DAPF	54DAPF	Max.Seed Yield kg/ha
Co	.96	3.75	6.54	10.29	926.1
¼VG	2.37	4.50	9.22	9.76	878.4
½VG	1.23	5.00	7.36	12.77	1149.3
¼FI	.89	3.02	8.64	7.35	777.6
½FI	1.30	3.25	6.14	10.19	917.1
LSD5%	0.08	0.11	0.21	0.24	

PART C SEED QUALITY

The results from the field experiments show that there was only a slight difference in the quality of seed of Verano stylo and Siratro obtained at successive harvests following dry season (with and without irrigation) and wet season plantings. At each harvest seed samples were tested for germination, moisture content and hard seed content. In each species four harvests were made with seed being removed from plants 7, 14, 26 and 40 days after peak flowering in Verano stylo and 14, 26, 40 and 54 days after peak flowering in Siratro.

C.1 *STYLOSANTHES HAMATA* CV. VERANO

Seed Moisture Content

The seed moisture content values obtained at different harvesting times in each of the dry season treatments (W1, W2) and during the wet season (W3), were not affected by water (Table C.1) or by cutting (Table C.2). Seed moisture content was found to be initially high (59-61%) at the stage 7 days after peak flowering (Table C.1). It then declined gradually until finally it reached 36-38% at the stage of maximum seed dry weight 26 days after peak flowering. Subsequent dehydration continued until seed reached moisture content of 16-17% 40 days after peak flowering. At the stage 26 days after peak flowering seed started to shatter, shattered seeds having a moisture content of approximately 6-7%.

Table C.1 SEED MOISTURE CONTENT PERCENTAGE AT SUCCESSIVE HARVESTS IN DRY SEASON NON-IRRIGATED (W1), IRRIGATED (W2) AND WET SEASON (W3) PLANTING OF VERANO STYLO

Irrigation Treatment	Harvesting Times			
	7DAPF	14DAPF	26DAPF	40DAPF
Non-Irrigated (W1)	59.6	53.3	38.0	16.5
Irrigated (W2)	60.8	54.0	36.7	16.0
Wet Season (W3)	61.0	52.6	37.6	17.0
LSD5%	NS	NS	NS	NS

The rate and extent of change in seed moisture content was also not influenced by cutting as shown in Table C.2 In both cut and uncut plants the differences in seed moisture content at each harvest between dry season (non-irrigated and irrigated) and wet season grown plants were very small. This was surprising considering the extreme contrasts in the environment between the two growing seasons and suggests that the changes in seed moisture content and the speed of dehydration during ripening in particular, are largely genetically controlled.

TABLE C.2 SEED MOISTURE CONTENT PERCENTAGE AT SUCCESSIVE HARVESTS ON CUT AND UNCUT PLANTS OF VERANO STYLO

Cutting Treatment	Harvesting Times			
	7DAPF	14DAPF	26DAPF	40DAPF
Co	58.0	53.3	38.0	17.0
¼VG	61.0	54.0	36.8	16.5
½VG	61.0	54.5	37.5	16.5
¼FI	61.5	54.9	38.5	17.0
½FI	60.5	53.5	36.5	16.0
LSD5%	NS	NS	NS	NS

Hard Seed Content

The testing of Verano stylo seeds for germination was carried out without applying any hard seed breaking treatment. It was therefore not surprising that the percentage of 'soft' seeds which produced normal seedlings was very low (0-2%). All remaining seeds were either 'hard' or 'dead'. The results presented in Table C.3 show that water, whether applied as irrigation or rainfall, had a slight effect on hard seed content during the early stages of seed development but 26 days and 40 days after peak flowering there was no significant effect. Hard seed was found on Stylo plants as early as 7 days after peak flowering when the mean seed moisture content was still very high (60-62%).

Table C.3 HARD SEED CONTENT PERCENTAGE AT SUCCESSIVE HARVESTS IN DRY SEASON NON-IRRIGATED (W1), IRRIGATED (W2) AND WET SEASON (W3) PLANTINGS OF VERANO STYLO

Irrigation Treatment	Harvesting Times 7DAPF	14DAPF	26DAPF	40DAPF
Non-Irrigated (W1)	24.6	49.0	68.3	75.7
Irrigated (W2)	25.2	51.8	68.1	76.6
Wet Season (W3)	27.4	52.2	68.8	76.0
LSD5%	1.6	1.9	NS	NS

The percentage of hardseededness, however, increased as the seed entered the ripening stage, over 68% hardseededness being obtained when seeds reached maximum dry weight 26 days after peak flowering. At the final harvest 40 days after peak flowering when most of the hooked seeds had dropped from the seedheads the level of hardseededness was over 75%. Again there were no significant differences in hard seed content between cut and uncut plants at any of the four harvests (Table C.4). This suggests that while cutting affected seeding potential it had little effect on the onset, sequence or extent of hard seed development. Again the levels of hard seed content were remarkably consistent between treatments despite widely differing growth conditions between dry season and wet season plants. This suggests that the development of this parameter is also generally under genetic control.

Table C.4 HARD SEED CONTENT PERCENTAGE AT SUCCESSIVE HARVESTS ON CUT AND UNCUT PLANTS OF VERANO STYLO

Cutting Treatment	Harvesting Times			
	7DAPF	14DAPF	26DAPF	40DAPF
Co	25.0	49.9	68.0	76.6
¼VG	24.6	50.5	68.5	75.5
½VG	23.0	51.2	67.5	76.5
¼FI	24.3	52.0	67.5	75.0
½FI	23.0	51.0	68.0	75.0
LSD5%	NS	NS	NS	NS

C.2 *MACROPTILIUM ATROPURPUREUM* CV SIRATRO

Seed Moisture Content

In both dry season (with and without irrigation) and wet season plantings Siratro seeds showed no significant difference in moisture content at harvests carried out 14, 26, 40 and 54 days after peak flowering (Table C.5). Initially, seed moisture was high at about 63%. Subsequently moisture content fell progressively until at the final harvest, it was 18-19%. Despite the large differences between the dry season and wet season environments the rate of seed drying during ripening was remarkably consistent.

Table C.5 SEED MOISTURE CONTENT PERCENTAGE AT SUCCESSIVE HARVESTS IN DRY SEASON NON-IRRIGATED (W1), IRRIGATED (W2) AND WET SEASON (W3) PLANTING OF SIRATRO

Irrigation Treatment	Harvesting Times 14DAPF	26DAPF	40DAPF	54DAPF
Non-Irrigated (W1)	63.4	53.1	28.6	19.2
Irrigated (W2)	63.5	53.4	27.3	19.7
Wet Season	63.7	53.5	27.9	18.3
LSD5%	NS	NS	NS	NS

Cutting was also shown to have no appreciable effect on moisture content at different stages of seed development (Table C.6).

Table C.6 SEED MOISTURE CONTENT PERCENTAGE AT SUCCESSIVE HARVESTS ON CUT AND UNCUT PLANTS OF SIRATRO

Cutting Treatment	Harvesting Times 14DAPF	26DAPF	40DAPF	54DAPF
Co	63.5	53.0	27.3	19.0
¼VG	63.0	53.4	28.4	19.3
½VG	63.0	53.2	27.9	19.7
¼FI	63.7	53.2	27.3	19.3
½FI	63.4	53.4	27.5	18.5
LSD5%	NS	NS	NS	NS

Germination Percentage

As previously described for Verano stylo, the germination testing of Siratro seeds was also carried out without applying any hardseed breaking treatment. Unlike Verano stylo however, Siratro showed very little hardseededness (0-5%). In Siratro the great majority of seeds either showed normal seedling development or were dead. During the period from 14 to 26 days after peak flowering water had a generally promotive effect on seed germination percentage. However by 40 and 54 days after peak flowering there were no significant differences in germination percentage (Table C.7).

Table C.7 GERMINATION PERCENTAGE AT SUCCESSIVE HARVESTS IN DRY SEASON NON-IRRIGATED (W1), IRRIGATED (W2) AND WET SEASON (W3) PLANTINGS OF SIRATRO

Irrigation Treatment	Harvesting Times 14DAPF	26DAPF	40DAPF	54DAPF
Non-Irrigated (W1)	84.6	89.8	83.0	82.5
Non-Irrigated (W2)	88.4	89.7	83.2	81.0
Wet Season (W3)	89.6	93.0	82.8	82.4
LSD5%	3.3	2.7	NS	NS

Some variation in germination percentage was observed in seed from each cutting treatment (Table C.8). However the differences were generally quite small and had disappeared in most treatments following seed maturity. There was a suggestion, however, that seeds from plants lightly cut during the vegetative stage had a slightly higher germination percentage at the final harvest than seeds from other cutting treatments. These variable effects were possibly due to differences in the proportions of green and brown pods present on plants at each harvesting time in different cutting treatments.

Table C.8 GERMINATION PERCENTAGE AT SUCCESSIVE HARVESTS ON CUT AND UNCUT PLANTS OF SIRATRO

Cutting Treatment	Harvesting Times			
	14DAPF	26DAPF	40DAPF	54DAPF
Co	84.6	84.8	80.0	82.0
¼VG	85.0	83.0	81.5	84.5
½VG	85.5	83.5	82.5	82.5
¼FI	84.5	83.0	82.5	82.0
½FI	83.0	83.0	81.0	82.5
LSD5%	NS	NS	NS	NS

DISCUSSION

This experiment was carried out in the field in the wet season and clearly indicated that both Verano stylo and Siratro grow well under tropical wet season conditions. Both species when sown at the beginning of the wet season had a relatively long vegetative growth period before reaching the reproductive stage (80 days for Verano stylo and 75 days for Siratro). They also had a relatively long period from the onset of floral initiation until plants reached peak flowering (75 days for Verano stylo and 95 days for Siratro). The pattern of flowering in both species showed two distinct periods of intense flower production. The second period of flowering was more pronounced. [illegible] Verano stylo required water for the production of maximum numbers of sites for flower formation before the end of the wet season. This resulted in large plants with high plant dry matter yield, branch numbers, leaf numbers and leaf area as well as high seedhead numbers and seed yield (Plant DM=50-60 g/plant, seed yield range 1930-2725 kg/ha). Cut plants generally had a lower dry matter yield than uncut plants. Besides reducing dry matter yield, cutting also reduced leaf numbers and leaf area and caused a subsequent depression in both seedhead numbers and seed yield. Late and severe cutting was particularly damaging. The most extreme seed yield reduction (25%) occurred between uncut plants and plants where cutting was delayed until floral initiation. Cutting had no effect on seed numbers per seedhead (15-16) or on 100 seed weight (0.29-0.30 g). Wet season grown Verano stylo plants gave higher seed yields than comparable plants sown in the dry season. Gutteridge (1982) also found that Verano stylo was able to produce high seed yields provided flowering proceeded without plants being subjected to moisture stress after grazing had ceased.

By comparison Siratro sown at the beginning of the wet season tended to produce too much vegetative growth (500-650 g/plant), high inflorescence numbers (30-35 per plant), and pod numbers (75-87 per plant) but disappointingly low numbers of seeds per pod (10-12). Similar findings have been reported by Hopkinson (1977), Wickham (1977) and Gutteridge (1982). Cutting Siratro in the wet season increased plant dry matter yield provided cutting was carried out early. Later cutting (floral initiation) resulted in a significant depression in dry matter yield. Cutting also increased branch numbers, especially in late cut plants which produced more branches than uncut plants. Only plants which were severely cut at the vegetative or floral initiation stages (½VG and ½FI) gave higher or similar seed yields to uncut (Co) plants (Co=926 kg/ha, ½VG=1149 kg/ha and ½FI=917 kg/ha). All other cutting treatments reduced seed yield. Cutting had no effect on the number of seeds per pod (10-12) or 100 seed weight (1.8-1.9 grams per plant). A stimulation of pod production in plants subjected to severe cutting suggests that heavy cutting particularly during the vegetative stage can allow useful quantities of forage to be obtained from Siratro seed crops without a reduction (and often an increase) in seed yield. Similar results have also been reported by Jones (1974) who showed that Siratro can tolerate severe cutting and still give high seed yields provided a sufficiently long recovery interval is allowed prior to the plants becoming reproductive.

Studies on the quality of the seed produced by both Verano stylo and Siratro showed that dry season (with or without irrigation) or wet season conditions had little or no effect on seed moisture content, hard seed content or seed germination. Verano stylo however showed a very high hard seed content compared with Siratro (75% in Verano stylo and 0-5% in Siratro). Cutting also had no effect on these parameters of seed quality.

CHAPTER 3

EFFECT OF WATER AND CUTTING ON *STYLOSANTHES HAMATA* CV VERANO UNDER CONTROLLED ENVIRONMENT CONDITIONS

INTRODUCTION

The results obtained from the field studies at Khon Kaen in Thailand revealed some interesting differences between the legumes concerned in their response to rainfall and irrigation, to water stress and to defoliation. Any of these differences were worthy of further study to explain the mechanism involved. Of particular interest, however, was the apparently amazing ability of Verano stylo to not only persist under 90 days of severe drought conditions but also to subsequently produce a seed yield which was only 25% less than that produced by plants in the fully irrigated treatment. Furthermore, there was strong evidence to indicate that not only was Verano stylo tolerant to light and timely cutting but was even stimulated by such defoliation in terms of seed yield.

It was therefore decided to investigate these effects of water stress and cutting on Verano stylo in greater detail in the controlled environment rooms at Plant Physiology Division, DSIR, Palmerston North, where it was possible to simulate the climate prevailing in Thailand and also to examine plant response more closely. A further factor in this decision was the relative ease of handling the more-erect legume Verano stylo compared with the more difficult trailing habit of Siratro. It was also felt that controlled environment conditions could be profitably used to identify the sites of formation, longevity and fate of buds and inflorescences on individual branch orders and their relative contribution to seed yield.

The effects of both cutting and simulated drought conditions were studied in this experiment, the objective of this study being:

1. To study the plants' reaction to simulated drought conditions applied at different stages of growth.
2. To determine those plant morphological changes which occur after cutting plants to different levels at different stages of growth.
3. To study the sites of inflorescence and seed formation on different branch orders and their contribution to total seed yield.

MATERIALS AND METHODS

Seeds of *Stylosanthes hamata* cv. Verano obtained from the final harvest of the field experiment in Thailand were used in this study.

A. POT PREPARATION

North Carolina Mixture (Coarse Gravel:Peat:Vermiculite 70:15:15 v/v) was placed in 1 gallon pots at 6 kg per pot, with 15 pots per trolley. The pots were fully watered and allowed to drain before sowing. Seeds were scarified using hot water treatment at 80^{o}C for 10 minutes before being sown at about 5-8 seeds per pot. The pots were placed on trolleys and moved into the controlled environment room. 120 pots were sown initially, this number being reduced to the most uniform 105 plants (7 trolleys per room) for use in the experiment.

B. SEEDLING EMERGENCE AND THINNING

Most seedlings emerged 3 days after sowing and were subsequently thinned to 1 plant per pot approximately 10 days after sowing (Plate 3.1).

C. CONTROLLED ENVIRONMENT ROOM CONDITIONS

The levels of environment imposed on plants during their growth in the controlled environment are described in Appendix 3.1. Briefly, these involved an alternating day/night temperature of 30^{o}C/20^{o}C, 12 hours daylength and day/night relative humidity of 70%/90%. There were no

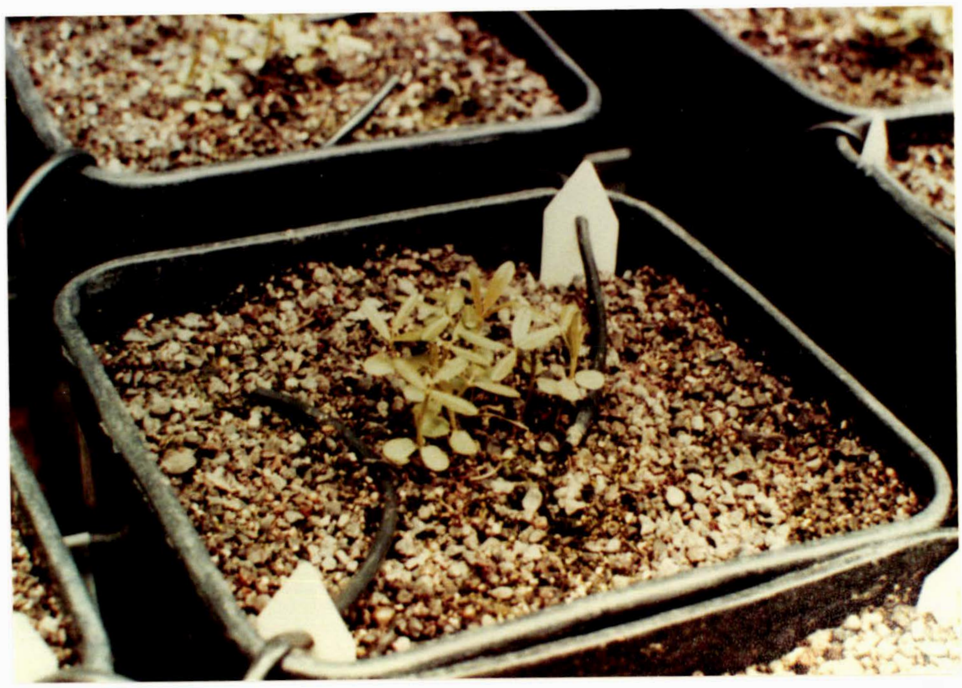


Plate 3.1 *Stylosanthes hamata* cv Verano seedlings 10 days after sowing.

significant departures from the required conditions of temperature, humidity or light levels during the experimental period of 5 months.

D. TREATMENTS

There were 5 cutting treatments used in this experiment. These were similar to those used in the field experiment in Thailand, i.e.

Stage of Growth

1. Vegetative cut - when Verano stylo had 5-6 primary branches (30 days after sowing)

2. Floral initiation cut - when 30-50% of Verano stylo plants showed floral bud formation (40 days after sowing)

Cutting Height

1. Verano stylo plants were cut to remove ¼ of plants' canopy height.

2. Verano stylo plants were cut to remove ½ of plants' canopy height.

Control

Uncut

The five cutting treatments can be listed as follows:

1. Control uncut (Co) Plate 3.2 a,b,c
2. Plants cut at vegetative growth stage to remove ¼ of plants' canopy height (¼VG) Plate 3.2a
3. Plants cut at vegetative growth stage to remove ½ of plants' canopy height (½VG) Plate 3.2a
4. Plants cut at floral initiation stage to remove ¼ of plants' canopy height (¼FI) Plate 3.2 b,c
5. Plants cut at floral initiation stage to remove ½ of plants' canopy height (½FI) Plate 3.2 b,d

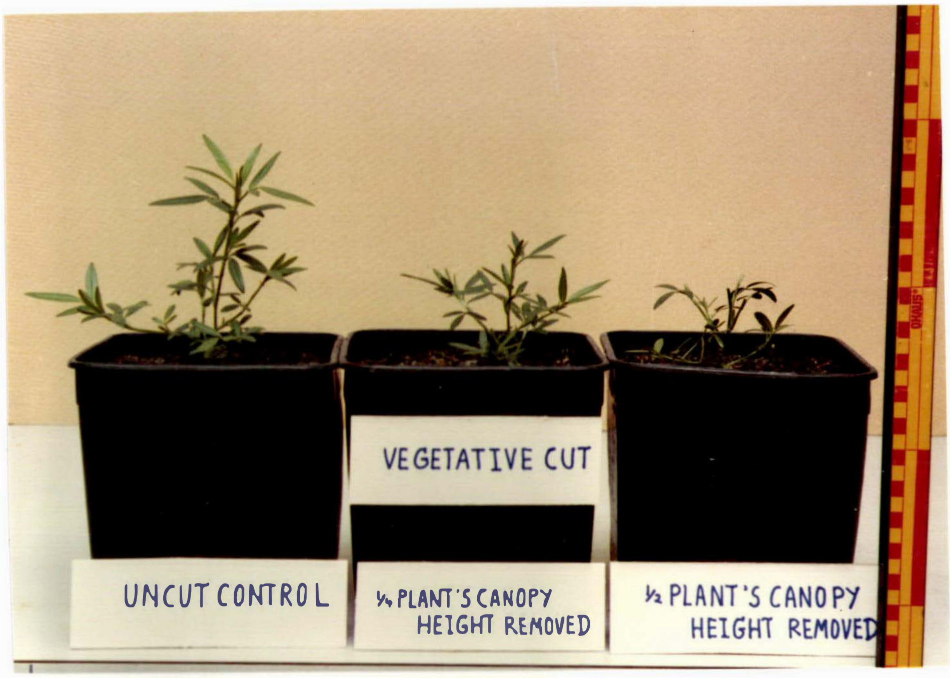


Plate 3.2a Uncut (Co) and cut plants at vegetative growth stage (¼VG and ½VG) 30 days after sowing.

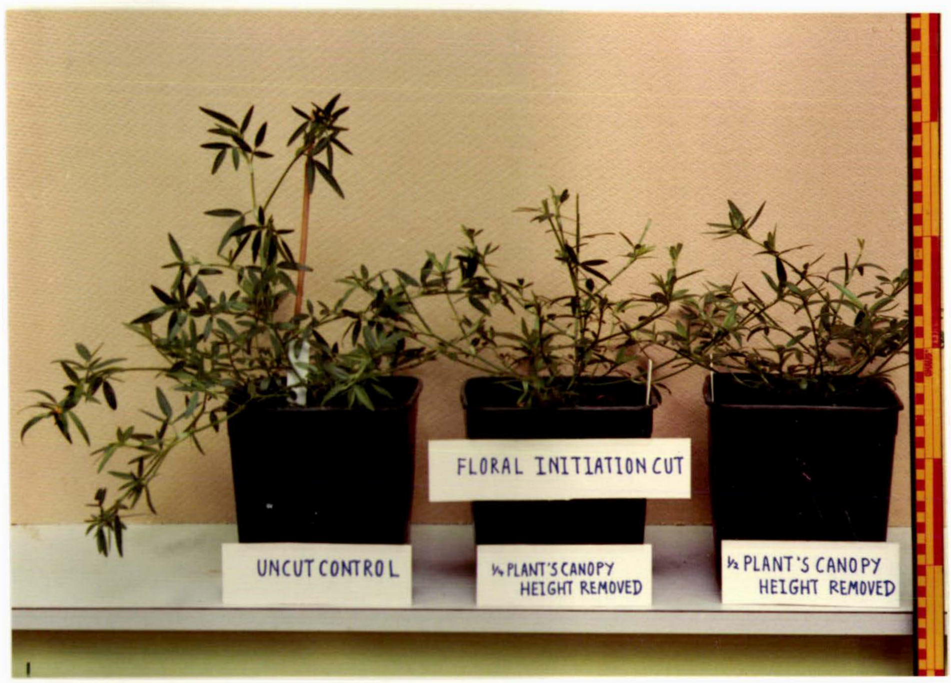


Plate 3.2b Uncut (Co) and cut plants at floral initiation growth stage (¼FI and ½FI) of W2 and W3 treatments 40 days after sowing.

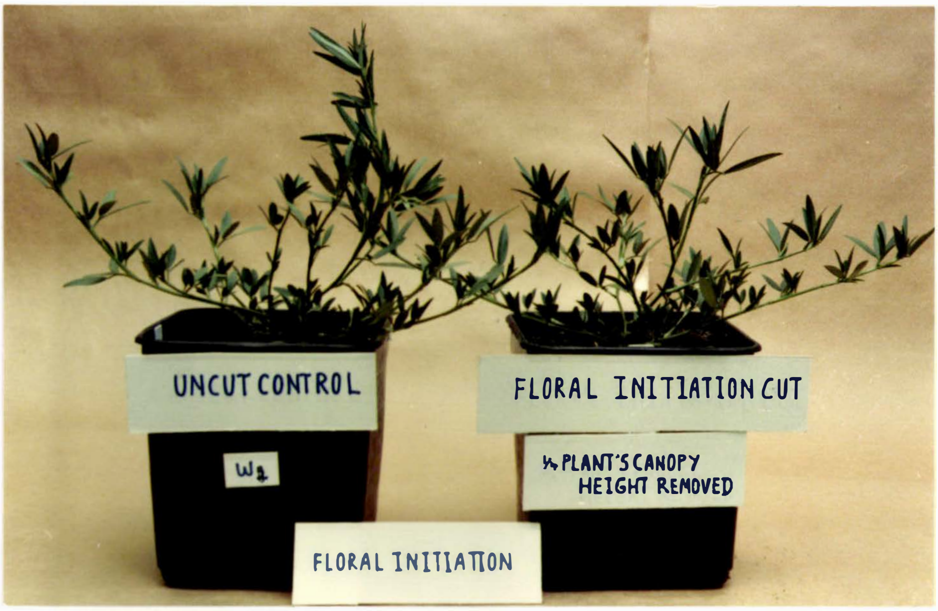


Plate 3.2c Uncut (Co) and ¼ of plant canopy removed at floral initiation growth stage (¼FI) of W1 treatment.

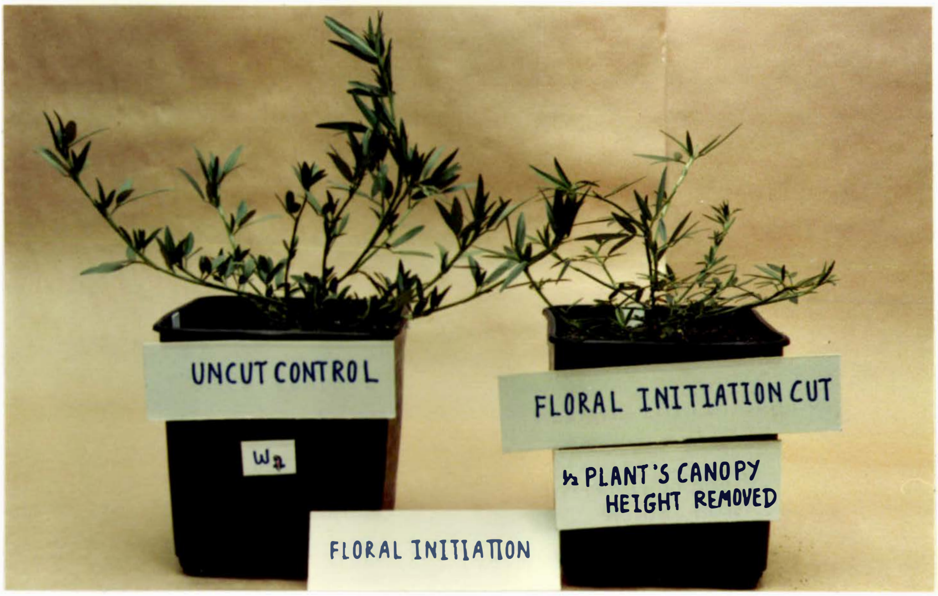


Plate 3.2d Uncut (Co) and ½ of plant canopy removed at floral initiation growth stage (½FI) of W1 treatment.

2. Water Treatments

The chosen water treatments involved 'high' and 'low' soil water levels. The 'high' soil water level was maintained as near as possible to a field capacity level of 25% soil moisture content. The 'low' soil water level was maintained at 2-7% soil moisture content (pF 2.6-2.85). The 3 different water treatments used in this experiment were as follows (Table A.3.1):

Table A.3.1 WATERING SCHEDULE

	VEGETATIVE (W1)	PEAK FLOWERING (W2)	CONTROL WATER (W3)
Sowing	+	+	+
Vegetative Cut (30 days after sowing)	-	+	+
Floral Initiation (40 days after sowing)	-	+	+
Peak Flowering (49-55 days after sowing)	-	+	+
15DAPF	-	-	+
20DAPF	-	-	+
25DAPF	-	-	+
30DAPF	-	-	+

+ 'high' water level, with plants being watered 4 times daily

- 'low' water level:
  - W1 300 ml/2 days by hand
  - W2 300 ml/day by hand

In the middle of each pot a gypsum block was embedded for measuring the soil moisture tension. A Wheatstone Bridge was connected to the gypsum block for reading the pF value. The pF value was kept in the range of 2.6-2.85 which had been established as being equal to a soil moisture content of 2-7%. At this soil moisture content and pF value the relative water content (RWC) of the leaf was also measured and maintained at about (pF2.85) 70% to make sure that plants were under moisture stress.

a. Treatment W1

This treatment involved a 'high' level watering from sowing to halfway through the vegetative stage (30 days after sowing), followed by the maintenance of a 'low' soil water level from the vegetative cut stage to 30 days after peak flowering. The pots were automatically watered using nutrient NCSU solution (Appendix 3.2) applied through the watering tubes 4 times daily at 6 hourly intervals until the 5th or 6th primary branch appeared (30 days after sowing). The automatic watering tubes were then removed and watering continued by hand. Following the cessation of watering the RWC and soil moisture content fell to the point where pF value was 2.85 and RWC was 70% when the plants wilted. This occurred approximately 8 days after watering was stopped. In this treatment plants were merely maintained at a 'Survival' level by 300 ml of NCSU nutrient solution being added every two days for the remainder of the experiments.

b. Treatment W2

This treatment involved a 'high' level watering from sowing to peak flowering (55 days after sowing), followed by the maintenance of a 'low' water level from peak flowering (55 days after sowing) to 30 days after peak flowering. The pots were watered using NCSU solution through the water tubes automatically 4 times daily at 6 hourly intervals until peak flowering. At this stage the automatic watering tubes were removed and watering was continued by hand to the specific low soil moisture content. In this treatment (W2) visible wilting occurred 68 hours after the cessation of watering at a soil pF value of 2.85 and leaf RWC of 70%. Since plants at this stage were bigger and consumed more water than plants in W1 treatment, 300 ml of NCSU was applied every 24 hours.

During the stress period the leaves also became visibly closed during most of the photoperiod. Four to six hours after applying water the leaves recovered from stress and closed again before the next rewatering when the soil pF neared 2.85 and RWC was 70-80%.

c. Treatment W3 Control

This treatment involved the maintenance of a 'high' soil water level from sowing to 30 days after peak flowering (85 days after sowing). The pots were automatically watered using NCSU solution 4 times daily at 6 hourly intervals throughout the experiment.

E. HARVESTING SCHEDULE

Seven harvests were carried out during the experiment. These allowed a comparison of water and cutting effects on vegetative development and subsequently on seed yield components. Three plants from each treatment were used at each harvest time.

Harvest	Days after sowing	Time of Harvest
1	30	Vegetative stage cut
2	40	Floral initiation stage cut
3	49-55	Peak flowering
4	70	15 days after peak flowering
5	75	20 days after peak flowering
6	80	25 days after peak flowering
7	85	30 days after peak flowering

F. PLANT MEASUREMENTS

At each harvest, plants were dissected into leaf lamina, stem, inflorescence, and components of seed yield on each branch order. Dry weight measurements were obtained by drying the samples in an air oven at 80^{o}C overnight. Details of plant measurements were as follows:

- No. of primary (1^{o}), secondary (2^{o}), tertiary (3^{o}) and quaternary (4^{o}) branches on each plant.

- Leaf number, leaf area, on 1^o, 2^o, 3^o and 4^o branches.
- Inflorescence counts were carried out every alternate day to determine peak flowering date.
- Number of seedheads present at nodal or terminal sites on each primary branch and on 2^o, 3^o and 4^o branches.
- Number of seeds set per seedhead at each branch site.
- Number of seeds obtained from each 1^o branch, 2^o and 3^o branches.
- 100 seed dry weight.
- Seed moisture content.

G. STATISTICAL ANALYSIS

A computer programme using a randomized design factorial arrangement of three water and five cutting treatments was used to analyse the data. The least significant difference at 5% level was used to identify statistical differences among the results.

RESULTS

The results from this controlled environment study show the effect of water and cutting on the vegetative yield and skeletal framework of Verano stylo plants. Both factors were important in affecting plant size and the number of sites available for seed production. The results are divided into three parts, each part will deal with the effect of water, cutting and the combined effect of water and cutting on plant growth and seed yield.

PART A THE EFFECTS OF WATER AND CUTTING ON VEGETATIVE AND REPRODUCTIVE GROWTH AND YIELD PER PLANT

A.1 EFFECTS OF WATER ON GROWTH AND YIELD OF VERANO STYLO UNDER CONTROLLED ENVIRONMENT CONDITIONS

A.1.1 Plant Growth and Yield

Dry Matter Yield

The results presented in Table A.3.2 show the effect of water on plant dry weight at successive harvests from the vegetative through to 30 days after peak flowering. The effect of water stress on plant size was very significant causing a noticeable reduction in the rate of growth soon after the stress was applied at each stage. In treatment W1, where water stress was imposed approximately 30 days after sowing, while plants were still vegetative, a significant reduction in vegetative yield was obtained at peak flowering only 10 days later (Plate 3.3a). A similar and rapid reduction in the growth of plants in the W2 treatment was recorded following peak flowering (Plate 3.3b). Plants receiving 'high' water levels throughout the experiment (W3) (Plate 3.3c) showed a substantially higher yield by the point of seed maturation 25 days after peak flowering.

Table A.3.2 EFFECT OF WATER ON PLANT DRY MATTER YIELD AT SUCCESSIVE HARVESTS OF VERANO STYLO UNDER CONTROLLED ENVIRONMENT CONDITIONS (g/pl)

Water Treatment	Harvesting Times						
	VG	FI	PF	15DAPF	20DAPF	25DAPF	30DAPF
W1	2.04	4.04	7.51	9.1	9.4	10.5	11.3
W2	2.92	6.71	17.13	24.8	34.1	44.2	49.6
W3	2.92	6.71	17.13	34.6	43.0	59.3	68.4
LSD5%			2.71	0.93	0.87	.96	0.95

Plate 3.3 All photo's taken at 15 days after peak flowering.

a. Plants receiving 'Low' watering at vegetative growth stage (W1).

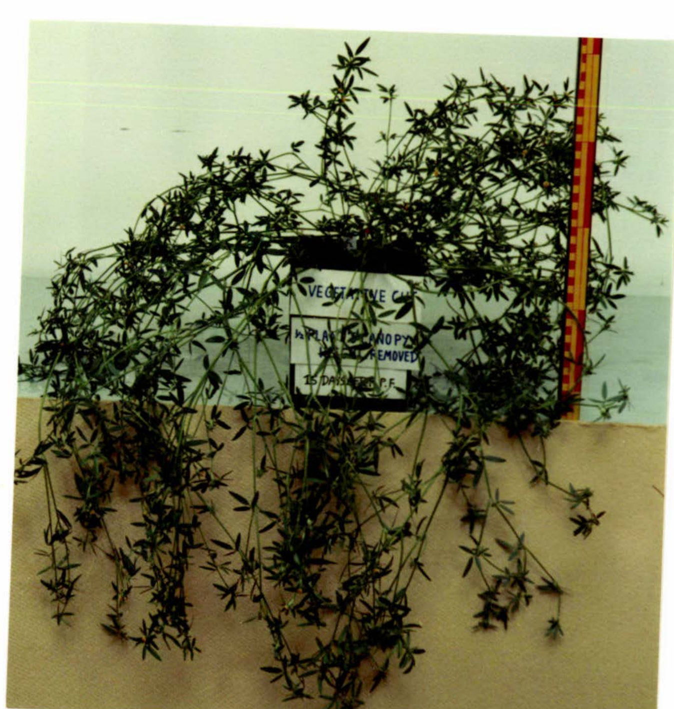
b. Plants receiving 'Low' watering at peak flowering stage (W2).

c. Plants receiving 'High' watering throughout the growing period(W3).


UNCUT CONTROL
VEGETATIVE CUT
½ PLANT'S CANOPY
HEIGHT REMOVED
15 DAYS AFTER P.F.

a

b



c

Branch Number

It was apparent that water stress markedly changed plant structure, the number of branches formed on plants in the different stress treatments being directly related to the water supply.

Table A.3.3 EFFECT OF WATER ON TOTAL BRANCH NUMBERS PER PLANT AT SUCCESSIVE HARVESTS OF VERANO STYLO UNDER CONTROLLED ENVIRONMENT CONDITIONS

Water Treatment	Harvesting Times						
	VG	FI	PF	15DAPF	20DAPF	25DAPF	30DAPF
W1	6	15.8	31.0	36.8	43.9	51.0	49.4
W2	6	38.8	85.4	80.6	97.0	98.7	102.2
W3	6	38.8	85.4	131.2	137.5	168.7	139.9
LSD5%				5.9	6.9	6.5	6.8

The results in Table A.3.3 show the total number of branches per plant at each harvest from the vegetative stage to 30 days after peak flowering. At peak flowering, plants which had been stressed from the vegetative stage (W1) had a significantly lower number of branches compared with plants which were not water-stressed until peak flowering (W2). In all treatments however major branch production occurred during the period from floral initiation to peak flowering. During seed development branch numbers did not change greatly. This suggests that water application during the vegetative stage and during the reproductive phase to peak flowering is a major determinant of final plant branch numbers.

Leaf Number

Water stress had a similar effect on leaf numbers to that previously described for plant dry weight (Table A.3.4). Lowest leaf numbers occurred when water stress was applied early in the growth of the plant (W1) and to a lesser extent when water stress was applied at peak flowering (W2). In the former treatment however, leaf numbers continued to increase at a relatively low rate under stressed conditions until 15 days after peak flowering and thereafter showed little change. Plants in the W2 treatment continued to increase their leaf numbers slowly under stress, with only little change occurring after 20 days after peak flowering. Under full watering (W3) leaf numbers increased steadily through to 25 days after peak flowering and then showed a slight decline in rate of development to a maximum number of leaves 30 days after peak flowering.

Table A.3.4 EFFECT OF WATER ON TOTAL LEAF NUMBERS PER PLANT AT SUCCESSIVE HARVESTS OF VERANO STYLO UNDER CONTROLLED ENVIRONMENT CONDITIONS

Water Treatment	Harvesting Times						
	VG	FI	PF	15DAPF	20DAPF	25DAPF	30DAPF
W1	30.3	69.6	136.2	293.4	298.4	323.0	321.2
W2	38.2	142.2	571.8	732.4	947.4	966.3	1044.4
W3	38.2	142.2	571.8	946.8	1652.2	2694.1	2883.0
LSD5%				105.3	118.2	115.3	136.3

Leaf Area

The results in Table A.3.5 show the total leaf area per plant at successive harvests from the vegetative stage until 30 days after peak flowering. Water had a significant effect on total plant leaf area. In particular, plants which were water stressed early (W1) had a consistently lower leaf area than plants which were not water stressed until peak flowering (W2) and plants which continued to receive ample water until the end of the experiment (W3). The leaf area of plants in treatment W1 declined after peak flowering, presumably as a result of leaf loss through shedding. Plants in the other two treatments continued to increase leaf area at least until maximum seed yield was reached 25 days after peak flowering. Water also affected leaf size. Observation showed that plants receiving high water levels formed larger leaves than plants under water stress.

Table A.3.5 EFFECT OF WATER ON TOTAL LEAF AREA PER PLANT AT SUCCESSIVE HARVESTS OF VERANO STYLO UNDER CONTROLLED ENVIRONMENT CONDITIONS (cm^2/pl)

	Harvesting Times						
Water Treatment	VG	FI	PF	15DAPF	20DAPF	25DAPF	30DAPF
W1	68.5	281.4	495.5	473.1	446.0	369.5	361.8
W2	82.9	501.9	1243.8	1485.4	1926.2	2016.3	2279.7
W3	82.9	501.9	1243.8	2024.1	3042.3	4103.4	4147.2
LSD5%				187.3	233.4	193.2	260.7

A.1.2 Effect on Reproductive Growth and Seed Yield

Despite the fact that Stylosanthes plants received quite different watering regimes in each treatment, the effect of water in regulating the duration of vegetative plant development from sowing to floral initiation was small. Similarly, differences in the time interval required for plants in different water treatments to complete flowering and seed development to the point of maximum seed yield were also small, a total difference of only 6 days occurring between the most extreme water treatment (W1) and the other two treatments in time from sowing to maximum seed yield (Table A.3.6).

Table A.3.6 SUMMARY OF DURATION OF EACH STAGE OF PLANT DEVELOPMENT IN VERANO STYLO PLANTS FROM EACH WATER TREATMENT UNDER CONTROLLED ENVIRONMENT CONDITIONS

Water Treatment	Days Required for Completion of each Stage				Total Days Required
	Vegetative		Reproductive		
	Sowing to VG Cut	Sowing to VG Cut	FI to PF	PF to Max. Seed Yield	
W1	30	40	9	25	74
W2	30	42	13	25	80
W3	30	42	13	25	80

The most affected part of the plant development sequence was the time from first flower appearance to peak flowering. This time interval was reduced by 4 days in early water stressed (W1) plants compared with plants in later-stressed (W2) or unstressed (W3) treatments.

Seedhead Number

The results in Table A.3.7 show that water stress suppressed the total seedhead numbers produced per plant in each harvest from 15 to 30 days after peak flowering. Plants to which stress was applied early (W1) or later at peak flowering (W2) both formed significantly fewer seedheads than plants receiving continuous water (W3).

Table A.3.7 EFFECT OF WATER ON TOTAL SEEDHEAD NUMBERS PER PLANT AT SUCCESSIVE HARVESTS OF VERANO STYLO UNDER CONTROLLED ENVIRONMENT CONDITIONS

Water Treatment	Harvesting Times 15DAPF	20DAPF	25DAPF	30DAPF
W1	40.8	41.0	59.2	65.6
W2	73.4	108.0	139.6	167.2
W3	197.2	184.4	256.4	243.8
LSD5%	5.8	5.4	7.4	6.8

Seedhead numbers continued to increase in all treatments at least until the point of maximum seed yield 25 days after peak flowering. At this stage seedhead numbers in treatment W2 were approximately double that in W1. Similarly seedhead numbers in treatment W3 were approximately double that in W2.

Seed Yield

The results in Table A.3.8 show that maximum seed yield was obtained 25 days after peak flowering in all water treatments. Plants stressed during the early vegetative stage (W1) had a significantly lower seed yield than plants stressed at peak flowering (W2) and non-stressed plants (W3). Water had its main effect in promoting seed yield with plants in the W3 treatment reaching a maximum yield value of approximately 90% greater than seed yield obtained from early-stressed plants (W1). Plants from treatment W2 were intermediate in their response to water which produced seed yield of about 30% of W3 treatment.

Table A.3.8 EFFECT OF WATER ON TOTAL SEED YIELD PER PLANT AT SUCCESSIVE HARVESTS OF VERANO STYLO UNDER CONTROLLED ENVIRONMENT CONDITIONS (g/pl)

Water Treatment	Harvesting Times			
	15DAPF	20DAPF	25DAPF	30DAPF
W1	0.58	0.94	1.19	1.07
W2	1.86	2.64	3.81	3.86
W3	3.71	4.99	10.51	8.15
LSD5%	0.34	0.48	0.67	0.74

A.2 EFFECT OF CUTTING ON GROWTH AND YIELD

A.2.1 Plant Growth and Yield

Dry Matter Yield

Table A.3.9 shows the effect of cutting on plant dry weight at successive harvests and clearly illustrates the significant reduction in yield which occurs in all cutting treatments. Plants which were more heavily cut, particularly at the vegetative growth stage (½VG), appeared to be most severely affected.

Table A.3.9 PLANT DRY MATTER YIELD ON CUT AND UNCUT PLANTS AT SUCCESSIVE HARVESTS OF VERANO STYLO UNDER CONTROLLED ENVIRONMENT CONDITIONS (g/plant)

Cutting Treatment	Harvesting Times						
	VG	FI	PF	15DAPF	20DAPF	25DAPF	30DAPF
Co	2.8	5.6	16.5	25.6	34.4	40.9	47.9
¼VG	2.2	5.6	13.1	23.6	31.4	38.6	41.1
½VG	1.5	4.6	13.5	21.7	23.1	34.9	39.4
¼FI		5.0	12.5	22.6	26.6	38.5	44.2
½FI		5.1	12.3	20.6	28.7	37.0	42.8
LSD5%	0.1	0.1	0.3	0.6	0.7	0.8	0.8

Branch Number

Cutting had a variable effect on total branch numbers formed per plant. The results in Table A.3.10 show that the total branch numbers per plant at successive harvests was relatively unaffected by cutting up to peak flowering. This suggests that early formed branches (primary and secondary branches) were less sensitive to the effects of cutting than branches formed on plants at a later stage. Certainly during the seed development stage commencing 15 days after peak flowering much more variable responses were measured.

Table A.3.10 TOTAL BRANCH NUMBERS PER PLANT ON CUT AND UNCUT PLANTS AT SUCCESSIVE HARVESTS OF VERANO STYLO UNDER CONTROLLED ENVIRONMENT CONDITIONS

Cutting Treatment	Harvesting Times						
	VG	FI	PF	15DAPF	20DAPF	25DAPF	30DAPF
Co	6	29	74	98	103	96	123
¼VG	6	32	73	98	115	136	113
½VG	6	38	78	89	96	119	107
¼FI		27	76	119	99	106	96
½FI		28	76	103	97	121	94
LSD5%				5	5	5	6

At the harvest taken 25 days after peak flowering, which coincided with the point of maximum seed yield, cutting was shown to have a stimulating effect on branch numbers. However at the harvests 5 days earlier (H5) and 5 days later (H7) a general depression in branch numbers was recorded in cut plants, particularly in plants cut severely during the vegetative stage or at floral initiation.

Leaf Number

Total leaf numbers were significantly reduced at all stages and intensities of cutting. Uncut plants generally had significantly higher leaf numbers than cut plants (Table A.3.11). Prior to peak flowering the depressing effects of cutting were not significant. At peak flowering plants in the uncut control (Co) had a significantly greater number of leaves than those in the cut treatments, with the various cutting treatments starting to show differing trends. By 15 days after peak flowering and subsequently, the relatively harsh effect of severe cutting at the vegetative stage became clearly evident. In contrast the most severe, late cutting treatment (½FI) showed amazing recovery through the final harvest 30 days after peak flowering.

Table A.3.11 TOTAL LEAF NUMBERS PER PLANT ON CUT AND UNCUT PLANTS AT SUCCESSIVE HARVESTS OF VERANO STYLO UNDER CONTROLLED ENVIRONMENT CONDITIONS

Cutting Treatment	Harvesting Times						
	VG	FI	PF	15DAPF	20DAPF	25DAPF	30DAPF
Co	36.1	150.7	701.6	1006.8	1317.6	1507.4	2244.6
¼VG	26.7	140.4	477.8	744.3	1059.7	1396.0	1385.0
½VG	21.8	112.7	456.7	714.3	796.0	1113.6	1269.0
¼FI	36.1	116.7	371.0	814.7	995.3	1305.5	1283.3
½FI	36.1	111.0	373.7	645.3	997.0	1314.7	1481.7
LSD5%				115.3	89.3	96.0	97.3

Leaf Area

Cutting had a variable effect on leaf area (Table A.3.12). The results show that cutting reduced total leaf area per plant in all treatments. However, in each cutting treatment Verano stylo plants showed a real capacity to replace leaf area following canopy removal although total leaf area was always below that of uncut plants. There was a suggestion that heavy cutting during the vegetative stage (½VG) was more damaging to final leaf area than less severe cutting at this stage (¼VG).

Table A.3.12 TOTAL LEAF AREA PER PLANT ON CUT AND UNCUT PLANTS AT SUCCESSIVE HARVESTS OF VERANO STYLO UNDER CONTROLLED ENVIRONMENT CONDITIONS (cm^2/pl)

Cutting Treatment	Harvesting Times						
	VG	FI	PF	15DAPF	20DAPF	25DAPF	30DAPF
Co	109.6	504.9	1119.1	1588	2026	2406	2678
¼VG	75.2	465.1	969.3	1284	1617	2303	2226
½VG	49.7	364.7	1021.8	1393	1605	1920	2059
¼FI		380.7	876.4	1251	1966	2154	2094
½FI		391.9	889.0	1157	1810	2033	2258
LSD5%		39	123	138	149	160	154

A.2.2 Effect on Reproductive Growth and Seed Yield

The indeterminate growth habit of *Stylosanthes hamata* makes the categorisation of reproductive development difficult. On any one plant during the reproductive phase it is normal to find fully-formed inflorescences in which florets have not yet undergone anthesis or flowering; inflorescences containing florets with anthers exserted, and inflorescences containing florets which have developed pods. In order to distinguish these three situations three different terms are used in the study:

1. Non flowered inflorescence = inflorescence
2. Inflorescence at anthesis = flower head
3. Inflorescence showing pod development = seed head

Seedhead Number

Cutting generally had a depressing effect on seedhead numbers formed per plant (Table A.3.13). This effect was more apparent in plants cut heavily during the vegetative stage and where cutting was delayed until floral initiation. There was however, a suggestion that light cutting during the vegetative stage (¼VG) stimulated seedhead formation. Certainly in this treatment, a significantly greater number of seedheads were present at the point of maximum seed yield 25 days after peak flowering than in either uncut plants, or plants from other cutting treatments. The effect was however not so evident at the final harvest 30 days after peak flowering. Nevertheless plants from this ¼VG treatment consistently produced more seedheads than plants from other cutting treatments.

Table A.3.13 SEEDHEAD NUMBERS PER PLANT ON CUT AND UNCUT PLANTS AT SUCCESSIVE HARVESTS OF VERANO STYLO UNDER CONTROLLED ENVIRONMENT CONDITIONS

Cutting Treatment	Harvesting Times			
	15DAPF	20DAPF	25DAPF	30DAPF
Co	109	129	161	174
¼VG	130	127	180	163
½VG	104	114	143	154
¼FI	113	92	130	156
½FI	84	111	145	158
LSD5%	7	8	6	6

Seed Yield

The results in Table A.3.14 show the effect of cutting on seed yield per plant at successive harvests. In all treatment maximum seed yield was recorded 25 days after peak flowering. This result compares well with the attainment of maximum seed yield in the field experiment previously described. Severe cutting during the vegetative stage or delaying cutting until floral initiation certainly depressed seed yield per plant. However, it seems that the stimulation in seedhead numbers following light cutting at the vegetative stage previously recorded (Table A.3.13) was reflected in higher seed yield in plants from this treatment at the point of maximum seed yield 25 days after peak flowering (Table A.3.14). In all treatments some loss of seed yield occurred in the 5 days after peak yield was observed as a result of seed shedding. This loss of seed was most severe in the highest yielding treatments (Co and ¼VG). These results suggest that light, early cutting of *Stylosanthes hamata* can be carried out without any depression in seed yield and may even result in some increase in seed yield per plant.

TABLE A.3.14 SEED YIELD PER PLANT ON CUT AND UNCUT PLANTS AT SUCCESSIVE HARVESTS OF VERANO STYLO UNDER CONTROLLED ENVIRONMENT CONDITIONS (g/pl)

Cutting Treatment	Harvesting Times			
	15DAPF	20DAPF	25DAPF	30DAPF
Co	2.14	3.15	5.67	4.70
¼VG	2.31	3.21	6.09	4.51
½VG	2.01	3.06	4.96	3.89
¼FI	2.25	2.49	4.42	4.34
½FI	1.60	2.38	4.69	4.47
LSD5%	0.23	0.32	0.53	0.34

A.3 EFFECT OF WATER AND CUTTING ON GROWTH AND YIELD

Plant Growth and Yield

All the measured parameters showed significant interactions between watering and cutting at all harvests. However, the responses and trends which occurred between harvests were often inconsistent. This was possibly due to the influence of cutting severity and timing on the change from apical dominance to lateral branch development and the effect of water in influencing plant recovery rate.

The most significant interactions tended to occur in the harvests from 15 days after peak flowering onwards, mainly as a result of the influence of water stress creating differences between the W2 and W3 treatments. However, some general statements concerning the interaction between water and cutting on different plant parameters should be made.

Dry Matter Yield

The results presented in Table A.3.15 show that early water stress (W1) did not prevent plants which were cut severely and late from replacing removed dry matter. However, this early stress did prevent plants from continuing subsequent dry matter accumulation. This resulted in a fairly constant dry matter yield for all the W1 cutting combinations. Adequate watering through to peak flowering (W2) stimulated plant growth. However, in certain cutting treatments (½VG and to a lesser extent ½FI) this yield was depressed to below the uncut treatment. This effect was most obvious in the harvests for the W2 treatment 15 and 20 days after peak flowering.

Where watering was continued throughout the whole experiment (W3) only a ½VG treatment depression in dry matter yield was observed. The ½FI treatment clearly demonstrated the promotive interaction of water and cutting in stimulating dry matter yield. This effect became more obvious from 20 days after peak flowering, presumably because plants had the necessary time to respond. Surprisingly, late cut plants ultimately produced dry matter yields similar to uncut plants in the W3 treatment.

Table A.3.15 EFFECT OF WATER AND CUTTING ON DRY MATTER YIELD PER PLANT AT SUCCESSIVE HARVESTS OF VERANO STYLO UNDER CONTROLLED ENVIRONMENT CONDITIONS (g/pl)

Cutting Treatment	PF			15DAPF			20DAPF			25DAPF			30DAPF		
	W1	W2	W3	W1	W2	W3	W1	W2	W3	W1	W2	W3	W1	W2	W3
Co	8.4	20.9	19.9	9.7	25.6	41.6	9.9	43.2	49.9	12.8	45.9	64.1	11.5	56.8	75.5
¼VG	7.6	17.5	14.1	8.8	27.2	34.8	9.8	41.1	43.3	10.3	45.2	60.1	11.7	49.9	61.8
½VG	6.9	17.9	15.7	8.7	21.6	34.9	9.2	27.3	32.9	10.0	45.2	49.3	12.0	48.6	57.4
¼FI	7.5	14.1	15.8	8.8	29.2	29.8	8.9	28.8	41.9	10.0	44.5	60.9	10.9	48.9	72.8
½FI	7.1	15.2	14.6	9.6	20.4	31.9	9.1	30.1	49.6	9.1	39.9	62.0	10.2	44.0	74.3
LSD5%		3.0			2.2			2.6			2.3			2.7	

The interactions (Table A.3.15) show that water did not give early and severely cut plants the capacity to respond to cutting. However, water was extremely important in allowing a complete compensation in dry matter yield in late cut plants (floral initiation) during the period from 20 days after peak flowering onwards compared to uncut plants.

The influence of water and cutting on plant size is clearly seen in Plates 3.4-3.6. Each series of plates show the size of plants from the same water treatment with a comparison between plants cut at the vegetative stage (¼VG) and an uncut plant (Co) at the final harvest 30 days after peak flowering. Obviously the early stressed plants (W1) in Plate 3.4 were unable to respond to cutting, unlike plants which were not water stressed until peak flowering (W2) in Plates 3.5 a,b. The size of plants which were adequately watered throughout the experiment (W3) is very much greater than plants from other treatments (Plates 3.6 a,b). This effect on plant size is also reflected in other cutting treatments which are shown in Plates 3.9 in Appendix 3.10.

Branch number

Although the interactions in Table A.3.16 do not seem to be very consistent there is a suggestion that total branch numbers are relatively insensitive to cutting and depend more on the duration of watering and time to allow an expression of this effect. This is not surprising because of the previously demonstrated compensatory effect of different branch orders. This effect is clearly seen in the early stress treatment (W1) where plants appear to reach a plateau in branch numbers 20-25 days after peak flowering irrespective of whether plants were cut or not.

The major interaction appears to be a stimulation in total branch numbers in the late cut treatments, particularly ½FI. This stimulation is most pronounced in the W2 treatment. Any suggestion that this effect occurred in the W3 treatment had disappeared by the final harvest. In the fully watered treatment (W3) the vegetative cut (particularly ½VG) reduced

Table A.3.16 EFFECT OF WATER AND CUTTING ON TOTAL BRANCH NUMBERS PER PLANT AT SUCCESSIVE HARVESTS OF VERANO STYLO UNDER CONTROLLED ENVIRONMENT CONDITIONS

Cutting Treatment	PF			15DAPF			20DAPF			25DAPF			30DAPF		
	W1	W2	W3	W1	W2	W3	W1	W2	W3	W1	W2	W3	W1	W2	W3
Co	27	51	61	39	76	136	42	83	151	51	97	126	45	94	139
¼VG	30	49	53	37	47	138	40	86	145	49	84	167	45	95	149
½VG	32	61	64	37	64	118	45	90	121	52	77	161	57	84	149
¼FI	34	67	78	37	113	135	42	92	150	53	81	148	48	86	131
½FI	32	79	93	34	73	140	46	111	119	49	118	172	52	130	137
LSD5%		6			7			4			4			4	

Plate 3.4 Uncut and early light cut plants of Verano stylo which had been stressed early in their vegetative growth (W1). Photo taken at final harvest 30 days after peak flowering.

a

b

Plate 3.5 a,b. Uncut (a) and early light cut (b) plants of Verano stylo which had been stressed from peak flowering (W2). Photo taken at final harvest 30 days after peak flowering.

a

b

Plate 3.6 a,b. Uncut (a) and early light cut (b) plants of Verano stylo which had received adequate water throughout the experiment (W3). Photo taken at final harvest 30 days after peak flowering.

total branch numbers in the harvests 15 and 20 days after peak flowering. However, given water and time, the vegetatively cut plants ultimately bore more branches than corresponding uncut plants.

Leaf Number and Leaf Area

The results on leaf number (Table A.3.17) and leaf area (Table A.3.18) suggest that the interactions between water and cutting for both parameters are very similar. In both cases water stress treatments (W1 and W2) show little if any capacity to stimulate leaf number or leaf area over and above the uncut plants. In the fully watered treatment (W3) cutting generally reduced both leaf number and leaf area below the level of uncut plants. This effect occurred from peak flowering onwards.

Seedhead Number and Seed Yield

The trends in the interactions between water and cutting on both seedhead numbers (Table A.3.19) and seed yield (Table A.3.20) were very similar. In the early water stress treatment (W1) seedhead numbers were initially depressed by late cutting. This trend continued through to 25 days after peak flowering but had disappeared by the end of the experiment. Although there was a suggestion of a similar effect on seed yield, results were less conclusive.

The greatest differences in seedhead numbers and seed yield were seen at the point of maximum seed yield 25 days after peak flowering. This was particularly evident in the W2 and W3 treatments. This harvest will be used to highlight the major interactive trends. Both the watered treatments (W2 and W3) generally showed a depression in seedhead numbers and seed yield in the ½VG and FI treatments. A similar interaction occurred in the stimulation or non-depression of seedhead numbers and seed yield in the ¼VG treatment. Late cutting (floral initiation) delayed the time of maximum seed yield in cases where plants were water stressed from peak flowering (W2). Only the ¼ vegetative cut:W2 treatment combination produced more seed per plant than the uncut control.

Table A.3.17 EFFECT OF WATER AND CUTTING ON TOTAL LEAF NUMBERS PER PLANT AT SUCCESSIVE HARVESTS OF VERANO STYLO UNDER CONTROLLED ENVIRONMENT CONDITIONS

Cutting Treatment	PF			15DAPF			20DAPF			25DAPF			30DAPF		
	W1	W2	W3	W1	W2	W3	W1	W2	W3	W1	W2	W3	W1	W2	W3
Co	173.3	647.4	660.4	295	759	1266	319	985	1642	342	1021	3160	292	1138	3356
¼VG	164.3	687.4	642.3	299	748	1186	277	990	1130	326	1024	2842	312	1093	2750
½VG	195.6	582.1	688.4	288	644	1211	267	955	1166	342	962	2036	365	980	2461
¼FI	169.0	446.3	497.3	305	927	1212	301	830	1855	323	822	2770	326	990	2533
½FI	155.3	497.3	469.1	280	584	1072	328	977	1686	281	939	2661	311	1021	3113
LSD5%		60.8			96.0			87.8			67.2			69.3	

Table A.3.18 EFFECT OF WATER AND CUTTING ON TOTAL LEAF AREA PER PLANT AT SUCCESSIVE HARVESTS OF VERANO STYLO UNDER CONTROLLED ENVIRONMENT CONDITIONS (cm^2/pl)

Cutting Treatment	PF			15DAPF			20DAPF			25DAPF			30DAPF		
	W1	W2	W3	W1	W2	W3	W1	W2	W3	W1	W2	W3	W1	W2	W3
Co	517	1387	1453	509	1739	2517	489	2121	3469	414	2138	4667	360	2760	4913
¼VG	499	1011	997	444	1632	1778	454	1912	2484	372	2051	4484	337	2259	4080
½VG	443	1020	1007	463	1388	1727	442	1927	2447	396	2199	3164	376	2207	3595
¼FI	534	956	1039	468	1430	1747	407	1851	3639	363	1938	4163	385	2208	3689
½FI	484	1144	1034	482	1238	1750	438	1820	3172	303	1757	4039	351	1964	4459
LSD5%		99			112			87			94			93	

Table A.3.19 EFFECT OF WATER AND CUTTING ON SEEDHEAD NUMBERS PER PLANT AT SUCCESSIVE HARVESTS OF VERANO STYLO UNDER CONTROLLED ENVIRONMENT CONDITIONS

Cutting Treatment	15DAPF			20DAPF			25DAPF			30DAPF		
	W1	W2	W3	W1	W2	W2	W1	W2	W3	W1	W2	W3
Co	49.3	93.7	175.7	49.3	115.3	184.6	57.4	155.7	257.6	64.3	203.9	250.7
¼VG	45.0	80.4	227.0	54.7	119.9	206.6	64.9	177.7	305.0	63.0	160.0	244.4
½VG	43.3	67.4	209.7	37.0	125.3	233.0	65.5	115.6	247.5	71.7	126.3	228.3
¼FI	35.6	84.3	192.2	39.7	86.5	149.8	59.3	103.3	227.1	57.0	180.4	224.6
½FI	29.9	43.7	186.3	38.6	89.6	136.7	39.3	153.0	244.3	64.6	164.6	246.9
LSD5%		5.9			8.7			11.5			9.4	

Table A.3.20 EFFECT OF WATER AND CUTTING ON SEED YIELD PER PLANT AT SUCCESSIVE HARVESTS OF VERANO STYLO UNDER CONTROLLED ENVIRONMENT CONDITIONS (g/pl)

Cutting Treatment	15DAPF			20DAPF			25DAPF			30DAPF		
	W1	W2	W3	W1	W2	W3	W1	W2	W3	W1	W2	W3
Co	.71	2.24	3.39	1.04	2.79	5.38	1.28	4.09	11.74	1.01	4.61	8.51
¼VG	.61	2.14	4.17	1.11	2.90	5.54	1.23	5.78	11.24	.97	3.87	8.69
½VG	.63	1.98	4.08	.84	2.92	5.94	1.42	3.31	10.12	1.26	2.93	7.50
¼FI	.53	2.07	3.29	.89	2.16	4.42	1.19	2.43	9.65	1.02	4.22	7.79
½FI	.43	0.96	3.41	.80	2.55	3.83	.84	3.42	9.81	1.10	3.70	8.30
LSD5%		.55			.83			.89			.73	

PART B EFFECT OF WATER AND CUTTING ON THE DEVELOPMENT AND SEED YIELD CONTRIBUTION OF DIFFERENT BRANCH ORDERS

The variable and often inconsistent results obtained in some of the whole plant parameters measured in the previous section suggested that more intensive study of some aspects of the seed components of *Stylosanthes hamata* cv Verano would be worthwhile. In particular the relative influence of water and cutting on the formation of the plant branching framework and floral development sites were considered important. It was therefore decided to consider branch and seedhead numbers in particular in more detail. This was thought to be necessary to try to explain more clearly the influence of water and cutting on such aspects as new branch formation, branch recovery and replacement following cutting and also the contribution different branch orders and floral development sites might make to final seed yield.

B.1 EFFECT OF WATER ON CONTRIBUTION OF GROWTH AND YIELD

B.1.1 Effect on Branching

The development of the primary branch structure of *Stylosanthes hamata* cv Verano occurred early in plant development and reached a constant value at floral initiation. The results in Table B.3.1 show that generally each plant produced about 7 primary branches irrespective of water treatment. However, both the time of onset and the extent of formation of higher order branches was strongly influenced by water. Successive branch order production occurred in 'waves', the stimulation of higher order branching tending to be delayed until the number of branches of the previous order had reached a maximum.

There were significant differences in the number of secondary, tertiary and quaternary branches produced on plants from different water treatments (Table B.3.1). Plants which received low water levels from the early vegetative stage (W1) produced an average of only 51.2 branches per plant nearly 70% of which were secondary branches. By comparison plants which were not water stressed until peak flowering produced

Table B.3.1 EFFECT OF WATER ON THE NUMBER OF PRIMARY, SECONDARY, TERTIARY AND QUATERNARY BRANCHES PER PLANT AT SUCCESSIVE HARVESTS OF VERANO STYLO UNDER CONTROLLED ENVIRONMENT CONDITIONS

Water Treatment	Harvesting Times						
	VG	FI	PF	15DAPF	20DAPF	25DAPF	30DAPF
No 1^{o} Br							
W1	6	7.4	7.4	7.4	7.2	7.4	7.2
W2	6	7.4	7.6	7.6	7.8	7.8	7.8
W3	6	7.4	7.6	7.6	7.6	8.0	7.8
LSD5%	NS	NS	NS	NS	NS	NS	NS
No 2^{o} Br							
W1	0	8.4	23.6	29.4	32.3	35.3	33.7
W2	0	24.0	37.8	38.0	40.1	40.7	38.2
W3	0	31.4	32.2	52.0	51.7	52.6	49.3
LSD5%		2.08	3.3	3.5	3.2	3.4	3.2
No 3^{o} Br							
W1	0	0	0	0	4.4	8.5	8.5
W2	0	0	37.4	35.0	42.3	38.5	43.2
W3	0	0	45.6	71.6	62.5	79.2	67.3
LSD5%			2.7	4.4	5.8	6.2	6.1
No 4^{o} Br							
W1	0	0	0	0	0	0	0
W2	0	0	0	0	6.8	11.7	13.0
W3	0	0	0	0	15.5	29.1	15.5
LSD5%					2.2	2.4	2.3

twice as many branches (mean 104.7) per plant 80% of which were almost equally divided between secondary and tertiary branches. In the continuous water treatment (W3) branching continued throughout the study reaching a mean total of 181.9 branches per plant. In these plants nearly 60% of the total branches were produced on tertiary or quaternary sites. The results clearly show that water stress significantly delayed the rate and extent of higher order branch formation. As an example plants in the later stressed (W2) and continuous water (W3) treatments produced tertiary branches at peak flowering (Harvest 3), while early stressed plants (W1) delayed the production of tertiary branches until harvest 5 (20 days later). The imposition of a water stress early in the plants' development (treatment W1) severely restricted the production of tertiary branches and completely prevented the formation of any quaternary branches.

B.1.2 Effect on Reproductive Growth and Seed Yield

Water had a major effect on the contribution of seed yield from each branch order.

Seedhead Number

The results in Table B.3.2 clearly show the major contribution secondary branches make to total seedhead number and the dramatic effect of water in stimulating seedhead production. The other interesting aspect is the difference in the number of seedheads formed on primary branches from plants in different water treatments despite the fact that water had no significant effect on the number of primary branches formed on these plants. At 30 days after peak flowering, for example, the 7.2 primary branches formed on early water stressed plants (W1) produced only 25 seedheads. In contrast, approximately the same number of primary branches on later water stressed (W2) and continuously watered plants (W3) produced 51 and 54 seedheads respectively.

Table B.3.2 EFFECT OF WATER ON THE SEEDHEAD NUMBERS FORMED ON PRIMARY, SECONDARY AND TERTIARY BRANCHES AT SUCCESSIVE HARVESTS OF VERANO STYLO UNDER CONTROLLED ENVIRONMENT CONDITIONS

Branch Order	Water Treatment	Number of Seedheads at each Harvest Stage			
		15DAPF	20DAPF	25DAPF	30DAPF
Primary	W1	17.4	17.9	23.0	25.1
	W2	24.0	37.6	39.4	51.0
	W3	34.6	31.7	49.8	53.8
	LSD5%	6.2	3.8	5.9	4.4
Secondary	W1	23.3	26.0	36.3	40.2
	W2	47.4	68.3	83.4	102.0
	W3	133.7	121.2	158.9	158.0
	LSD5%	21.3	11.5	10.8	18.4
Tertiary	W1	0	0	0	0
	W2	5.1	16.0	16.3	33.3
	W3	33.7	29.5	47.9	41.7
	LSD5%				

The influence of water on seedhead formation is also dramatically shown on secondary branches where the three water treatments (W1, W2, W3) produced 40, 102 and 158 seedheads respectively at 30 days after peak flowering. This difference was a major response to water influencing seedhead formation since only a comparatively minor water stimulus to secondary branch numbers had been previously recorded (Table B.3.1). Put into perspective these figures represent 1.1, 2.5 and 3.0 seedheads per secondary branch in the W1, W2 and W3 water treatments respectively.

Early water stress (W1) completely prevented the formation of seedheads on tertiary branches. However, later water stress (W2) and continuous watering (W3) did allow relatively small numbers of seedheads to be produced on tertiary branches.

Despite the formation of some quaternary branches in W2 and W3 treatment plants none of these branches produced seedheads during the study.

Seed Yield

While the results in Table B.3.2 have shown that the number of seedheads formed on each branch order is different, the results in Table B.3.3 show that the number of seeds formed in each seedhead is remarkably constant between water treatments within any one branch order. Certainly the maximum numbers of seeds per seedhead formed on primary and secondary branches was very similar (10.3-10.5). The maximum number of seeds per seedhead on tertiary branches however was approximately half (5.0) that recorded on lower order branches. In each branch order maximum seeds per seedhead were recorded at the harvest coinciding with peak seed yield 25 days after peak flowering.

It is possible that earlier harvests were less fertile in terms of seed numbers, while seedheads measured 30 days after peak flowering had already lost seed through shattering.

Table B.3.3 EFFECT OF WATER ON THE NUMBER OF SEEDS PER SEEDHEAD FORMED ON PRIMARY, SECONDARY AND TERTIARY BRANCHES AT SUCCESSIVE HARVESTS OF VERANO STYLO UNDER CONTROLLED ENVIRONMENT CONDITIONS

Branch Order	Water Treatment	Number of seed/seedhead			
		15DAPF	20DAPF	25DAPF	30DAPF
Primary	W1	7.2	9.0	10.3	8.6
	W2	7.4	9.0	10.3	8.8
	W3	7.4	9.0	10.3	8.8
	LSD5%		NS		
Secondary	W1	8.4	8.2	10.4	8.2
	W2	8.4	8.2	10.5	8.2
	W3	8.5	8.2	10.5	8.2
	LSD5%		NS		
Tertiary	W1	2.1	4.0	5.0	4.5
	W2	3.0	4.1	5.0	4.3
	W3	3.1	4.1	5.0	4.5
	LSD5%		NS		

These results demonstrate that seed numbers per seedhead is relatively unresponsive to different water treatments.

Plants stressed during the early vegetative stage had a significantly lower seed yield than plants stressed at peak flowering (W2) and nonstressed plants (W3) (Table B.3.4). While it has been previously shown that seed yield depends on the number of the seedheads on each branch order, the results in Table B.3.4 again reflect the fact that seedheads formed on secondary branches contribute most of the yield. Water had a similar effect on seed yield on each branch order.

For example, plants in the early water stressed treatment (W1) produced a maximum seed yield of 1.19 gm per plant distributed almost equally (45%, 55%) between primary and secondary branches. These plants formed tertiary branches which did not produce any seed. However, plants which were not water stressed until after peak flowering (W2) produced a maximum of 3.96 gm per plant with primary, secondary and tertiary branches respectively contributing 31%, 63% and 6%. Plants receiving continuous water (W3) produced a maximum seed yield of 10.48 gm per plant with percentage contributions of 23%, 69% and 8% from primary, secondary, and tertiary branches respectively.

Table B.3.4 EFFECT OF WATER ON SEED YIELD PER PLANT FORMED ON PRIMARY, SECONDARY AND TERTIARY BRANCHES AT SUCCESSIVE HARVESTS OF VERANO STYLO UNDER CONTROLLED CONDITIONS (g/pl)

Branch Order	Water Treatment	Seed Yield per Plant at each Stage			
		15DAPF	20DAPF	25DAPF	30DAPF
Primary	W1	.28	.45	.54	.42
	W2	.67	.75	1.24	1.03
	W3	.65	1.08	2.46	1.77
	LSD5%	.19	.16	.38	.18
Secondary	W1	.29	.49	.65	.64
	W2	1.19	1.77	2.32	2.48
	W3	2.61	3.54	7.23	4.57
	LSD5%	.42	.39	.54	.73
Tertiary	W1	0	0	0	0
	W2	.02	.08	.24	.20
	W3	.40	.37	.79	.53
	LSD5%				

In all treatments seed yield per plant increased to a maximum 25 days after peak flowering. This was generally followed by a yield reduction as seed shattering became evident.

B.2 EFFECT OF CUTTING ON CONTRIBUTION OF GROWTH AND YIELD

B.2.1 Effect on Branch Number

The effect of different cutting treatments on the number of branches formed on different branch orders at successive harvests is shown in Table B.3.5. Generally, cutting reduced the number of primary and secondary branches but increased the number of tertiary and quaternary branches on *Stylosanthes* plants.

The greatest reduction in primary branch numbers occurred in plants cut during the vegetative stage. These plants however responded by producing significantly higher numbers of quaternary branches. Plants cut at floral initiation showed only a small reduction in primary branches but a more significant reduction in secondary branch numbers. This overall depression was partly compensated for by some increase in tertiary branch formation.

Total branch numbers per plant were highest in treatments involving light cutting during the vegetative stage (¼VG=141.5) or at floral initiation (¼FI=138.2). Other cutting treatments produced maximum total branch numbers similar to uncut plants (125.2).

Table B.3.5 EFFECT OF CUTTING ON THE NUMBER OF PRIMARY, SECONDARY, TERTIARY AND QUATERNARY BRANCHES PER PLANT AT SUCCESSIVE HARVESTS OF VERANO STYLO UNDER CONTROLLED ENVIRONMENT CONDITIONS

Cutting Treatment	Harvesting Times						
	VG	FI	PF	15DAPF	20DAPF	25DAPF	30DAPF
No 1^o Br							
Co	6	9	10	10	10	10	10
¼VG	6	6	6	6	6	6	6
½VG	6	6	6	6	6	6	6
¼FI		8	8	8	8	8	8
½FI		8	8	8	8	8	8
No 2^o Br							
Co	0	20.0	37.0	45.7	48.0	48.8	46.7
¼VG	0	25.7	38.0	41.3	44.4	46.3	43.6
½VG	0	21.7	31.7	39.0	40.1	41.7	42.6
¼FI	0	19.3	22.1	39.0	37.1	39.9	38.4
½FI	0	19.7	21.1	34.0	36.9	37.7	30.8
LSD5%		3.66	5.86	5.14	2.59	2.85	3.74
No 3^o Br							
Co	0	0	27.5	42.5	28.7	30.0	52.1
¼VG	0	0	27.7	50.5	54.5	49.4	40.0
½VG	0	0	40.0	42.0	34.2	38.7	42.4
¼FI	0	0	27.0	72.0	41.9	40.0	37.7
½FI	0	0	46.5	60.5	39.4	52.1	42.4
LSD5%			4.86	7.75	4.22	5.24	6.6
No 4^o Br							
Co					16.0	7.0	14.3
¼VG					10.0	34.7	23.0
½VG					16.0	32.3	15.7
¼FI					11.7	18.3	11.7
½FI					12.8	23.7	13.0
LSD5%					2.36	2.4	2.4

B.2.2 Effect on Reproductive Growth and Seed Yield

Seedhead Number

The results showing the effects of cutting on the number of seedheads formed on each branch order at successive harvests are presented in Table B.3.6. Early cutting (¼VG) stimulated total seedhead numbers mainly as a result of greater numbers of seedheads formed on secondary branches. In all other cutting treatments total seedhead numbers were lower than in uncut plants. Late and severe cutting was particularly damaging to the number of seedheads formed on primary branches. Heavily and late cut plants compensated for a reduction in primary branch seedheads by a stimulation in the number of seedheads formed on tertiary branches. No plants, whether they had been cut or not, produced any seed-heads on quaternary branches.

Seed Yield

The results in Table B.3.7 show the seed yield per branch order produced on cut and uncut plants at successive harvests. Seed yield per plant followed a similar pattern to that previously described for seedhead number. Cutting plants lightly during the vegetative stage (¼VG) stimulated seed yield from primary branches.

All other cutting treatments reduced seed yield compared with uncut plants with late and severe cutting being particularly damaging. By comparison cutting had little effect on secondary branch seed yields. Cut plants also showed some stimulation of seed yield from tertiary branches but this was insufficient to completely compensate for the loss of seed yield on primary branches following cutting. Maximum seed yield per plant was obtained in early vegetative cut plants 25 days after peak flowering (6.00 gm/pl). Lowest seed yields were produced on plants cut at floral initiation (4.40 gm and 4.67 gm in ¼FI and ¼FI treatments respectively). Uncut plants reached a maximum seed yield of 5.67 gm.

Table B.3.6 EFFECT OF CUTTING ON THE SEEDHEAD NUMBERS FORMED ON PRIMARY, SECONDARY AND TERTIARY BRANCHES AT SUCCESSIVE HARVESTS OF VERANO STYLO UNDER CONTROLLED ENVIRONMENT CONDITIONS

Branch Order	Cutting Treatment	Seedhead Numbers per Plant at Different Harvests			
		15DAPF	20DAPF	25DAPF	30DAPF
Primary Branch	Co	42.6	46.9	62.7	68.0
	¼VG	28.0	31.8	47.6	45.1
	½VG	29.3	30.2	36.1	45.0
	¼FI	13.6	14.7	26.9	30.8
	½FI	12.1	8.4	13.7	20.7
	LSD5%	8.3	5.2	7.3	4.5
Secondary Branch	Co	56.1	75.1	87.7	93.2
	¼VG	89.5	85.8	106.1	98.0
	½VG	65.5	58.9	89.6	92.0
	¼FI	81.5	66.4	85.6	103.9
	½FI	57.8	68.4	94.9	112.6
	LSD5%	15.3	10.3	9.3	16.5
Tertiary Branch	Co	6.4	6.9	10.6	13.1
	¼VG	12.6	9.4	25.9	19.5
	½VG	9.5	25.2	17.3	17.2
	¼FI	17.9	10.5	17.2	21.3
	½FI	14.3	11.5	36.8	24.8
	LSD5%	NS	5.4	6.4	5.1

Table B.3.7 EFFECT OF CUTTING ON SEED YIELD PER PLANT FORMED ON PRIMARY, SECONDARY AND TERTIARY BRANCHES AT SUCCESSIVE HARVESTS OF VERANO STYLO UNDER CONTROLLED ENVIRONMENT CONDITIONS (g/pl)

Branch Order	Cutting Treatment	Seed Yield per Plant at Different Harvest Stages 15DAPF	20DAPF	25DAPF	30DAPF
Primary Branch	Co	.94	1.33	2.30	1.93
	¼VG	.66	.92	1.74	1.31
	½VG	.65	.87	1.27	.97
	¼FI	.28	.44	.95	.97
	½FI	.25	.24	.62	.67
	LSD5%	.18	.15	.34	.16
Secondary Branch	Co	1.11	1.73	3.24	2.61
	¼VG	1.51	2.16	3.85	2.92
	½VG	1.25	1.90	3.38	2.70
	¼FI	1.78	1.94	3.18	3.03
	½FI	1.19	1.96	3.43	3.33
	LSD5%	.39	.33	.46	.63
Tertiary Branch	Co	.09	.09	.13	.16
	¼VG	.14	.13	.42	.28
	½VG	.11	.29	.31	.22
	¼FI	.19	.11	.27	.34
	½FI	.16	.18	.62	.47
	LSD5%	NS	.07	.21	.20

B.3 EFFECTS OF WATER AND CUTTING ON THE CONTRIBUTION OF GROWTH AND YIELD

Although a number of yield components showed a significant interaction between water and cutting treatments, only those components receiving particular attention in this section, viz. branching and seedhead numbers are presented and discussed (Raw data for all variable numbers is presented in Appendix 3.3, 3.4, 3.5).

B.3.1 Effect of Water and Cutting on Branch Number

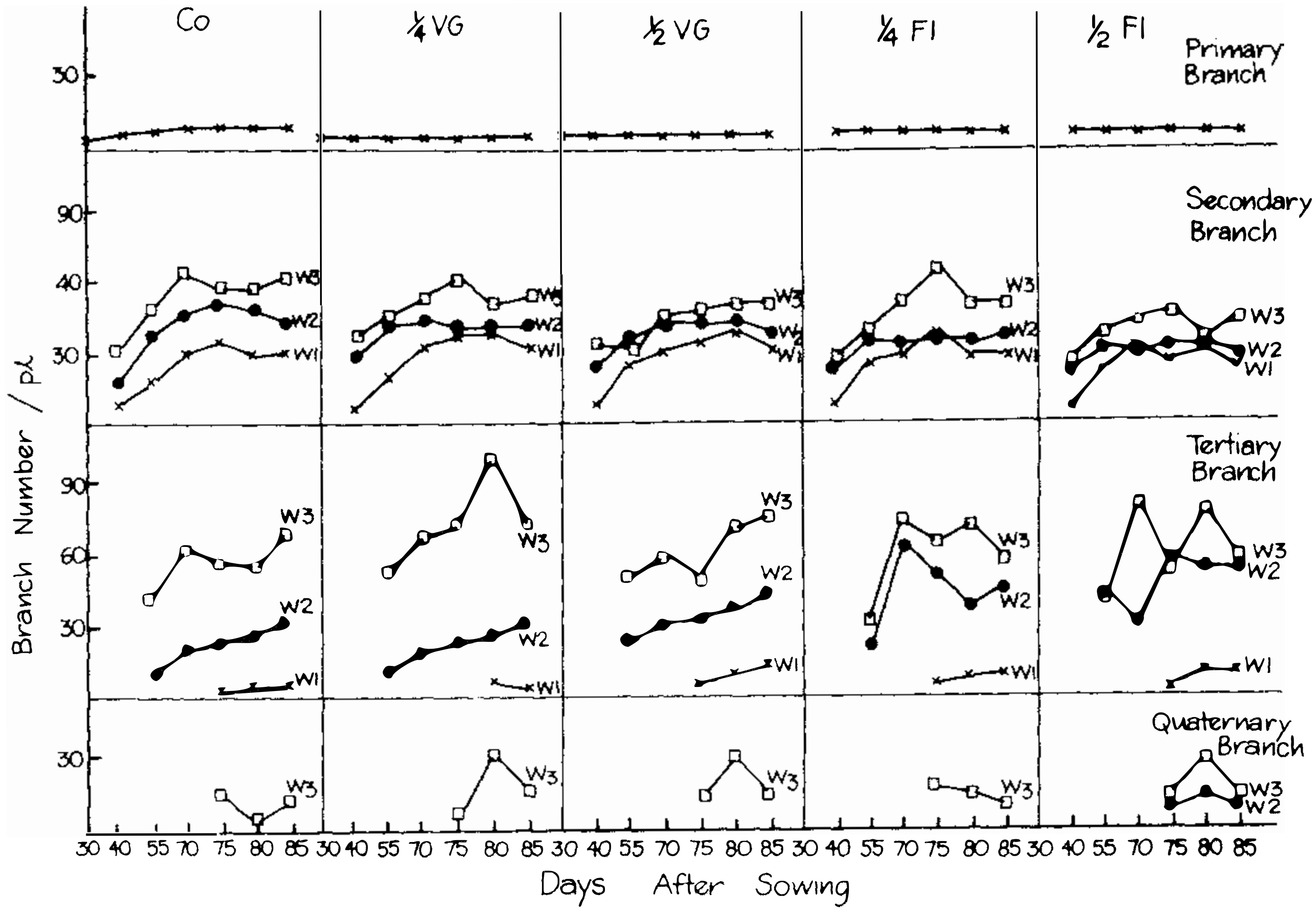
There was no significant interaction between water and cutting on primary branch numbers (Appendix 3.3). The results presented in Figure 3.1 show that there were some interactions between these variables on higher order branch numbers. In plants receiving continuous water (W3) or where watering was continued to peak flowering (W2) delayed cutting and increased cutting severity generally reduced secondary branch numbers. By comparison secondary branch numbers on plants water stressed early in their growth (W1) were relatively unaffected by cutting. In cutting treatments where secondary branch numbers were reduced, there was a tendency for tertiary branch numbers to be increased. This was particularly the case in treatment W2 where cutting was delayed until floral initiation or in treatment W3 in all cutting treatments. Tertiary branches were only formed on plants receiving continuous water (W3) and on plants which were cut heavily and late (½FI) but which had also received water until peak flowering (W2) (Figure 3.1).

B.3.2 Effect on Reproductive Growth and Seed Yield

Seedhead Number

As shown in Figure 3.2 water had a dramatic effect in stimulating seedhead number, particularly on secondary and tertiary branches. Early water stressed plants (W1) obviously produced relatively few primary and secondary branch seedheads and no tertiary branch seedheads. By comparison the influence of water in stimulating particularly secondary branch seedheads but also tertiary branch seedheads

Figure 3.1 EFFECT OF WATER AND CUTTING ON THE NUMBER OF BRANCH ORDERS AT SUCCESSIVE HARVESTS OF VERANO STYLO UNDER CONTROLLED ENVIRONMENT CONDITIONS



was very marked. The interaction with cutting was also important. The results in Figure 3.2 show that seedhead numbers on primary branches of plants watered to peak flowering (W2) were reduced to a greater extent under late cutting than under early cutting. These reactions were reversed in terms of seedhead numbers on secondary branches. Seedhead numbers on tertiary branches of continuously watered plants (W3) appeared to suffer to a much greater extent under light but late cutting. However, those plants cut late and severely (½FI) showed a greater capacity to increase seedhead numbers on tertiary branches than plants from other cutting treatments. This was particularly apparent in the W2 and W3 treatments at the point of maximum seed yield 25 days after peak flowering.

It is also interesting that late and severe cutting completely prevented the development of seedheads on the primary branches of plants watered to peak flowering (W2). Provided plants were well watered at least until peak flowering (W2 and W3), cut plants generally compensated for reduced primary branch seedhead numbers by a stimulation of seedhead numbers on secondary and tertiary branches. This compensatory effect did not occur if watering was inadequate (W1).

Seed Yield

Seed yields formed on each branch order (Figure 3.3) clearly reflect the pattern of seedhead numbers previously described. Certainly the effect of water in stimulating seed yield was very apparent, particularly on secondary and tertiary branches. By comparison the effect of cutting was small, all cut plants showing a very similar pattern of seed yield development in each water treatment. However there was a noticeable interaction between water and cutting, with seed yield from primary branches being depressed to a greater extent under late cutting than early cutting or uncut treatments, particularly when watering was terminated at peak flowering (W2). Again seed yield from secondary branches under this W2 treatment tended to compensate for the above decrease by showing a noticeable increase at later harvests. The results also clearly show

Figure 3.2 EFFECT OF WATER AND CUTTING ON THE NUMBER OF SEEDHEADS FORMED ON EACH BRANCH ORDER AT SUCCESSIVE HARVESTS OF VERANO STYLO UNDER CONTROLLED ENVIRONMENT CONDITIONS

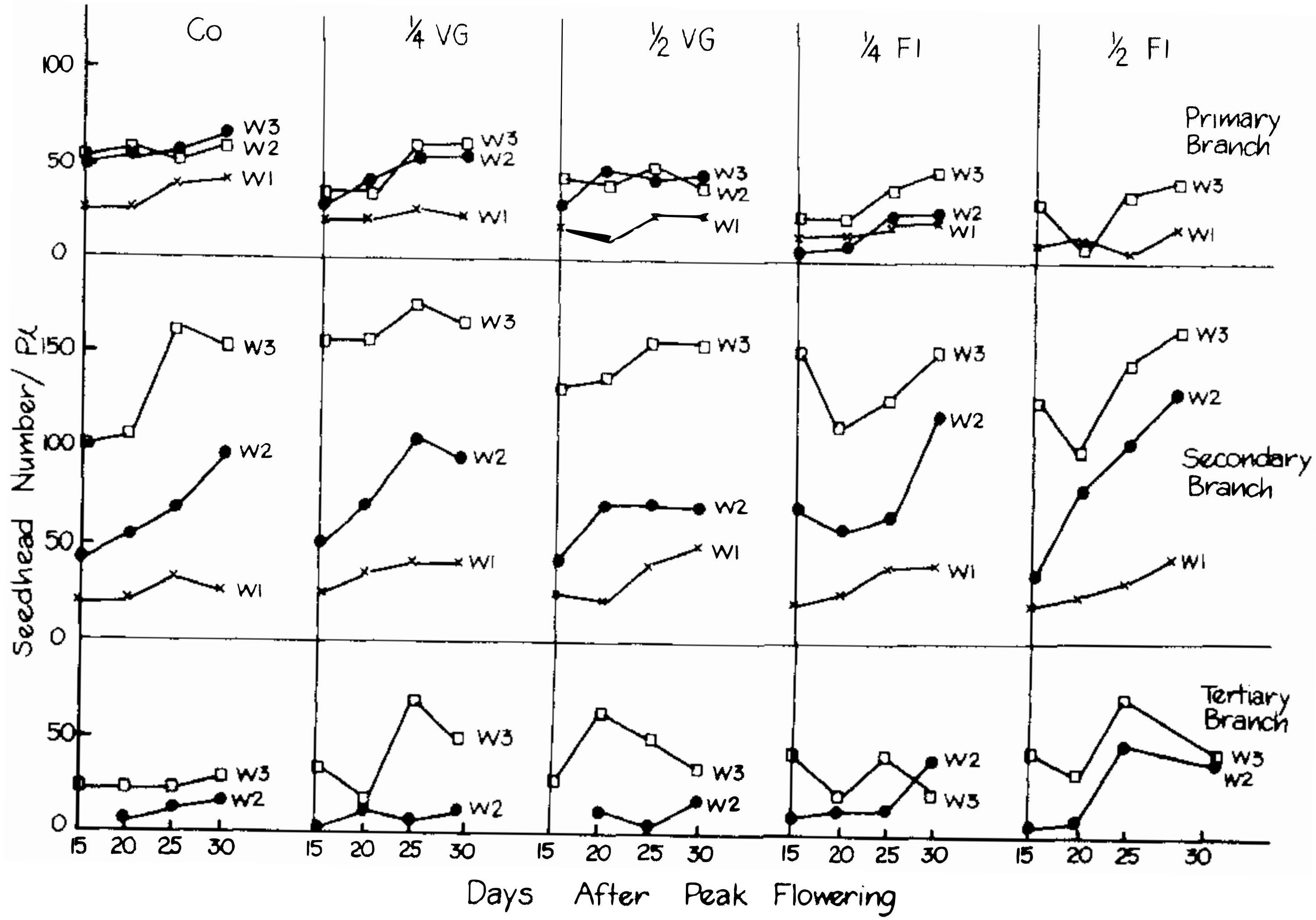
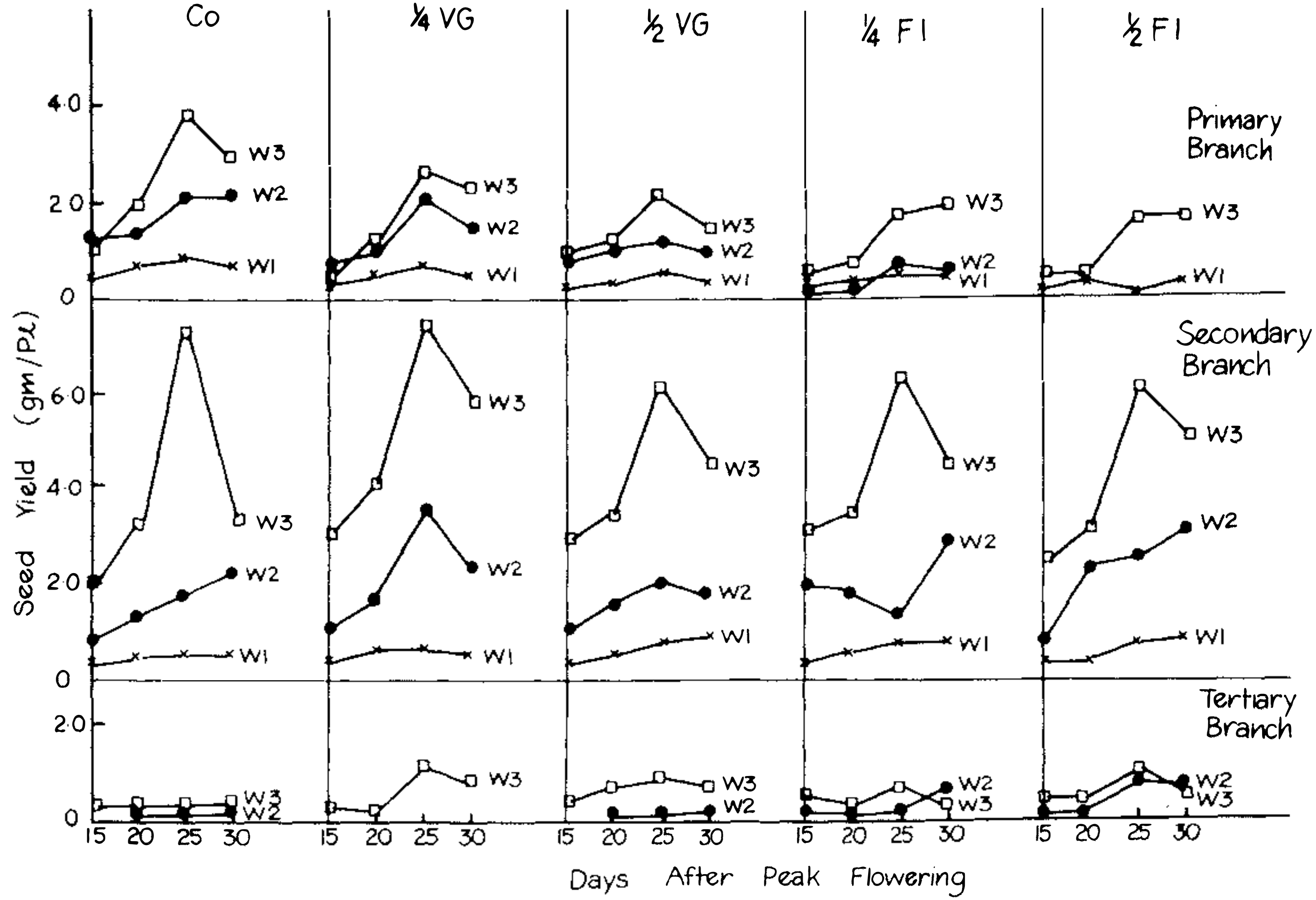


Figure 3.3 EFFECT OF WATER AND CUTTING ON THE SEED YIELD FORMED ON EACH BRANCH ORDER AT SUCCESSIVE HARVESTS OF VERANO STYLO UNDER CONTROLLED ENVIRONMENT CONDITIONS (g/pl)



the dominant contribution of secondary, and to a lesser extent, primary branch seedheads to total seed yield and the relatively insignificant contribution made by seed-heads formed on tertiary branches in response to adequate watering.

PART C EFFECT OF WATER AND CUTTING ON THE CONTRIBUTION TO SEED YIELD MADE BY THE POSITION OF THE SEEDHEAD

The previous section has clearly shown the contribution made to total seed yield by different branch orders. In addition, it has explored the influence of both water and cutting on branch and seedhead numbers and on seed yield. The results however, have also highlighted the variation in reproductive capacity obtained between different branch orders. This suggests there are quite large differences in the reproductive potential of different sites within the plant. The results presented in this section attempt to clarify the contribution to seed yield made by seedheads formed at terminal sites on different branch orders and to determine the influence of water and cutting in modifying seeding site responses.

C.1 INFLUENCE OF DIFFERENT SEEDHEAD POSITION ON SEED NUMBERS

The results presented in Table C.3.1 show the number of seeds formed per seedhead at nodal or terminal sites on different branch orders at different harvests from 15-30 days after peak flowering. The results show that at each harvest the highest number of seed occurs in seedheads formed at nodal position on primary and secondary branches with a severe reduction occurring in the number of seeds present per seedhead on tertiary branches. This was visually suggested by the different size of the inflorescences on nodal and terminal sites (Plate 3.7). Seed numbers in seed-heads formed at terminal sites were less markedly affected by branch order but still showed superior seed numbers on primary and secondary branches. On tertiary branches the seed numbers formed in seedheads at nodal and terminal sites was similar mainly as a result of depression in seed numbers in nodal seedheads. As seed matured seed numbers on all

Table C.3.1 NUMBER OF SEEDS PER SEEDHEAD AT NODAL AND TERMINAL POSITIONS FORMED ON PRIMARY, SECONDARY AND TERTIARY BRANCHES AT SUCCESSIVE HARVESTS IN VERANO STYLO UNDER CONTROLLED ENVIRONMENT CONDITIONS

Branch Order	Harvesting Times 15DAPF Node	15DAPF Terminal	20DAPF Node	20DAPF Terminal	25DAPF Node	25DAPF Terminal	30DAPF Node	30DAPF Terminal
Primary	10.7	4.0	12.0	5.0	15.3	5.3	10.0	5.7
Secondary	10.7	4.7	12.0	4.3	15.7	5.3	10.6	5.7
Tertiary	3.7	2.5	5.0	3.3	5.7	4.3	5.0	4.0
LSD5%	1.9	.9	1.1	.9	1.6	1.1	1.7	.9

a

b

Plate 3.7 a,b Showing the relative size of inflorescences at nodal (a) and terminal (b) positions in Verano stylo.

seedheads increased to a maximum 25 days after peak flowering. Seed numbers per seedhead then decreased due to seed shattering. This was particularly due to the dropping of hooked seeds while the unhooked seeds generally stick to the seedhead and shed at a later stage.

C.2 EFFECT OF WATER ON SEEDHEAD NUMBER AND SEED YIELD

Seedhead Number

It is apparent from the results presented in Table C.3.2 that water had a dramatic effect on the number of seedheads formed at nodal and terminal sites on different branch orders. The results at successive harvests show that water stress applied at the early stage of growth (W1) significantly reduced seedhead numbers formed at nodal sites in every branch order. However, the number of seedheads formed at terminal sites in the treatment was not as severely affected. No tertiary branch seedheads were formed in this treatment. In plants which received ample water throughout the experiment (W3) high numbers of nodal site seedheads were formed presumably as a result of the effect of water in extending branch length and therefore increasing nodal sites for seedhead formation. Terminal sites were also increased in this treatment, although the effect was not as great. Secondary and tertiary branch terminal seedhead numbers were more strongly stimulated by water than primary branch terminal sites. Plants to which water stress was not imposed until peak flowering (W2) showed an intermediate response.

Seed Yield

Plants stressed during the early vegetative stage had a significantly lower seed yield than plants stressed at peak flowering (W2) and non-stressed plants (W3) (Table C.3.3). The results clearly show that seed yield depends on the site of the seedhead on each branch order.

Table C.3.3 shows that in every water treatment by far the greatest proportion of total seed yield came from seed-

Table C.3.2 EFFECT OF WATER ON SEEDHEAD NUMBERS AT NODAL AND TERMINAL POSITIONS FORMED ON PRIMARY, SECONDARY AND TERTIARY BRANCHES AT SUCCESSIVE HARVESTS IN VERANO STYLO UNDER CONTROLLED ENVIRONMENT CONDITIONS

Branch Order	Water Treatment	15DAPF		20DAPF		25DAPF		30DAPF	
		Node	Terminal	Node	Terminal	Node	Terminal	Node	Terminal
Primary	W1	11.3	6.1	13.7	4.2	16.2	6.8	18.0	7.1
	W2	21.1	2.9	29.7	7.9	33.9	5.5	38.7	12.3
	W3	27.0	7.6	30.7	1.0	44.7	5.1	50.4	3.4
	LSD5%	8.6	4.2	5.1	2.2	8.9	NS	5.4	3.5
Secondary	W1	6.3	17.0	11.1	14.9	15.8	20.5	20.9	19.3
	W2	34.9	12.5	53.0	15.3	62.5	20.9	74.3	27.7
	W3	87.0	46.7	92.1	29.1	123.2	35.7	125.9	32.1
	LSD5%	18.2	21.9	12.9	10.0	11.3	10.2	20.5	13.4
Tertiary	W1		0	0	0	0	0	0	0
	W2		5.1	7.0	9.0	4.0	12.3	15.0	18.3
	W3	10.9	22.8	15.0	14.5	22.8	25.1	12.2	29.5

Table C.3.3 EFFECT OF WATER ON SEED YIELD AT NODAL AND TERMINAL POSITIONS ON PRIMARY, SECONDARY AND TERTIARY BRANCHES AT SUCCESSIVE HARVESTS IN VERANO STYLO UNDER CONTROLLED ENVIRONMENT CONDITIONS (g/pl)

Branch Order	Water Treatment	15DAPF		20DAPF		25DAPF		30DAPF	
		Node	Terminal	Node	Terminal	Node	Terminal	Node	Terminal
Primary	W1	.22	.05	.41	.04	.47	.07	0.35	.07
	W2	.63	.04	.69	.06	1.18	.06	0.93	.10
	W3	.64	.01	1.07	.01	2.36	.10	1.72	.05
	LSD5%	.21	.02	.17	.02	.38	.07	.19	.05
Secondary	W1	.14	.15	.31	.18	.44	.21	.42	.22
	W2	1.07	.12	1.61	.16	2.08	.24	2.16	.32
	W3	2.14	.47	3.16	.38	6.52	.71	3.93	.64
	LSD5%	.46	.22	.39	.11	.52	.18	.81	.25
Tertiary	W1								
	W2		.02		.08	.10	.14		.20
	W3	.18	.22	.21	.16	.45	.34	.13	.40

heads formed at nodal positions and that water had a major effect on the seed yield obtained from these positions. Seedheads formed on terminal positions on each branch contributed minimally to total seed yield per plant.

The results also show that water affects the seed yield obtained on different branch orders and positions. Water had its main effect in promoting the seed yield from seedheads formed at the nodes of secondary branches. Plants which received less water early in their growth (W1) produced relatively low yields from primary and secondary branches irrespective of site and formed no seed at either site on tertiary branches. Conversely plants which received a high level of water throughout the growing period (W3) reacted favourable to water by expressing the highest seed yield. Seed yield from treatment W2 was intermediate in its response to water and to primary and secondary branch nodal site stimulation of yield.

By comparing the seed yield obtained from each water treatment at maximum seed yield it can be seen that the overall seed yield per plant from treatment W1 was only about one third (1.2 g) of that obtained from plants in treatment W2 (3.8 g) and was nearly 9 times lower than seed yield from plants in treatment W3 (10.5 g) (Table C.3.3).

The results in Table C.3.4 also show that in W1 treatment at maximum seed yield (25DAPF) 76% of the yield came from nodal site seedheads and 24% from terminal sites. In both of the other water treatments (W2 and W3) almost 90% of total seed yield came from nodal sites and only 10% from terminal sites. These results suggest that the effect of water in determining seed yield according to site is decided before peak flowering. This is supported by the fact that the relative apportioning of total seed yield per plant between nodal and terminal positions on branches was not changed by continuing to water plants after this stage of growth. The results also show that reduced seed yield (presumably a reflection of reduced seeds per seedhead and

Table C.3.4 EFFECT OF WATER ON SEED YIELD FORMED AT NODAL AND TERMINAL POSITIONS AT SUCCESSIVE HARVESTS IN VERANO STYLO UNDER CONTROLLED ENVIRONMENT CONDITIONS (g/pl)

Water Treatment	Seed yield per plant (gm) from node and terminal positions at different harvest stages							
	15DAPF		20DAPF		25DAPF		30DAPF	
	Node	Terminal	Node	Terminal	Node	Terminal	Node	Terminal
W1	.36	.21	.72	.22	.91	.28	.78	.30
W2	1.71	.17	2.33	.30	3.38	.43	3.25	.62
W3	2.94	.76	4.48	.53	9.32	1.15	7.07	1.09
LSD5%	.28	.21	.30	.13	.30	.15	.40	.18

seedhead numbers) at nodal and terminal sites occurs as a result of early water stress (W1). In this case however, the reduction in seed yield at nodal sites was partly compensated for by a proportionally greater increase in seed yield from terminal site seedheads.

C.3 EFFECT OF CUTTING ON SEEDHEAD AND SEED YIELD

Seedhead Number

The different stages of plant growth and severity of cutting used in this experiment had a marked effect on the number of seedheads formed at each position (nodal or terminal) on each branch order.

The results in Table C.3.5 show that all cut plants produced fewer seedheads at both nodal and terminal sites on primary branches. This was due to the lower number of primary branches on cut plants. Plants which were cut at floral initiation were most affected, particularly if cutting was severe.

A different picture emerged in the case of secondary branches. In most cases there was generally no great difference in the number of seedheads formed at terminal positions on secondary branches between cut and uncut plants. However, there was some compensation for reduced primary branch nodal seedheads in cut plants by a general stimulation in secondary branch nodal position seedheads. This compensatory effect was particularly apparent in plants cut lightly during the vegetative stage (¼VG) and plants at floral initiation (¼FI, ½FI). The general stimulation of seedhead numbers at both nodal and terminal positions by cutting was very apparent on tertiary branches.

The general conclusion is that maximum seedhead numbers were produced on secondary branches irrespective of whether plants were cut or not. However any management system which stimulated secondary branch formation appeared to be beneficial in promoting greater numbers of seedheads per plant.

Table C.3.5 EFFECT OF CUTTING ON SEEDHEAD NUMBERS AT NODAL AND TERMINAL POSITIONS ON PRIMARY, SECONDARY AND TERTIARY BRANCHES AT SUCCESSIVE HARVESTS IN VERANO STYLO UNDER CONTROLLED ENVIRONMENT CONDITIONS

Branch Order	Cutting Treatment	15DAPF		20DAPF		25DAPF		30DAPF	
		Node	Terminal	Node	Terminal	Node	Terminal	Node	Terminal
Primary	Co	34.3	8.3	40.0	6.9	52.7	10.0	55.0	13.0
	¼VG	23.8	4.2	26.4	5.4	39.8	7.8	36.4	8.7
	½VG	21.3	8.0	26.4	3.8	29.9	6.2	40.8	4.2
	¼FI	9.7	3.9	13.2	1.5	23.3	3.6	26.9	3.9
	½FI	9.9	2.2	7.2	1.2	12.3	1.4	18.8	1.9
	LSD5%	7.2	2.5	4.3	1.8	7.4	3.5	4.5	2.9
Secondary	Co	36.1	20.0	61.8	13.3	61.6	26.1	61.5	31.7
	¼VG	56.9	32.6	52.1	33.7	74.1	32.0	72.4	25.6
	½VG	36.6	28.9	32.2	26.7	65.2	24.4	67.1	24.9
	¼FI	57.7	23.8	53.6	12.8	62.3	23.3	76.0	27.9
	½FI	38.5	19.3	56.0	12.4	72.3	22.6	91.5	21.1
	LSD5%	15.1	NS	10.7	8.3	9.4	NS	17.0	NS
Tertiary	Co	2.2	4.2	5.0	1.9	1.0	9.6	0	13.1
	¼VG	4.7	7.9	3.2	6.2	12.4	13.5	5.7	13.8
	½VG	2.2	7.3	7.7	7.5	8.8	8.5	0	17.2
	¼FI	4.2	13.7	1.9	8.6	6.5	10.7	5.6	15.7
	½FI	3.8	10.5	9.6	1.9	16.1	20.7	5.0	19.8
	LSD5%	NS	NS	5.8	4.4	6.2	6.4	NS	5.1

Seed Yield

The results in Table C.3.6 show that seed yield on different branch orders reflected the relative contribution of nodal and terminal position seedhead numbers previously recorded. At the time of maximum seed yield 25 days after peak flowering for example, uncut plants produced a total seed yield of 5.67 gm/plant composed of 5.11 gm from nodal seedheads and 0.56 gm from terminal position seedheads. These figures can be compared with the lowest yielding cutting treatment (¼FI) which produced a total seed yield of only 4.40 gm/plant made up of 3.93 gm from nodal sites and 0.47 gm from terminal seedheads. The previously described stimulation of secondary branch seedheads and to a lesser extent tertiary seedheads by cutting is also reflected in the seed yield results in Table C.3.6.

C.4 EFFECT OF WATER AND CUTTING ON SEEDHEAD NUMBERS AND SEED YIELD

Seedhead Number

A diagrammatic presentation of the distribution of nodal and terminal seedheads on Verano stylo plants in the different water and cutting treatments is shown in Plate 3.8. This rather different form of presentation was confined to the harvest 25 days after peak flowering when maximum seed yield were generally recorded. More detailed and comprehensive data are presented in Appendix 3.8.

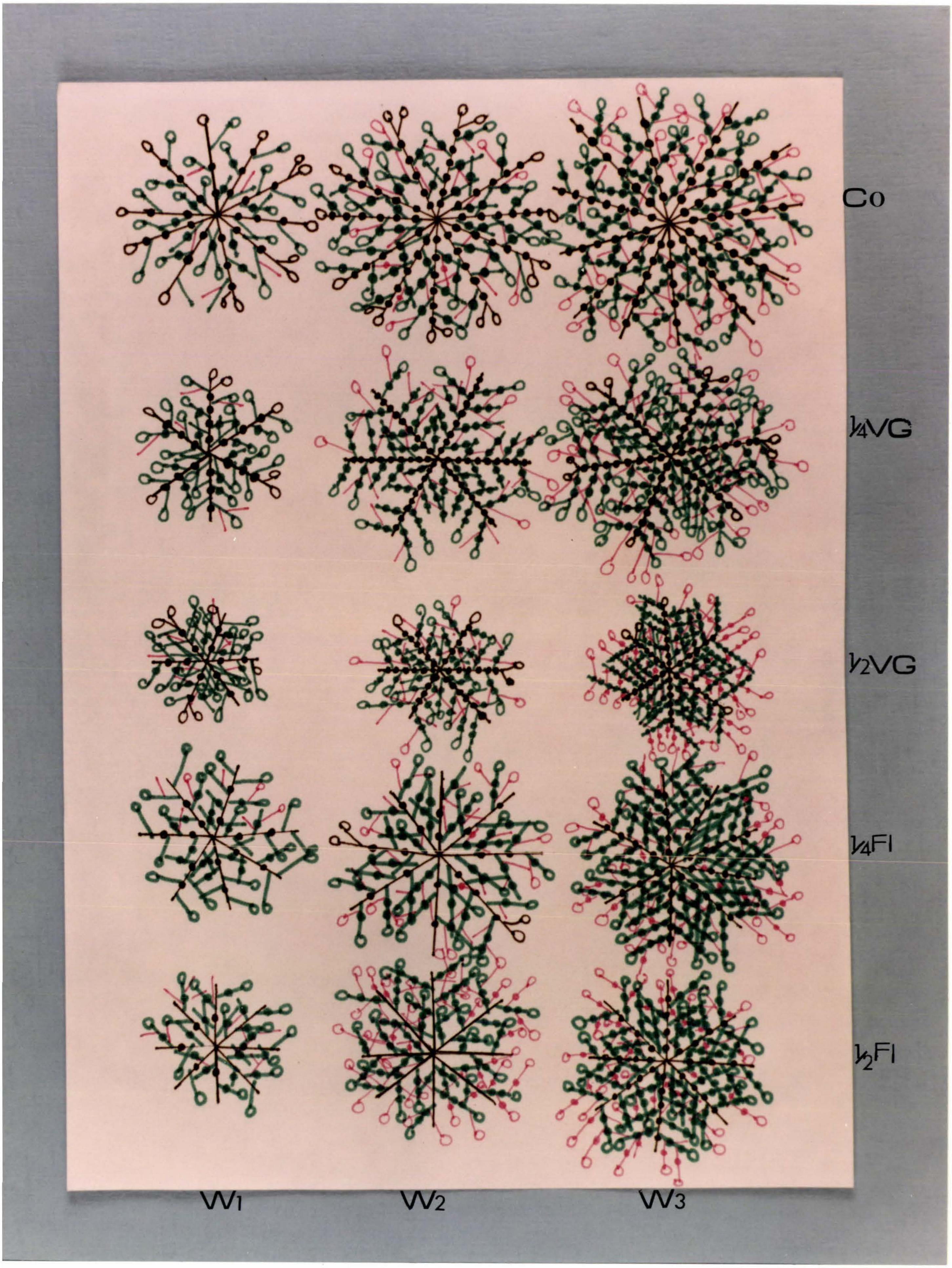
(i) Primary branch nodal position seedheads: Cutting reduced seedhead numbers in all water treatments. Uncut plants which received adequate watering until at least peak flowering (W2) produced 45-65 seedheads at nodal sites on primary branches compared with 0-55 seedheads on cut plants, major differences occurring with increased cutting severity and later cutting.

Table C.3.6 EFFECT OF CUTTING ON SEED YIELD AT NODAL AND TERMINAL POSITIONS ON PRIMARY, SECONDARY AND TERTIARY BRANCHES AT SUCCESSIVE HARVESTS IN VERANO STYLO UNDER CONTROLLED ENVIRONMENT CONDITIONS (g/pl)

Branch Order	Cutting Treatment	15DAPF		20DAPF		25DAPF		30DAPF	
		Node	Terminal	Node	Terminal	Node	Terminal	Node	Terminal
Primary	Co	.86	.08	1.26	.07	2.23	.07	1.80	.13
	¼VG	.62	.04	.87	.05	1.69	.05	1.19	.12
	½VG	.57	.08	.83	.04	1.23	.04	.92	.05
	¼FI	.23	.05	.43	.01	.94	.01	.93	.04
	½FI	.23	.02	.23	.01	.61	.01	0.65	.02
	LSD5%	.17	.03	.14	.01	.33	.06	.16	.04
Secondary	Co	.92	.19	1.58	.15	2.86	.38	2.13	.48
	¼VG	1.19	.32	1.73	.43	3.35	.50	2.54	.38
	½VG	.97	.28	1.58	.32	2.96	.38	2.30	.40
	¼FI	1.54	.24	1.79	.15	2.85	.33	2.63	.40
	½FI	0.97	.22	1.80	.16	3.10	.33	3.01	.32
	LSD5%	.38	.18	.32	.09	.44	.15	.68	NS
Tertiary	Co	.05	.04	.07	.02	.02	.11	0	.16
	¼VG	.08	.06	.06	.07	.25	.17	.11	.17
	½VG	.04	.07	.11	.18	.19	.12	0	.22
	¼FI	.06	.13	.03	.08	.14	.13	.15	.19
	½FI	.06	.10	.13	.05	.35	.27	.22	.25
	LSD5%	NS	NS	.07	.07	.19	.13	.20	NS

Plate 3.8 Diagrams showing nodal and terminal position seedheads on each branch order of Verano stylo plants from all water and cutting treatments 25 days after peak flowering.

- ● = nodal position
- ○ = terminal position
- ▮ = primary branch
- ▮ = secondary branch
- ▮ = tertiary branch


Co
¼VG
½VG
¼Fl
½Fl
W1
W2
W3

(ii) Primary branch terminal position seedheads: Cutting reduced terminal site seedhead formation. Even the supply of ample water to cut plants was not sufficient to compensate for the depression of terminal site seedhead numbers due to cutting. However, in uncut plants a positive water response was obtained (Plate 3.8 and Appendix 3.8).

(iii) Secondary branch nodal position seedheads: There was a suggestion that water and late cutting in particular combined to stimulate secondary branch nodal position seedhead numbers. In the severe floral initiation cut for example (½FI) total secondary branch nodal seedheads in treatment W1, W2 and W3 were approximately 30, 100 and 140 compared with respective figures of 10, 65 and 110 in uncut plants (Appendix 3.8).

(iv) Secondary branch terminal position seedheads: There was a distinct relationship between water and cutting in affecting the number of seedheads formed at terminal positions on secondary branches. Treatment W3 for example produced up to 45 seedheads/plant in uncut plants compared with 20-60 seedheads in plants from different cutting treatments (Plate 3.8).

(v) Tertiary branch nodal position seedheads: Only well watered plants (W3) produced seedheads on tertiary branches at nodal sites except that plants stressed after peak flowering (W2) and cut at floral initiation did produce small numbers (approximately 20) seedheads at nodal sites (Plate 3.8 and Appendix 3.8).

(vi) Tertiary branch terminal position: Early stressed plants (W1) produced no tertiary branch seedheads in both cut and uncut plants. Plants receiving water until peak flowering and beyond (W2 and W3) produced 10-40 seedheads at terminal positions on tertiary branches (Plate 3.8).

Seed Yield

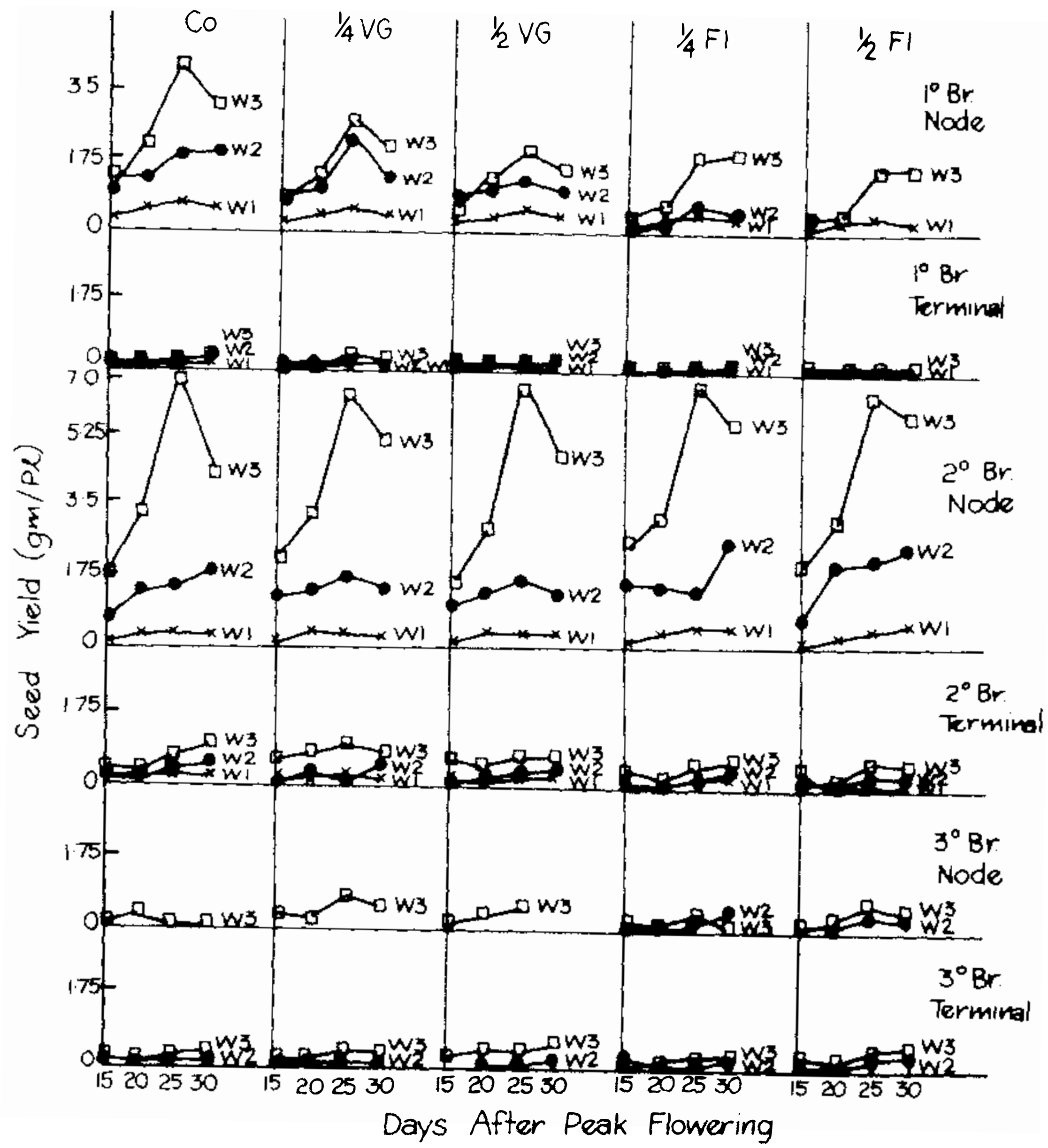
The seed yield produced at nodal and terminal sites on different branch orders is shown graphically in Figure 3.4 and Appendix 3.9. Differences in seed yield simply reflect the seedhead numbers distribution from each position and branch order previously described (Plate 3.8). Seed yield from different branch orders and sites was strongly influenced by water and to a lesser extent by cutting. The effect of these factors on seed yield is summarised below:

(i) Primary branch nodal position seed yield: Although water continued to increase seed yield in all treatments there was a significant depression in yield in cut plants, this effect becoming more apparent with late and severe cutting. The quantity of seed produced by early stressed plants was low in all treatments. No seed was formed on plants receiving water stress after peak flowering (W2) when these plants were cut severely and late (½FI).

(ii) Primary branch terminal position seed yield: There was very little contribution to seed yield from seeds formed on primary branches at the terminal position irrespective of water or cutting (Figure 3.4).

(iii) Secondary branch nodal position seed yield: The results in Figure 3.4 show the dramatic influence of continuous watering (W3) in stimulating seed yield at nodal sites on secondary branches. By comparison the effect of cutting on seed yield was small, although plants water stressed from peak flowering (W2) did show some increase in yield due to a stimulation of seeding capacity at nodal sites on secondary branches when plants were cut at floral initiation. Early stressed plants (W1) and continuously watered plants (W3) were less responsive to this late cutting stimulus.

Figure 3.4 EFFECT OF WATER AND CUTTING ON SEED YIELD FORMED ON EACH BRANCH ORDER AND POSITIONS AT SUCCESSIVE HARVESTS OF VERANO STYLO UNDER CONTROLLED ENVIRONMENT CONDITIONS (g/pl)



(iv) Secondary branch terminal position seed yield: Although water did slightly increase seed yield from terminal sites on secondary branches there was little effect due to cutting. Overall however, the contribution of seed produced terminally on secondary branches was low.

(v) Tertiary branch nodal position seed yield: Early stressed plants (W1) produced no seed on tertiary branches. However plants receiving ample water (W3) produced some seed from nodal sites on these branches, there being a suggestion that seed yield was improved by cutting. Plants water stressed at peak flowering only formed seed at nodal sites on tertiary branches in situations where plants were cut late (FI).

(vi) Tertiary branch terminal position seed yield: No tertiary branch terminal site seed yield occurred on plants which had been water stressed early (W1). However watering until peak flowering (W2) or later (W3) did result in a small contribution to seed yield from these sites, although there was no apparent effect due to cutting.

Table C.3.7 summarises the contribution to seed yield made by each branch order and by seedhead position from all water and cutting treatments. The results presented are for the highest seed yield harvest 25 days after peak flowering. In all water and cutting treatments by far the greatest contribution to seed yield came from seed produced at nodal positions on primary and secondary branches. The highest contribution to seed yield by terminal site seed-heads came from those formed on secondary branches. Tertiary branch seedheads, whether they were formed at nodal or terminal positions, contributed very little, and in some cases zero, seed yield.

In most cases primary branch seed yield was reduced by delay in cutting and by increased cutting severity. However, any reduction by cutting was generally compensated for

Table C.3.7 SUMMARY OF THE PERCENTAGE OF THE CONTRIBUTION OF THE SEED YIELD FORMED ON EACH BRANCH ORDER AND POSITION AT 25 DAYS AFTER PEAK FLOWERING IN VERANO STYLO UNDER CONTROLLED ENVIRONMENT CONDITIONS

		W1					W2					W3				
		Co	¼VG	½VG	¼FI	½FI	Co	¼VG	½VG	¼FI	½FI	Co	¼VG	½VG	¼FI	½FI
Nodal Position	Primary	55.5	45.5	35.5	34.0	22.0	48.4	37.0	36.0	25.0	0	34.0	21.0	19.0	18.0	17.0
	Secondary	19.5	28.5	44.0	42.0	59.0	38.0	59.0	55.0	56.0	67.0	58.0	56.0	64.0	69.0	67.0
	Tertiary	0	0	0	0	0	0	0	0	3.0	12.0	0	7.0	6.0	4.0	7.0
Terminal Position	Primary	9.4	5.7	6.0	5.0	1.0	5.0	0	1.0	1.0	0	0	2.0	1.0	0	1.0
	Secondary	15.6	20.3	15.0	19.0	18.0	6.6	3.0	7.0	10.0	9.0	6.0	10.0	7.0	6.0	6.0
	Tertiary	0	0	0	0	0	2.0	1.0	1.0	5.0	12.0	2.0	4.0	3.0	3.0	2.0

by a proportional increase in the percentage seed yield contribution by seedheads formed on secondary branches. It was surprising that late and severely cut plants (½FI) failed to produce any seed yield on primary branches in the W2 treatment. This might be due to the fact that the supply of water after severe cutting was inadequate for the restoration of floral sites which had been removed from these relatively large plants.

The percentage contribution to total seed yield by different branch orders and sites was remarkably constant between the water treatments. While plants from all water treatments generally produced over 90% of their seed yield on primary and secondary branches the main differences occurred in the percentage of total seed yield produced at nodal sites compared with terminal sites on primary and secondary branches. In early stressed plants (W1) the proportion was approximately 75%:25%. However in plants which were adequately watered until peak flowering (W2) or throughout the experiment (W3) this proportion of total seed yield between nodal and terminal sites on primary and secondary branches was approximately 90%:10%.

Although there was an increasing percentage of seed yield contributed by tertiary branches as a response to improved watering (W2, W3), this contribution was generally low. Early stressed plants (W1) were unable to produce any seed on tertiary branches.

These results therefore highlight the ability of Verano stylo plants to compensate for primary branch removal due to cutting by increasing the percentage of seed yield on secondary branches. They also show the major contribution to seed yield made by nodal site seedheads; the influence of water in affecting the proportion of seed yield produced at nodal sites on primary and secondary branches; and the relatively unimportant contribution to seed yield by terminal position seedheads and by seedheads formed on tertiary branches.

DISCUSSION

The water treatments selected in this controlled environment experiment were chosen to try to simulate as closely as possible the climatic conditions experienced in the previous field experiments in Thailand. Water markedly affected the growth and yield of *Stylosanthes hamata* cv Verano in the controlled environment, and in particular appeared to change plant structure.

Both vegetative and reproductive growth were greatly reduced following water stress, particularly if stress was imposed early in the growth cycle and response to rewatering for survival was very poor. This lack of response to water following stress has also been found in lupin by Withers (1979). Observation showed that stylo plants seemed capable of reacting for lower water availability by an alteration of leaf orientation, a reduction in leaf area and by an increase in leaf shedding. These effects have also been noted in a number of other plants by Ludlow (1976) in grasses and by Whiteman (1977) in Townsville stylo. In the case of water stress initiated at the vegetative stage both cut and uncut plants were unable to fully recover their growth, unlike plants which did not receive a water stress until the peak flowering stage. Early water stress resulted in reduced growth rates for the rest of the growth period. This was reflected in lower branch numbers, shorter branches, fewer leaves, reduced leaf area and fewer sites for seed-head development. All of these variables resulted in lower total seed yield (1.19 g/pl). In the early stress treatment (W1) both cut and uncut plants of Verano stylo produced mainly secondary branches with little tertiary branch development. However when water stress was not imposed until later in the growth cycle, plants had sufficient time to utilise available water to develop greater numbers of higher order branches, especially in the case of plants receiving cutting. Water stress during flowering also reduced seed yield, compared with the maximum seed yield from plants receiving water throughout the period of seed development (W2=3.26 g/pl, W3=9.25 g/pl). This effect has been previously described by Fischer and Hagan (1965); Salter and Goode (1967) and Fischer and Campbell (1977).

Both floral initiation and branch initiation were particularly sensitive to water stress. While water had an effect on the number of sites for seedhead formation the contribution to seed yield was different between water treatments. Early water stress, applied at the vegetative stage, resulted in seed yield being obtained almost equally from primary and secondary branches (45% from primary and 55% from secondary branches). However, water stress applied later at peak flowering resulted in a change in the contribution percentages of seed yield from different branch orders (32% from primary, 62% from secondary, 6% from tertiary). In particular the percentage of seed yield obtained from secondary branches was increased and some contribution from seeds produced on tertiary branches became apparent. In plants receiving adequate water throughout the growth cycle, highest yield was obtained from seeds borne on secondary branches (23% from primary branches, 69% from secondary branches, 8% from tertiary branches).

The position of seedhead formation was also important. In particular, seedheads produced at branch nodes produced higher seed numbers than seedheads formed at the terminal site on the branch. This resulted in about 75-90% of total seed yield coming from seedheads formed at nodal positions. The number of seedheads obtained at nodal sites in later stressed plants and well watered was higher than in early stressed plants.

Cutting on its own did not greatly affect vegetative or reproductive yield. Early cutting however, appeared to stimulate higher branch orders. This early removal of herbage by cutting at the vegetative stage resulted in more branches being formed than occurred following later cutting and in uncut plants. This effect was very worthwhile if water continued to be available. The cutting of Verano stylo also reduced leaf numbers and leaf area and supported the suggestion that *Stylosanthes* spp., along with most tropical legumes, is susceptible to cutting damage (Humphreys, 1975).

In the present study, removing 25% of the top of the plant canopy at the early vegetative stage (¼VG) apparently allowed time for the plant to recover structurally before floral initiation commenced. Such management resulted in higher branch numbers and higher density of inflorescences. If cutting was begun when plants were small they then had time to replace the growth which had been removed, allowing the production of abundant seeds. A similar effect following grazing has been previously noted in stylo by Kretschmer (1968). In the present study the earlier cutting treatments yielded similar or higher seed yield than uncut plants. This effect is also confirmed by other workers (Rossiter, 1961; Kretschmer, 1968; Loch and Humphreys, 1970; Wilaipon *et al.*, 1979 and Wilaipon and Humphreys, 1981) who have all shown that early cutting before the onset of flowering increases seed yield. In all early cut treatments resultant seed yield came mainly from secondary branches with a small contribution from tertiary branches. Similar findings have been recorded by Humphreys (1981) who has shown the defoliated plants display an increased capacity to equilibrate inflorescence density through increased secondary and tertiary branching in defoliated swards.

Late cutting of *Stylosanthes* which removed the floral initials has been shown to be particularly harmful to seed yield (Humphreys, 1978). In the present study removing even 25% or 50% of the top growth of the plant at the stage of floral initiation decreased seed yield. Apparently the quantity of seed produced is strongly dependent on plant vigour and the quantity of vegetative material present at flowering (Kretschmer, 1968). This late cutting effect on seed yield was caused by a number of factors, including a reduction in the number of floral sites at terminal positions on primary branches; the fact that plants did not have enough time to recover before flowering commenced and also because of a lack of time to allow compensation by producing tertiary branches. This general effect has also been found by Loch and Humphreys (1970) in *S. humilis*. They noted in particular, that defoliation at floral initiation reduced the fertility of the bud sites. Wilaipon *et al.* (1979) also observed that defoliation of Verano stylo at different stages during early or advanced floral initiation had a significant effect on seed yield. The main seed yield contribution obtained following late cutting was from secondary branches which generally produced over 72% of total seed yield, while tertiary branches produced only about 6-13% of seed yield.

Cut plants have a great potential to compensate yield from secondary and tertiary branches compared with uncut plants. Whether or not the plant has the opportunity to express this potential following cutting appears to be strongly dependent on water availability during the post-cutting period of plant growth, and particularly during the interval between cutting and floral initiation. The results therefore clearly demonstrate the strong interaction between water and cutting in *Stylosanthes hamata* cv Verano.

CHAPTER 4

GENERAL DISCUSSION

Both *Stylosanthes hamata* cv Verano and *Macroptilium atropurpureum* cv Siratro have been widely used for pasture improvement in many tropical countries. These two forage legumes are considered important due to their versatility and wide environmental adaptation. Humphreys (1979), however, has found that *S. hamata* is more versatile in its edaphic adaptation than *S. humilis* and *Macroptilium atropurpureum* cv Siratro, particularly the medium rainfall areas of the tropics and sub-tropics. In an area such as the North-east of Thailand Topark-Ngarm and Lorwilai (1980) and Topark-Ngarm (1980) have found that *S. hamata* and *M. atropurpureum* cv Siratro show distinct promise for pasture improvement and have the potential to be widely used on communal grazing areas. However, further acceptance and wider use by farmers is currently restricted by the lack of reliable supplies of high quality seed. Despite their vegetative growth capacity, major interest has occurred more recently in seed production of these two forage legumes since both are potentially high value crops requiring suitable management to produce an adequate and economic seed return. Seed production is the final stage in a sequence of plant processes, some of which can be more readily controlled by the grower than others. Humphreys (1978) mentioned that the potential yield of forage legume crops is often limited by the characteristics of the plants themselves such as a long sequence of inflorescence production, uneven seed ripening, and dropping or shattering of seed. Such characteristics can lead to seed harvesting inefficiency, since only a small portion of the total seed crop is available for recovery at any one time. Improved technology for tropical pasture seed production is related to an understanding of those physiological processes which control seed yield.

Knowledge of how the manipulation of defoliation practices can lead to a more uniform and synchronised flowering and therefore a more contracted flowering period, improved uniformity of branching and increased seed yield would all assist in overcoming seed harvesting problems.

The effect of defoliation on plant growth and reproduction are generally not well understood. Humphreys (1979) mentioned that research work in this field has shown that it is not possible to predict plant response with confidence unless repeated local experience is available.

Results from the field study indicate that a management system involving removal of the top part of the plant early enough to allow time for structural recovery and provided enough water is available for plant growth after defoliation and before flowering commences, seems to increase seed yield. However, cutting without any supplemental irrigation water following a dry season planting results in low seed yield. Cutting carried out at a time which removes reproductive apices also seems to be a bad practice. The effect of removal of plant tissue by cutting is usually characterised by its frequency, severity, timing in relation to plant developmental stage and environmental conditions. This can be beneficial if cutting is applied when favourable climatic conditions occur. Although Gardener (1977) suggested that Verano seed yield could be dramatically affected by the timing of defoliation, the present study both field and controlled environment conditions showed that cutting Verano stylo in the vegetative stage did not reduce seed yield. A similar effect also occurred if plants were cut lightly up to the time of floral initiation in the field condition. This tolerance to the timing of cutting is supported by similar field studies conducted Wilaipon *et al.* (1979) and Wilaipon and Humphreys (1981).

By comparison the response of Siratro to time of planting and cutting is quite different. The fact that Siratro favours an alternation of wet and dry conditions for high seed yield has been shown by Humphreys (1979). Certainly, results from the field study show that Siratro responds to cutting by increasing stem density, and by increasing the length of primary branches remaining after cutting (Plate 4.1). In such situations however, plants produce very few higher order branches. Verano stylo on the other hand seems to have a greater capacity to increase the number of higher branch orders and to provide more inflorescences (Plate 4.2). By growing Siratro and Verano stylo in the field at the same time, cutting was shown to affect seed yield differently. In the non-irrigated dry season planting Siratro could be cut lightly or heavily at the vegetative stage up to floral initiation without seed yield reduction. By comparison any treatment other than a light cutting at the vegetative up to the floral initiation stage in Verano stylo reduced seed yield.

Field studies showed that Siratro appeared to have flowering and seed formation patterns which were tolerant to grazing and to a wide range of environmental conditions. In the dry season Siratro plants which received irrigation could be cut lightly or heavily not only during the vegetative stage as in the non-irrigated treatment, but right through to floral initiation without reducing seed yield. This high yield was due to a favourable alternation of wet and dry conditions combining to increase floral density (Plate 4.3). Siratro crops grown in the wet season gave very poor reproductive growth (Plate 4.4) although heavily cut plants seemed to give higher reproductive growth than plants cut less intensively. It appears from this study that Verano stylo requires high amounts of water to maximise both vegetative and reproductive yield (Plate 4.5). This effect was apparent in both field and controlled environments. Wilaipon (1979) also found that moisture stress influenced flowering and seed yield in Verano stylo. To obtain high seed yields in this species it became apparent that cut plants in particular need water for growth to recover from cutting in order to replace the vegetative framework removed by cutting the top of the canopy. In this study it appears that the crop is capable of adapting to cutting and to moisture stress and exhibits the ability to compensate yield by increasing higher order branch numbers. This provides

Plate 4.1   Siratro plant showing extreme primary branch length but comparatively few higher order branches.

Plate 4.2   Verano stylo plant showing the capacity to increase the number of higher order branches.

Plate 4.3 Siratro sward showing profuse pods production following alternating wet and dry conditions.

Plate 4.4 Siratro sward in the wet season showing profuse vegetative growth and relatively few seedpods.

Plate 4.5 General view of Verano stylo in the wet season at peak flowering stage.

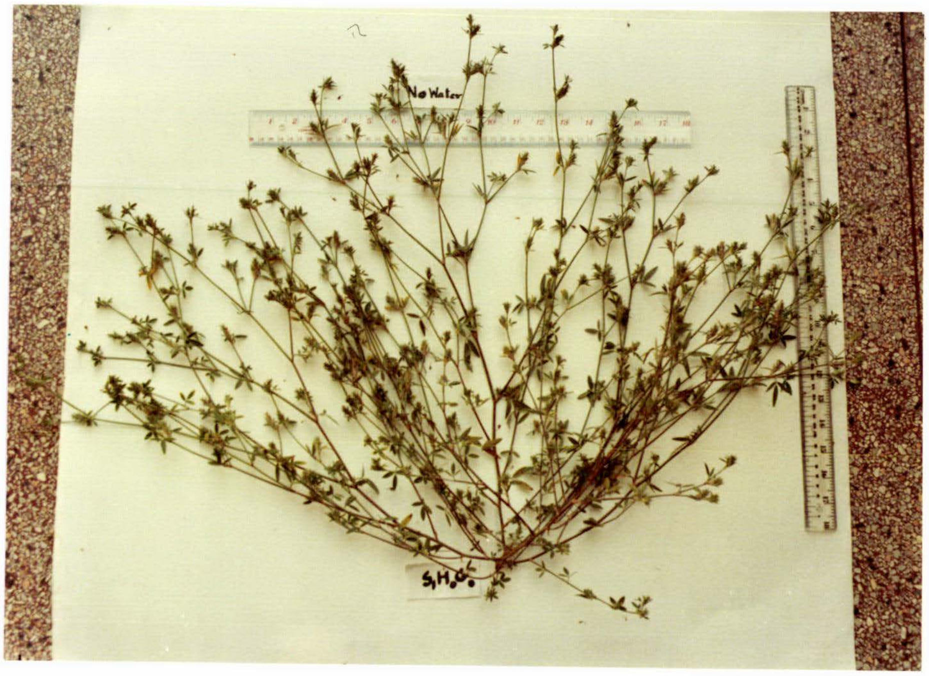
more sites for inflorescence production with a resultant increase in seed yield. The results from the controlled environment room experiment, which was designed to simulate an environment as close as possible to that pertaining in the Thailand field experiments, confirmed that water markedly affected the growth and yield of Verano stylo. The water effect on the yield of both cut and uncut plants was clearly shown when plants were grown in controlled environments. However the seed yield obtained under environmentally controlled drought conditions designed to simulate a dry season non-irrigated planting in the field was only about 30% of the seed yield obtained in the field (i.e. equivalent to 320 kg/ha compared with 1053 kg/ha). This suggests that Verano stylo has a greater ability to tolerate drought conditions in the field than in a controlled environment room. This is clearly shown in a comparison of field grown plants (Co and ¼FI), (Plate 4.6 a.b) and similar plants grown under growth room conditions (Plate 4.6 c). All plants were photographed 15 days after peak flowering and had been subjected to water stress from approximately half way through the vegetative phase. Ludlow and Ng (1976) have pointed out that in the field water deficits are usually built up more slowly than in the controlled environment situation. This is particularly so in field situations where roots can exploit a greater soil volume for water than they can in laboratory experiments where plants are grown in pots.

The quantity and quality of plant growth depends on the rates of various physiological processes, which are closely related to the internal water balance and turgidity of the plant. The plants' internal water balance is controlled by the relative rates of water absorption and water loss, and therefore all soil, plant and climatic factors influencing these processes are likely to affect plant growth and modify the plant response to soil moisture conditions. Salter and Goode (1967) mentioned that factors influencing the water relations of plants and their yield may be grouped into soil factors, plant factors and weather

Plate 4.6 a. Field grown uncut plant with no irrigation in the dry season at 15 days after peak flowering.

b. Field grown cut plant (¼FI) with no irrigation in the dry season at 15 days after peak flowering.

c. Plants grown in the controlled environment conditions at 15 days after peak flowering.


No Water

a

b


UNCUT CONTROL
FLORAL INITI
1/4 PLANT'S CANOPY HEIGHT REMOVED
15 DAYS AFTER P.F.

c

factors. As far as soil factors are concerned legumes vary in their ability to grow at different levels of soil acidity, alkalinity and soil texture. Yields of forage and seed and plant persistence are all responsive to the interaction of climatic and soil factors (Hollowell, 1957). Humphreys (1978) found that pasture seed, while it is a potentially high value crop, requires suitable soil types before it is possible to obtain adequate returns. For seed production *S. hamata* must be grown on free draining, upland sandy loam soils (Hare and Waranyuwat, 1980). Khon Kaen University, where the field part of this study was conducted, is situated on such a soil of the Yasothon series. This type of soil can retain moisture even in the dry season with very little runoff. In the wet season field capacity is reached throughout the profile. However, this soil also has a sandy top soil which acts as an effective mulch allowing soil moisture to be kept for plant growth throughout the dry season. This type of soil is very suitable for growing Verano stylo for seed production since it is a crop which benefits from being grown on good agricultural soil. Soil fertility is also an important factor, suggesting that the application of high levels of fertiliser is profitable for pasture legume seed crops. In addition, adequate soil depth is essential to ensure good root development and thereby provide an adequate supply of essential nutrients and water for the plant (Eyles, pers. comm.).

Verano stylo is a plant that can grow very well in tropical regions with a pronounced dry season (Skerman, 1977). Wilaipon and Humphreys (1981) found that at Khon Kaen in Thailand, stylo can produce high seed yields even under grazing. Stylo is also a highly drought resistant species which has the capacity to extend roots up to 150 cm into the soil in search of soil moisture (Humphreys, 1981). Andrew and Jones (1978) refer to work by McCown who found that *S. hamata* growing on sandy red earth soils in Australia can extract water from soil depths of at least 300 cm by the end of the dry season. Similarly, Wilaipon (pers. comm.) in Thailand, found that Verano stylo plants continue to explore a greater depth of soil to enable them to grow and complete their life cycle even when the wet season is over. Gutteridge (1982) found similar results at Khon Kaen and suggested it was likely that Verano stylo extended its finer roots to depths greater than 75 cm, but under field conditions they were difficult to trace. However, he also found that Siratro extended its roots to a depth of up to 210 cm by the end of the dry season. This adaptation of the root system has been noted in a number of plants, both grass and legumes (Hurd, 1968, 1975; Torssell *et al.* 1968; Passioura 1974; Ludlow, 1975; Whiteman, 1977; Fisher and Turner, 1978; Kummerow, 1980; Levitt, 1980; Taylor, 1980 and Weib, 1980). Besides the ability to adapt by deep rooting under dry conditions stylo plants also react to moisture shortage by reducing the size of the leaf, by reducing leaf numbers, by leaf shedding (Plate 4.7) and also by utilising leaf movement for the restriction of transpiration (Plate 4.8). These effects were also found by Tudsri (unpublished data) working with Verano stylo under water stress conditions. Ludlow (1975) found that many plants have developed mechanisms to reduce water loss during the dry period by folding or rolling their leaves, shedding leaves or by developing a thick leaf cuticle or dense hair covering for drought avoidance. Begg and Torssell (1974) found that *S. humilis* actually moves its leaves parallel to the incident radiation as plant water deficits increase. Dubetz (1969) found similar leaf movement characteristics in stressed beans. Begg and Turner (1976) also mentioned leaf shedding or accelerated leaf death as adaptive mechanisms for reducing water use and the advantages or reduced leaf area in slowing down evapotranspiration.

Climatic factors such as net radiation, temperature, humidity and wind also greatly influence the water balance of plants by affecting their rate of transpiration. It appears that plants in the present study had longer 'sunshine' hours in the controlled environment room than in the field. In the former case a constant 12 hours daylength was employed. However, Vorasoot and Tienroj (1977) have recorded that sunshine hours at Khon Kaen where the field site was located vary from month to month. During the dry season the duration

Plate 4.7 Verano stylo plant in the field in the dry season showing severe leaf shedding.

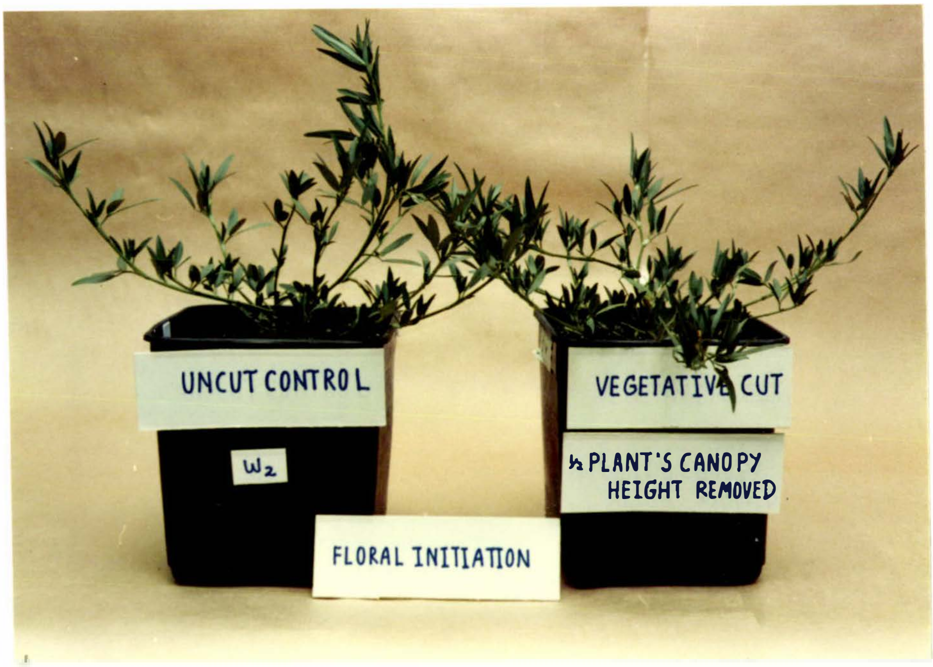


Plate 4.8 Verano stylo plants under severe water stress showing more vertical orientation of leaves (leaf-closing).

of sunshine hours is about 6-8 hours per day. The amount of net radiation that plants receive seems to affect their transpiration rate. This effect is likely to be greater when water deficits exist. For these reasons it appears that stylo plants grown in the controlled environment room were in fact subjected to more 'stress' than plants grown in the field. This is important, particularly since it gives plants grown in the field a greater chance for adaptation because the effects of stress occur more slowly. Such an effect has also been mentioned by Kramer (1969) and Shaw (1962).

The results from the field trial show that both Verano stylo and Siratro survived a period of over 90 days in the dry season without rainfall (Plate 4.9 and 4.10). Despite this Verano stylo still produced a seed yield of 1053 kg/ha which is about 75% of the 1455 kg/ha of seed yield obtained from plants that received irrigation water in the dry season while Siratro also produced similar seed yields of 1248 kg/ha which is about 95% of the 1317.6 kg/ha seed yield obtained from plants that received irrigation water.

This suggests the possibility that although Verano stylo plants can adapt to drought conditions, they may also obtain water from other sources. Chaney (1981) listed a number of sources of plant water including atmospheric moisture (fog, dew and water vapour), soil water and internal water reservoirs. Dew is considered to be one main source of water observed in this study. Monteith (1957) stated that the optimum conditions for dew fall involve clear skies for rapid cooling, a level of relative humidity at sunset of at least 75% and a wind speed of not more than 1-3 m sec^{-1} throughout the night. Climatic data recorded during this dry period in the field experiment falls into this category and heavy dew was consistently observed in the field. Dew was also observed to last in the field until at least mid morning. This situation presumably created cooler conditions around plants which helped in reducing transpiration rate. Slatyer (1960) found that in countries where little rainfall occurs during the growing season, dew may contribute signif-

Plate 4.9 General view of dry season planting of Verano stylo, showing the effect of 90 days without rainfall or irrigation.

Plate 4.10 General view of the dry season planting of Siratro, showing the ability of Siratro in tolerating the dryness of 90 days without rainfall or irrigation.

icantly to the plant water economy. The evaporation of dew from leaves may reduce transpiration in the morning and also reduce water deficits. Dew-fall normally evaporates within a few hours of sunrise and plants with inadequate soil moisture reserves endure severe water stress from the hottest part of the day. This situation may help to explain the survival of plants during the dry season in Thailand. Many experiments had been carried out which attempt to determine the contribution of dew to the plant water economy. Kramer (1959) suggested that dew and atmospheric moisture may increase growth far beyond the same amount of water added to the soil. This effect was also found to occur with tomato and corn plants in work by Breazeale and McGeorge (1953) and Tuller and Chilton (1971), and by Duvdevani (1957) in cucumber.

Removal of the terminal parts of stylo plants seemed to promote vegetative expansion of axillary buds, which resulted in increased branching and bud density. This increased the number of sites available for greater inflorescence density (Humphreys, 1979). In this study the results showed that cutting *S. hamata* cv Verano at different intensities and stages of growth caused favourable or unfavourable responses to seed production. The results from both field and controlled environment studies show that early and light cutting did not decrease seed yield but in some cases increased seed yield compared with uncut plants. In the field where plants were able to recover from cutting and moisture stress better than in the controlled environment room cutting as late as floral initiation, provided it was not severe could be carried out without greatly reducing seed yield. The early removal of herbage resulted in an increasing number of higher order branches. This ability of stylo plants to increase their branching capacity resulted in a higher density of inflorescence sites.

The maximum contribution to seed yield obtained from stylo plants came from secondary branches. However, the results also showed the capacity of defoliated stylo plants to stimulate inflorescence density through the production of increased numbers of secondary and tertiary branches. Plant recovery following defoliation was more rapid if cutting left axillary buds intact. Robertson and Humphreys (1976) also found that grazed plants of *S. humilis* had the ability to develop a low branching habit which enabled inflorescences to form under repeated grazing or cutting. A similar result has also been mentioned by Humphreys (1981).

Cut plants need water for growth to recover from cutting, particularly if cutting is intense and is applied at later stages of growth up to floral initiation. Late heavy cutting involving removal of ½ of the top of the plant seriously decreased seed yield if subsequent conditions were unsuitable for plant recovery but if plants were fully watered seed yield was not seriously decreased. This effect was due to the removal of inflorescence sites in the terminal position on each branch and the reduced capacity of those axillary buds that remained on primary branches after cutting to produce secondary branches. This effect was particularly severe if there was a shortage of water. Late cutting of plants which resulted in removal of the floral parts was usually harmful to seed yield as also mentioned by Humphreys (1978). In addition to the physical removal of floral sites the assimilate supply to the developing inflorescences is reduced by severe defoliation or cutting. This results in reduced floret differentiation and decreased seed set. The effects are generally more severe if climatic conditions are not favourable; especially soil moisture, weather conditions and nutrient supply during the reproductive period (Humphreys, 1978). This was confirmed in the present study with *Stylosanthes hamata* that cut plants respond well to water as shown by results from the 'full watering' treatment (W3) in the controlled environment experiment and the wet season planted treatments in the field experiment. In both cases both cut and uncut plants gave high seed yields and heavy cutting did not cause any serious seed yield reduction. Similar results have also been found by Fisher (1973) in *S. humilis*; Loch *et al.* (1976) in *S. guianensis* cv. Cook; and Wilaipon *et al.* (1979) in *S. hamata*.

Grazing or cutting forage legume seed crops (Verano stylo and Siratro) provides an additional source of income for farmers and increases seed yield. The present study has clearly shown that cutting (both Verano stylo and Siratro) can have adverse or favourable effects depending on its frequency, its intensity, and how much of the canopy remains after cutting. The time of cutting and the stage of plant growth are also important. If cutting begins when plants are small they will have the ability to replace the removed growth and produce abundant seeds. However if cutting is later and severe, it will have adverse effects and they will have less ability to replace the floral sites that were removed resulting in reducing seed yield.

Besides defoliation effects on growth and seed production, there can also be some effect on legume nodulation (Humphreys and Robinson, 1966; Whiteman and Lulham, 1970; and Humphreys, 1975). Humphreys (1975) also found that photosynthetic area is reduced and non-structural carbohydrate levels decline following cutting. Cutting also improves the light environment to young green inflorescences and associated leaves which can lead to an increase in seed yield (Humphreys, 1981).

Defoliation can also be used to manipulate competitive relationships in favour of the sown crop species in situations where grazing or cutting practices prevent taller companion species from shading them. This situation was mentioned by Humphreys (1979) in studies on the management of swards of *S. humilis*.

Cutting may be used to produce a lower and more uniform framework of branches which gives a smaller volume of plant material to cut and thresh. Humphreys (1979) suggested this as a very worthwhile management practice in tropical twining legumes like Siratro which produce a large volume of plant material which is very difficult to handle in the harvester and which shades developing pods. This situation can be avoided by earlier grazing. Such a management system may also give a better synchronisation of flowering which will help to overcome the problem of indecision in the selection of correct harvesting time. This situation was readily seen in the response to cutting of Siratro plants observed in the field experiment.

The growth room study has also been able to explain the distribution of seed yield within the plant. The results show that in *S. hamata* secondary branch orders contribute more than 60-75% of the seed yield produced by each plant. However the results also show that nodal inflorescences or seedheads give higher numbers of seeds per seedhead (11-16) than seedheads formed at terminal sites on branches (4-6).

The results from the present study have enabled a number of possible alternative recommendations to be made for managing *S. hamata* cv Verano and *M. atropurpureum* cv Siratro for seed production in the tropics. Verano stylo is a plant that requires water for maximum vegetative growth. It is also important that plants be given the opportunity to produce maximum numbers of sites for inflorescence formation before the dry season starts. This was particularly evident in the controlled environment room study, especially with respect to secondary branches which produced most of the seedheads and seed yield per plant. However this was not so evident in the field study in Thailand, possibly because fewer secondary branches were produced in the field environment. In fact the plant receiving least water (no irrigation) was still capable of producing 75% of the seed yield of the fully irrigated treatment. Obviously, in that location, plants were able to obtain some 'additional' water for limited but highly efficient seed yield development. Moisture-saving mechanisms are also recognised as a possible factor in the process.

It was also significant to note that light cutting of Verano stylo during the early vegetative growth stage through to floral initiation could be carried out without any reduction in seed yield. Similarly, if plants were grown in the wet season or receive supplemental irrigation in the dry season, heavy cutting involved removal of half of the canopy height could also be carried out from the vegetative stage up to floral initiation without any serious reduction in seed yield.

Cutting seems to be one practical way of increasing seed yield in Siratro. The improved uniformity of shoot population and synchronisation of flowering which occurs following cutting of Siratro plants can be advantageous in making it easier to decide on the correct harvesting time to obtain maximum seed yield. However when Siratro is grown in the wet season it tends to produce large amounts of vegetative growth but very little reproductive development. Large quantities of vegetative material therefore can and should be removed to reduce harvesting problems and for the added benefit of livestock. The wet season is not suitable for seed pod development in Siratro due to smaller pod size and fewer seeds per pod.

Having studied these various environmental effects on legume seed production and drawn appropriate conclusions, it is extremely important that such findings are then incorporated into practical recommendations and practices that the Thai farmer can comprehend and adopt.

The village seed production programme in the North-east of Thailand has expanded greatly over the past five years. With the rapid progress being made and the wider use of forage legumes to improve pasture quality, there has been an associated increased demand for seed. The present study suggests that farmers could increase returns from their land through the use of multiple cropping systems for both seed and forage. There are many advantages for farmers in the multiple use of forage legumes. These include providing vegetative growth from cutting as feed for cattle and buffaloes during the dry period, the opportunity to improve the fertility of the land and the provision of employment in the dry season during harvest time. In addition forage legume seed production gives a higher financial return per rai (1 rai = .16 ha) for the farmer compared to competitive alternatives such as kenaf or cassava. The legume crop is also relatively easy to manage and can be produced at a relatively low cost. According to Hare (1980) there is an increasing demand for pasture seeds throughout Thailand and the introduction of improved tropical grasses and legumes for pasture and seed production continues to be important. Village seed production has been increasingly adopted by farmers over the past few years because of its relative profitability and ease of management. However, there are problems in extending new ideas to farmers. Farmers normally do not adopt a new idea or practice as soon as they hear about it. There are always some farmers who adopt new practices first, and others who tend to follow slowly and cautiously. Farmer incomes in the North-east of Thailand are low and they prefer to grow those crops that sell readily for cash. Hare (1980) considers that village forage seed production programmes have really only been successful because villagers are paid by the Aid project and at a better price than alternative upland crops. Farmers are also likely to be encouraged to grow forage legumes for seed if they are sure they will receive cash promptly for their harvested crop. The current village seed production project being carried out by the Livestock Department in the North-east of Thailand receives money to buy seed from such aid sources as New Zealand and the World Bank Loan Fund. It has however been found necessary to have a seed trader or merchant as the middle man to buy the seed from the farmer and export the seed. According to Hare (1980) the price for Verano stylo received by the farmer is about 30 Baht/kg (1.5 NZ$) with an export price (Arthur Yates & Co. Ltd., 1980) of 110 Baht/kg (5.5 NZ$). Similarly the village purchase price for Siratro seed is 50 Baht compared with a 350 Baht export price.

Information about cutting or grazing management for maximising seed yields is needed to produce a management package which will allow the growing of food for cattle and buffaloes and also high seed yield. There are two critical periods of animal feed shortage in the North-east region of Thailand. The first period occurs at the end of the wet season when forage on upland grazing areas becomes scarce. The second period comes at the end of the dry season when rice stubble resources are exhausted.

There are therefore three possible management recommendations which could be put to Thai farmers based on the results of this study.

ALTERNATIVE 1: WET SEASON PLANTING

In growing specialist crops of *S. hamata* cv Verano for seed production, farmers could grow the crop in the wet season. This would allow them to cut and carry forage during the vegetative stage up to floral initiation without any deleterious effects on seed yield. This cut and carry method has a number of advantages. Because cutting height is controllable there need be no reduction in seed yield. Such defoliation height control is generally not possible in grazing situations. Cutting also prevents seed contamination occurring through the introduction of undesirable species by the grazing animal. Under a similar system Siratro could be cut heavily either at the vegetative stage or up to floral initiation without reducing seed yield. However, if Siratro is grown entirely in the wet season then seed yield is not going to be maximized since under such relatively high rainfall conditions pod size tends to be small with low seed numbers per pod.

ALTERNATIVE 2: DRY SEASON PLANTING WITH IRRIGATION

This system would be suitable for growing both Verano stylo and Siratro. If the farmer sowed the seed in the middle of the wet season and was able to supply irrigation water at least once a week during the dry period until 14 days after peak flowering, he could obtain an increased seed yield in both species. With the use of irrigation, light herbage cuts involving removal of about ¼ of the plant canopy height at the vegetative growth stage up to floral initiation or hard cutting at the vegetative growth stage only could be carried out without any reduction in subsequent seed yield. Seed yield of Verano stylo using this management is about 25% higher than that obtained with a non-irrigation system. Siratro produced for seed by this management system could also be cut lightly or heavily from the vegetative stage up to floral initiation without reducing seed yield. Seed yield is likely to be about 30% higher than that obtained in the wet season but only approximately 7% higher than from a similar dry season planting without irrigation.

ALTERNATIVE 3: DRY SEASON PLANTING WITHOUT IRRIGATION

Normally the cultivated land in the North-east region of Thailand is composed of upland and lowland areas. The farmer is able to grow rice as the main crop in the lowland areas and could grow Verano stylo or Siratro for seed production as a second crop on the upland area. In this situation, the farmer could sow Verano or Siratro seed in the first half of the wet season (July), after the sowing of the rice nursery area in the lowland area and before the rice seedlings are ready for transplanting. Certainly, labour is generally available at this time. Sowing the seed in July would allow farmers to cut and carry forage to animals during the normal animal feed shortage period in October. Successive light cuts could be taken from the vegetative stage up to floral initiation without any reduction in seed yield. By using this method farmers would also be able to use the straw after the seed has been threshed as a feed for animals or for making hay to use during the second main period of animal feed shortage at the end of the dry season.

A minor modification of this alternative could be used in a very dry year when the rainfall is low and there is no standing water in the paddy fields. Such situations occur frequently in the North-east of Thailand and are important because they prevent the sowing of the rice crop. Unless rice seedlings are transplanted by August it is not possible to get adequate yields from paddy. This 'minor' modification of Alternative 3 could therefore be used in such situations and would involve sowing Verano stylo or Siratro in the middle of the wet season (August). No supplemental irrigation water would generally be available but light cutting could be carried out at the early vegetative stage up to the stage of floral initiation. Seed yield obtained from this system would therefore be somewhat lower than if irrigation was used, but could still be about 75% of that obtained with irrigation in Verano stylo, and over 90% of that obtained with irrigation in Siratro.

According to the social, economic, climatic and traditional farming patterns in North-east Thailand, Alternative 3 is considered to be the recommendation most likely to be accepted by farmers in the region. Traditionally Thai farmers, especially in the North-east region, are not enthusiastic about growing a crop which is not for human consumption even if the recommended crop can give them a higher income than the rice crop. However it is socially and economically accepted that growing forage legumes on upland areas has advantages. The growing of Verano stylo or Siratro in the dry season without irrigation incorporates the most efficient use of the land, the better use of spare labour while waiting for rice seedlings to develop to a stage ready for transplanting, and also provides supplementary income from selling seeds. An additional advantage is that farmers can use the vegetative parts of the plants for feeding animals and the threshed straw as a conserved fodder for feeding cattle and buffaloes during the normal feed shortage period in the dry season.

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APPENDIX 1.a NUMBER OF SEEDS PER SEED HEAD OF CUT AND UNCUT PLANTS FROM NON-IRRIGATED (W1), IRRIGATED (W2) IN THE DRY SEASON AND WET SEASON (W3) PLANTING AT SUCCESSIVE HARVESTS OF VERANO STYLO.

Cutting Treatment	7 DAPF			14 DAPF			26 DAPF			40 DAPF		
	W1	W2	W3	W1	W2	W3	W1	W2	W3	W1	W2	W3
Co	10	10	10	10	11	11	16	16	16	10	10	11
¼ VG	11	11	10	11	11	11	15	16	16	11	11	11
½ VG	10	11	11	11	11	11	16	16	16	11	11	12
¼ FI	10	10	10	11	11	11	16	16	15	11	11	12
½ FI	10	10	10	11	12	11	16	16	16	11	11	12

APPENDIX 1.b ONE HUNDRED SEED WEIGHT OF CUT AND UNCUT PLANTS FROM NON-IRRIGATED (W1), IRRIGATED (W2) IN THE DRY SEASON AND WET SEASON (W3) PLANTS AT SUCCESSIVE HARVESTS OF VERANO STYLO.

Cutting Treatment	7 DAPF			14 DAPF			26 DAPF			40 DAPF		
	W1	W2	W3	W1	W2	W3	W1	W2	W3	W1	W2	W3
Co	0.21	0.22	0.22	0.25	0.26	0.25	0.31	0.31	0.31	0.30	0.29	0.30
¼ VG	0.22	0.21	0.21	0.26	0.27	0.26	0.31	0.32	0.32	0.30	0.30	0.31
½ VG	0.22	0.21	0.21	0.25	0.26	0.25	0.31	0.32	0.32	0.31	0.31	0.31
¼ FI	0.21	0.21	0.21	0.25	0.26	0.25	0.31	0.31	0.31	0.31	0.31	0.31
½ FI	0.21	0.22	0.21	0.26	0.26	0.26	0.30	0.31	0.31	0.30	0.30	0.30

APPENDIX 2.a NUMBER OF SEEDS PER POD OF CUT AND UNCUT PLANTS FROM NON-IRRIGATED (W1), IRRIGATED (W2) IN THE DRY SEASON AND WET SEASON (W3) PLANTING AT SUCCESSIVE HARVESTS OF SIRATRO.

Cutting Treatment	14 DAPF			26 DAPF			40 DAPF			54 DAPF		
	W1	W2	W3	W1	W2	W3	W1	W2	W3	W1	W2	W3
Co	12	12	9	14	15	9	16	16	12	16	16	12
¼ VG	12	12	9	15	15	10	16	15	11	16	15	11
½ VG	11	11	9	15	14	10	16	16	12	16	15	12
¼ FI	11	10	9	14	15	10	16	16	12	16	16	12
½ FI	11	11	11	15	15	10	16	16	11	16	16	12

APPENDIX 2.b ONE HUNDRED SEED WEIGHT OF CUT AND UNCUT PLANTS FROM NON-IRRIGATED (W1), IRRIGATED (W2) IN THE DRY SEASON AND WET SEASON (W3) PLANTING AT SUCCESSIVE HARVESTS OF SIRATRO.

Cutting Treatment	14 DAPF			26 DAPF			40 DAPF			54 DAPF		
	W1	W2	W3	W1	W2	W3	W1	W2	W3	W1	W2	W3
Co	1.90	1.88	1.83	1.90	1.92	1.82	1.90	1.93	1.87	1.95	1.93	1.89
¼ VG	1.93	1.92	1.79	1.93	1.92	1.80	1.90	1.92	1.83	1.96	1.95	1.80
½ VG	1.90	1.91	1.82	1.95	1.94	1.83	1.90	1.92	1.79	1.95	1.98	1.84
¼ FI	1.92	1.93	1.83	1.96	1.98	1.80	1.95	1.93	1.81	1.96	1.90	1.84
½ FI	1.90	1.91	1.81	1.96	1.96	1.82	1.98	1.96	1.84	1.96	1.96	1.83

APPENDIX 3.1 TREATMENT CONDITIONS IN EACH CE ROOM

	Room 21	Room 22
Photosynthetic Quantum Flux Density ($\mu E\ m^{-2}\ sec^{-1}$)*		
Pre expt	704	696
Post expt	688	694
Mean	696	695
Photosynthetic irradiance ($W\ m^{-2}$)**		
Pre expt	149	148
Post expt	143	144
Mean	146	146
Photosynthetic irradiance ($W\ m^{-2}$)***		
Pre expt	156	159
Post expt (calculated)	150	154
Mean	153	157
Daylength (hours)	12	12
Temperature ($\pm$ 0.5^{o}C)		
Day	30.0	30.0
Night	20.0	20.0
Relative Humidity ($\pm$ 5% RH)		
Day	70.0	70.0
Night	90.0	90.0

* Licor LI 185 Meter with LI 190S Quantum sensor

** Licor LI 185 Meter with LI 190SE Flat Response Photosynthetic Irradiance sensor

*** "Swissteco" pyranometer with Schott RG8 filter system (only used for pre-experiment measurements)

APPENDIX 3.2 CLIMATE LAB - N.C.S.U. PHYTOTRON NUTRIENT

2 ml A + 2 ml B/l water

	Molecular Wt. (g)	Conc. (grams/litre)	Final Soln. (grams/litre)	PPM	
Stock solution A:					
Ammonium nitrate NH_4NO_3	80.02	80.05	.1601	N	56.05
Calcium nitrate $Ca(NO_3)_2 \times 4H_2)$	236.15	159.25	.3185	Ca N	54.06 37.79
Sequestrene 330 10% DTPA Na Fe	468.20	29.8	.0596	Fe Na	5.96 2.93
Stock solution B:					
Potassium phosphate KH_2PO_4	136.08	12.5	.025	K P	7.18 5.69
Potassium phosphate K_2HPO_4	174.17	5.5	.011	K P	4.94 1.96
Postassium nitrate KNO_3	101.11	63.9	.1278	K N	49.42 17.71
Magnesium sulfate $MgSO_4 \times 7H_20$	246.50	30.81	.06162	Mg S	6.08 8.02
Sodium sulfate Na_2SO_4	142.05	35.5	.071	Na S	22.98 16.03
Zinc sulfate $ZnSO_4 \times 7H_2O$	287.55	0.025	.00005	Zn S	0.011 0.006
Manganese chloride $MnCl_2$	197.92	0.26	.00052	Mn Cl	0.144 0.186
Copper sulphate $CuSO_4 \times 5H_20$	249.68	0.01	.00002	Cu S	0.005 0.003
Boric acid H_3BO_3	61.82	0.35	.0007	B	0.123
Sodium molybdate $Na_2MoO_4 \times 2H_2O$	241.93	0.0027	.0000054	Na Mo	0.001 0.002

Nutrient	PPM	um		Nutrient	PPM	um	
N	111.55	NH_4	2200	B	0.123	BO_3	11.39
		NO_3	6130				
P	7.65	PO_4	6.8	Mn	0.144		2.55
K	61.54		80	Cu	0.005		0.08
S	24.06	SO_4	750	Zn	0.011		0.17
Ca	54.06		1280	Mo	0.002		0.02
Fe	5.96		125	Cl	0.186		5.36
Mg	6.08		250	Na	25.911		1125

pH of final solution = 6.5-7.5

APPENDIX 3.3 EFFECT OF WATER AND CUTTING ON THE NUMBERS OF BRANCH ORDER PER PLANT AT SUCCESSIVE HARVESTS OF VERANO STYLO UNDER CONTROLLED CONDITIONS.

Branch Order	Cutting Treatment	VG (H1)			FI (H2)			PF (H3)			15 DAPF (H4)		
		W1	W2	W3	W1	W2	W3	W1	W2	W3	W1	W2	W3
No. of Primary	Co	6	6	6	9	9	9	9	9	10	9	10	10
	¼ VG	6	6	6	6	6	6	6	6	6	6	6	6
	½ VG	6	6	6	6	6	6	6	6	6	6	6	6
	¼ FI				8	8	8	8	8	8	8	8	8
	½ FI				8	8	8	8	8	8	8	8	8
	LSD 5%												
No. of Secondary	Co.				10	32	32	18	51	51	30	45	62
	¼ VG				10	38	38	24	47	47	31	41	52
	½ VG							26	35	35	31	36	50
	¼ FI							26	40	40	29	38	50
	¼ FI							34	34	34	26	30	46
	LSD 5%								8.44			7.40	
No. of Tertiary	Co.							0	31	44	0	21	64
	¼ VG							0	36	57	0	32	69
	½ VG							0	29	51	0	22	62
	¼ FI							0	34	30	0	67	77
	½ FI							0	47	46	0	35	86
	LSD 5%								6.99			11.14	
No. of Quaternary	Co.												
	¼ VG												
	½ VG												
	¼ FI												
	½ FI												
	LSD 5%												

APPENDIX 3.3 continued

Branch Order	Cutting Treatment	20 DAPF (H5)			25 DAPF (H6)			30 DAPF (H7)		
		W1	W2	W3	W1	W2	W3	W1	W2	W3
No. of Primary	Co	10	11	10	10	11	11	10	11	11
	¼ VG	6	6	6	6	6	6	6	6	6
	½ VG	6	6	6	6	6	6	6	6	6
	¼ FI	8	8	8	8	8	8	8	8	8
	½ FI	8	8	8	8	8	8	8	8	8
	LSD 5%									
No. of Secondary	Co	30	49	25	36	51	59	31	50	59
	¼ VG	34	45	55	37	40	62	37	44	50
	½ VG	32	44	44	36	40	49	37	41	50
	¼ FI	30	31	51	39	36	65	32	32	52
	½ FI	35	31	44	29	36	48	32	53	57
	LSD 5%		3.73			4.11			5.39	
No. of Tertiary	Co	2	23	60	5	28	57	4	33	70
	¼ VG	0	35	74	6	38	104	2	45	73
	½ VG	7	40	55	10	31	74	14	37	77
	¼ FI	5	50	71	7	37	76	9	46	58
	½ FI	4	62	52	13	58	85	13	55	59
	LSD 5%		6.08			7.55			9.5	
No. of Quaternary	Co	0	0	16	0	7	0	0	0	14.3
	¼ VG	0	0	10	0	0	35	0	0	23
	½ VG	0	0	16	0	0	32	0	0	16
	¼ FI	0	3	20	0	0	18	0	0	12
	½ FI	0	10	15	0	16	31	0	13	13
	LSD 5%		2.83			2.88			2.95	

APPENDIX 3.4 EFFECT OF WATER AND CUTTING ON LEAF NUMBER PER PLANT ON EACH BRANCH ORDER AT SUCCESSIVE HARVESTS OF VERANO STYLO UNDER CONTROLLED CONDITIONS.

Branch Order	Cutting Treatment	VG (H1) W1	VG (H1) W2	VG (H1) W3	FI (H2) W1	FI (H2) W2	FI (H2) W3	PF (H3) W1	PF (H3) W2	PF (H3) W3	15 DAPF W1	15 DAPF W2	15 DAPF W3
Primary	Co	30.3	39	39	68.7	80.7	80.7	101	244.7	244.7	119.3	266.3	265.0
	¼ VG	34	23	23	47.7	66.3	66.3	75	171.7	171.7	95.3	164.3	180.0
	½ VG	27	19	19	42.0	54.7	54.7	64	163	163	75	172	199
	¼ FI				47	58	58	69	81	81	102	16	117
	½ FI				35	48	48	51	66	66	77	45	80
	LSD 5%					9.5			19.8			43.0	
Secondary	Co				25.3	112.0	112.0	72	357	357	178	385	653
	¼ VG				26.3	119.3	119.3	89.3	412.0	412.0	203.3	440.0	621.0
	½ VG				18.3	89.3	89.3	95.3	326.7	326.7	213.0	367.0	621.0
	¼ FI				17.3	94.3	94.3	100.3	296.3	296.3	203.3	484.3	675.3
	½ FI				21.3	89.7	89.7	104.3	306.0	234.7	203.0	330.7	589.0
	LSD 5%					31.2			60.8			96	
Tertiary	Co.							0	157.3	157.3	0	108.3	392.7
	¼ VG							0	103.7	103.7	0	143.7	385.0
	½ VG							0	215.7	215.7	0	104.7	390
	¼ FI							0	120.3	120.3	0	426.7	419.7
	½ FI							0	167.7	167.7	0	208.7	402.7
	LSD 5%								46.3			87.8	
Quaternary	Co												
	¼ VG												
	½ VG												
	¼ FI												
	½ FI												
	LSD 5%												

APPENDIX 3.4 continued

Branch Order	Cutting Treatment	20 DAPF W1	20 DAPF W2	20 DAPF W3	25 DAPF W1	25 DAPF W2	25 DAPF W3	30 DAPF W1	30 DAPF W2	30 DAPF W3
Primary	Co	126.3	308.7	276.3	136.6	312.0	859.7	120.0	381.3	851.3
	¼ VG	74.7	237.3	273.7	104.7	271.7	416.0	79.0	228.7	423.0
	½ VG	66	214	250	80	233	288	69	222	396
	¼ FI	76	56	211	60	129	347	79	102	481
	½ FI	78	0	117	36	0	327	55	0	394
	LSD 5%		60.0			72.0			80.0	
Secondary	Co	159	509	836	191	510	1577	158	573	1786
	¼ VG	202	539	527	203	534	1302	225	576	1411
	½ VG	176	520	623	224	537	1012	240	530	1282
	¼ FI	205	428	939	242	461	1507	212	561	1477
	½ FI	233	517	899	190	498	1287	202	590	1894
	LSD 5%		22.4			106			244.2	
Tertiary	Co	4	167	452	15	167.3	641.3	14.3	183.3	639.3
	¼ VG	0	214	383	19	218	884	8	288	732
	½ VG	25	221	326	38	192	560	56	228	671
	¼ FI	20	346	603	21	232	790.3	35	327	516
	½ FI	17	420	569	55	441	841	54	384	737
	LSD 5%		162.8			67.8			105.7	
Quaternary	Co	0	0	78	0	31	82	0	0	80
	¼ VG	0	0	47	0	0	240	0	0	185
	½ VG	0	0	67	0	0	177	0	0	113
	¼ FI	0	3	102	0	0	126	0	0	59
	½ FI	0	10	101	0	64	206	0	13	88
	LSD 5%		30.6			29.5			36.1	

APPENDIX 3.5 EFFECT OF WATER AND CUTTING ON LEAF AREA ON EACH BRANCH ORDER AT SUCCESSIVE HARVESTS OF VERANO STYLO UNDER CONTROLLED CONDITIONS (cm^2/pl).

Branch Order	Cutting Treatment	VG (H1)			FI (H2)			PF (H3)			15 DAPF (H4)		
		W1	W2	W3	W1	W2	W3	W1	W2	W3	W1	W2	W3
Primary	Co	66	131	131	259	411	411	366	612	612	273	683	655
	¼ VG	82	72	72	220	293	293	298	425	425	198	408	496
	½ VG	57	46	46	189	244	244	230	444	444	172	428	423
	¼ FI				237	256	256	321	251	251	193	142	170
	½ FI				167	221	221	232	295	295	181	112	151
	LSD 5%											86.4	
Secondary	Co				83	144	269	151	697	693	236	821	1230
	¼ VG				83	274	289	201	799	440	246	955	1009
	½ VG				54	250	182	213	714	684	291	769	1186
	¼ FI				52	205	201	213	626	646	275	1144	1003
	½ FI				62	206	227	251	703	521	301	1333	1006
	LSD 5%					86.86			175.6			174.1	
Tertiary	Co							0	78	301	0	235	732
	¼ VG							0	187	319	0	269	473
	½ VG							0	163	380	0	191	719
	¼ FI							0	155	242	0	903	574
	½ FI							0	279	318	0	393	593
	LSD 5%												
Quaternary	Co												
	¼ VG												
	½ VG												
	¼ FI												
	½ FI												
	LSD 5%												

APPENDIX 3.5 continued

Branch Order	Cutting Treatment	20 DAPF (H5)			25 DAPF (H6)			30 DAPF (H7)		
		W1	W2	W3	W1	W2	W3	W1	W2	W3
Primary	Co	281	804	813	198	775	1236	180	923	1280
	¼ VG	181	526	454	152	620	694	121	540	618
	½ VG	153	492	366	123	610	552	98	560	574
	¼ FI	138	148	410	101	343	517	110	235	700
	½ FI	147	0	227	49	0	505	86	0	574
	LSD 5%		116.1			136.8			116.6	
Secondary	Co	196	1058	1665	200	999	2346	163	1366	2554
	¼ VG	273	1019	1135	204	1088	2012	210	1202	2113
	½ VG	262	1039	1249	232	1211	1558	222	1201	1867
	¼ FI	254	1010	1842	242	1118	2264	238	1309	2151
	½ FI	275	1031	1715	211	1002	1930	217	1225	2674
	LSD 5%		258.3			213.3			327.5	
Tertiary	Co	12	259	908	16	311	959	17	371	940
	¼ VG	0	367	769	16	343	1362	6	51	1072
	½ VG	27	396	662	35	379	870	56	446	977
	¼ FI	15	693	1173	20	477	1186	37	664	744
	½ FI	16	735	1028	43	670	1257	48	662	1072
	LSD 5%		191.3			95.8			167.0	
Quaternary	Co	0	0	183	0	53	126	0	0	139
	¼ VG	0	0	126	0	0	416	0	0	278
	½ VG	0	0	170	0	0	283	0	0	177
	¼ FI	0	21	214	0	0	196	0	0	95
	½ FI	0	56	202	0	84	347	0	77	139
	LSD 5%		48.9			47.8			45.0	

APPENDIX 3.6. EFFECT OF WATER AND CUTTING ON SEED HEAD NUMBERS FORMED ON EACH BRANCH ORDER AT SUCCESSIVE HARVESTS OF VERANO STYLO UNDER CONTROLLED ENVIRONMENT CONDITIONS.

Branch Order	Cutting Treatment	Harvesting Times											
		15 DAPF			20 DAPF			25 DAPF			30 DAPF		
		W1	W2	W3	W1	W2	W3	W1	W2	W3	W1	W2	W3
Primary	Co	27	50	51	27	57	57	37	76	75	38	91	75
	¼ VG	19	30	36	20	40	35	26	56	60	25	54	56
	½ VG	17	27	44	13	45	32	24	40	43	23	37	39
	¼ FI	14	3	24	14	8	21	20	24	37	21	22	49
	½ FI	10	0	20	13	0	11	7	0	34	19	0	42
	LSD 5%		9			6			12			6	
Secondary	Co	22	44	102	12	56	109	31	71	162	26	99	154
	¼ VG	26	49	157	35	68	154	38	105	175	38	94	162
	½ VG	26	41	130	24	71	135	41	72	155	49	71	156
	¼ FI	22	72	151	25	63	111	39	66	151	42	117	153
	½ FI	20	32	128	25	82	794	32	103	149	45	128	166
	LSD 5%		19			13			13			22	
Tertiary	Co	0	0	13	0	2	18	0	10	20	0	13	26
	¼ VG	0	2	34	0	11	17	0	7	71	0	12	46
	½ VG	0	0	29	0	9	66	0	3	48	0	18	33
	¼ FI	0	9	45	0	13	19	0	13	39	0	42	22
	½ FI	0	4	38	0	7	28	0	50	61	0	36	39
	LSD 5%		6			8			9			8	

APPENDIX 3.7 EFFECT OF WATER AND CUTTING ON SEED YIELD FORMED ON EACH BRANCH ORDER AT SUCCESSIVE HARVESTS OF VERANO STYLO UNDER CONTROLLED ENVIRONMENT CONDITIONS (g/pl).

Branch Order	Cutting Treatment	Harvesting Times											
		15 DAPF			20 DAPF			25 DAPF			30 DAPF		
		W1	W2	W3	W1	W2	W3	W1	W2	W3	W1	W2	W3
Primary	Co	0.44	1.30	1.09	0.66	1.38	1.96	0.83	2.17	4.02	0.62	2.20	3.00
	¼ VG	0.31	0.86	0.82	0.48	1.08	1.22	0.63	2.16	2.66	0.42	1.40	2.12
	½ VG	0.29	0.83	0.82	0.38	1.08	1.14	0.59	2.24	2.12	0.38	1.00	1.54
	¼ FI	0.25	0.11	0.48	0.38	0.25	0.70	0.46	0.65	1.82	0.37	0.57	1.98
	½ FI	0.17	0.19	0.41	0.36	0	0.36	0.19	0	1.71	0.34	0	1.68
	LSD 5%		0.21			0.13			0.41			0.20	
Secondary	Co	0.25	0.94	2.14	0.39	1.39	3.41	0.45	1.81	7.45	0.39	2.30	5.16
	¼ VG	0.30	1.28	2.94	0.63	1.70	4.08	0.60	3.47	7.40	0.55	2.37	5.83
	½ VG	0.32	1.09	2.34	0.45	1.65	3.59	0.84	2.04	7.13	0.89	1.72	5.51
	¼ FI	0.29	1.93	3.11	0.51	1.78	3.53	0.73	1.60	7.21	0.65	2.92	5.53
	½ FI	0.26	0.75	2.55	0.44	2.36	3.09	0.64	2.61	7.05	0.76	3.12	6.10
	LSD 5%		0.47			0.40			0.54			0.83	
Tertiary	Co	0	0	0.29	0	0.02	0.25	0	0.06	0.26	0	0.12	0.70
	¼ VG	0	0.01	0.41	0	0.12	0.27	0	0.06	1.18	0	0.44	0.74
	½ VG	0	0	0.34	0	0.10	0.77	0	0.04	0.88	0	0.21	0.45
	¼ FI	0	0.09	0.49	0	0.12	0.20	0	0.19	0.62	0	0.73	0.29
	½ FI	0	0.02	0.29	0	0.19	0.32	0	0.81	0.73	0	0.58	0.42
	LSD 5%		0.08			0.07			0.19			0.10	

APPENDIX 3.8 EFFECT OF WATER AND CUTTING ON SEED HEAD NUMBERS ON EACH BRANCH ORDER AND POSITIONS AT SUCCESSIVE HARVEST OF VERANO STYLO UNDER THE CONTROLLED ENVIRONMENT CONDITIONS.

Branch Order	Cutting Treatment	15 Days after Peak Flowering						20 Days after Peak Flowering					
		W1		W2		W3		W1		W2		W3	
		Node	Terminal	Node	Terminal	Node	Terminal	Node	Terminal	Node	Terminal	Node	Terminal
Primary	Co	16.7	10.0	45.0	5.3	41.3	9.7	19.0	8.3	45.7	11.3	56.3	1.0
	¼ VG	12.0	7.0	25.7	4.0	33.7	1.7	14.0	6.3	30.3	9.7	35.0	.3
	½ VG	12.3	5.0	24.7	1.7	27.0	17.3	12.3	1.3	35.0	10.0	32.0	0
	¼ FI	8.0	6.0	3.3	0	17.7	5.7	11.7	2.3	7.8	0	20.0	1.3
	½ FI	7.3	2.3	6.7	0.7	15.7	3.7	11.3	2.3	0	0	10.3	1.3
	LSD 5%	Node = 9.7			Terminal = 4.5			Node = 6.2			Terminal = 2.6		
Secondary	Co	3.3	19.3	27.7	15.7	77.3	25.0	7.3	14.7	47.0	9.0	92.7	16.3
	¼ VG	6.3	19.7	35.3	13.7	93.3	64.3	15.7	18.7	44.3	24.3	96.3	58.0
	½ VG	8.3	17.7	31.7	9.3	69.7	59.7	10.7	12.7	52.3	18.7	86.0	48.7
	¼ FI	8.3	13.3	56.0	15.7	108.7	42.3	12.7	12.3	52.0	11.3	96.0	14.7
	½ FI	5.3	15.0	24.0	8.0	86.3	42.0	9.0	16.0	69.3	13.3	89.7	4.0
	LSD 5%	Node = 19.3			Terminal = 23.2			Node = 13.7			Terminal = 7.07		
Tertiary	Co	0	0	0	0	0	12.7	0	0	0	2.3	15.0	3.3
	¼ VG	0	0	0	1.7	14.0	20.3	0	0	0	11.3	9.7	7.3
	½ VG	0	0	0	0	6.7	22.0	0	0	0	9.3	23.0	43.3
	¼ FI	0	0	0	9.3	12.7	31.7	0	0	0	13.0	5.7	12.7
	½ FI	0	0	0	4.3	11.3	27.3	0	0	7.0	0	21.7	5.7
	LSD 5%	Node = 6.6			Terminal = 13.0			Node = 8.4			Terminal = 6.4		

APPENDIX 3.8 continued

Branch Order	Cutting Treat-ment	25 Days after Peak Flowering						30 Days After Peak Flowering					
		W1		W2		W3		W1		W2		W3	
		Node	Terminal	Node	Terminal	Node	Terminal	Node	Terminal	Node	Terminal	Node	Terminal
Primary	Co	24.7	12.3	58.7	17.3	74.7	0.3	26.0	11.7	64.0	27.3	75.0	0
	¼ VG	19.0	7.3	55.3	1.3	45.0	14.7	16.7	8.0	43.7	10.3	48.7	7.7
	½ VG	17.3	7.0	35.0	5.3	37.3	6.3	17.0	5.7	31.3	5.7	37.7	1.3
	¼ FI	14.0	6.0	20.3	3.7	35.7	1.0	15.3	6.0	16.0	5.7	49.3	0
	½ FI	6.0	1.3	0	0	31.0	3.0	15.0	4.3	0	0	41.3	1.3
	LSD 5%	Node = 12.7			Terminal = 5.0			Node = 6.5			Terminal = 4.2		
Secondary	Co	10.7	19.7	45.7	24.7	128.3	34.0	10.3	16.3	64.3	35.0	110.0	43.7
	¼ VG	13.3	25.3	89.7	14.7	119.3	56.0	14.3	24.0	71.3	22.7	131.7	30.0
	½ VG	21.0	20.3	53.3	18.7	121.3	34.3	30.0	19.0	48.3	22.7	123.0	33.0
	¼ FI	17.3	22.0	45.3	21.3	125.0	26.7	19.7	22.0	85.3	31.7	123.0	30.0
	½ FI	16.7	15.3	78.3	25.3	122.0	27.3	30.3	15.0	102.3	26.3	142.0	24.0
	LSD 5%	Node = 12.0			Terminal = 26.7			Node = 21.7			Terminal = 14.2		
Tertiary	Co	0	0	2.7	6.6	0	20.3	0	0	0	13.3	0	26.0
	¼ VG	0	0	0	6.7	37.3	33.7	0	0	0	12.0	17.0	29.3
	½ VG	0	0	0	3.3	26.3	22.0	0	0	0	18.3	0	33.3
	¼ FI	0	0	1.7	11.0	17.7	21.0	0	0	16.7	25.0	0	22.3
	½ FI	0	0	15.7	33.7	32.7	28.3	0	0	13.3	22.7	1.67	36.7
	LSD 5%	Node = 9.0			Terminal = 9.3			Node = 8.0			Terminal = 7.4		

APPENDIX 3.9 EFFECT OF WATER AND CUTTING ON SEED YIELD FORMED ON EACH BRANCH ORDER AND POSITIONS AT SUCCESSIVE HARVESTS OF VERANO STYLO UNDER THE CONTROLLED CONDITIONS (g/pl).

		15 Days after Peak Flowering						20 Days after Peak Flowering					
		W1		W2		W3		W1		W2		W3	
		Node	Terminal	Node	Terminal	Node	Terminal	Node	Terminal	Node	Terminal	Node	Terminal
Primary Branch	Co	0.35	.09	1.25	.05	1.00	.09	0.57	.09	1.27	.11	1.95	.01
	¼ VG	0.24	.07	0.82	.04	0.80	.02	0.42	.06	0.98	.10	1.22	.00
	½ VG	0.24	.05	0.81	.02	0.65	.17	0.37	.01	0.98	.10	1.14	0
	¼ FI	0.16	.09	0.11	0	0.42	.06	0.35	.03	0.24	.01	0.69	.01
	½ FI	0.15	.02	0.18	.01	0.37	.04	0.34	.02	0	0	0.35	.01
	LSD 5%	Node = .22		Terminal = .04				Node = .14		Terminal = .02			
Secondary Branch	Co	.09	.16	.78	.16	1.89	.25	.22	.17	1.31	.08	3.21	.20
	¼ VG	.13	.17	1.14	.14	2.30	.64	.40	.23	1.42	.28	3.36	.72
	½ VG	.18	.14	1.01	.08	1.72	.61	.30	.15	1.44	.21	3.0	.59
	¼ FI	.17	.12	1.77	.16	2.67	.44	.36	.15	1.67	.11	3.34	.18
	½ FI	.11	.15	0.67	.08	2.13	.42	.25	.19	2.23	.13	2.92	.17
	LSD 5%	Node = .49		Terminal = .24				Node = .41		Terminal = .12			
Tertiary Branch	Co	0	0	0	0	.16	.13	0	0	0	.02	.22	.03
	¼ VG	0	0	0	.01	.23	.18	0	0	0	.12	.17	.10
	½ VG	0	0	0	0	.12	.22	0	0	0	.10	.34	.43
	¼ FI	0	0	0	.09	.19	.30	0	0	0	.12	.08	.12
	½ FI	0	0	0	.02	.18	.11	0	0	.13	.06	.26	.06
	LSD 5%	Node = .08		Terminal = .09				Node = .07		Terminal = .07			

APPENDIX 3.9 continued

		25 Days after Peak Flowering						30 Days after Peak Flowering					
		W1		W2		W3		W1		W2		W3	
		Node	Terminal	Node	Terminal	Node	Terminal	Node	Terminal	Node	Terminal	Node	Terminal
Primary Branch	Co	0.71	.12	1.98	.19	4.01	.01	0.50	.12	1.92	.28	3.0	0
	¼ VG	0.56	.07	2.15	.01	2.37	.29	0.34	.08	1.29	.11	1.95	.17
	½ VG	0.51	.08	1.19	.05	1.99	.13	0.32	.06	0.94	.06	1.51	.03
	¼ FI	0.40	.06	0.61	.04	1.80	.02	0.31	.06	0.51	.06	1.98	0
	½ FI	0.18	.01	0	0	1.65	.06	0.30	.04	0	0	1.65	.03
	LSD 5%	Node = .42 Terminal = .08						Node = .20 Terminal = .05					
Secondary Branch	Co	.25	.20	1.54	.27	6.78	.67	.21	.18	1.90	.40	4.29	.87
	¼ VG	.35	.25	3.30	.17	6.31	1.09	.29	.26	2.09	.28	5.23	.60
	½ VG	.62	.22	1.82	.22	6.44	.69	.61	.28	1.45	.27	4.85	.66
	¼ FI	.50	.23	1.36	.24	6.68	.53	.41	.24	2.56	.36	4.92	.61
	½ FI	.49	.15	2.31	.30	6.50	.55	.60	.16	2.81	.31	5.62	.48
	LSD 5%	Node = .56 Terminal = .18						Node = .86 Terminal = .26					
Tertiary Branch	Co	0	0	0	.06	0	.26	0	0	0	.12	.35	.35
	¼ VG	0	0	0	.06	.74	.44	0	0	0	.44	.33	.41
	½ VG	0	0	0	.04	.56	.32	0	0	0	.21	0	.45
	¼ FI	0	0	.07	.12	.35	.27	0	0	.44	.29	0	.29
	½ FI	0	0	.41	.40	.64	.09	0	0	.32	.26	.33	.09
	LSD 5%	Node = .19 Terminal = .13						Node = .10 Terminal = .20					

APPENDIX 3.10

Plate 3.9a Early and heavy cut at vegetative growth stage (½VG) of Verano stylo

a.1 Early stressed plants at vegetative growth stage (W1)

a.2 Stressed plant at peak flowering stage (W2)

a.3 Non-stressed plant (W3)


UNCUT CONTROL
VEGETATIVE CUT
½ PLANT'S CANOPY HEIGHT REMOVED
30 DAYS AFTER P.F.

a1


HEIGHT REMOVED
30 DAYS AFTER P.F.

a2

a3

Plate 3.9b Late and light cut at floral initiation growth stage (¼FI) of Verano stylo

b.1 Early stressed plants at vegetative growth stage (W1)

b.2 Stressed plant at peak flowering stage (W2)

b.3 Non-stressed plant (W3)


UNCUT CONTROL
W8
FLORAL INITIATION CUT
½ PLANT'S CANOPY HEIGHT REMOVED
20 DAYS AFTER P.F.

b1


FLORAL INITIATION CUT
W2
½ PLANT'S CANOPY HEIGHT REMOVED
20 DAYS AFTER P.F.

b2

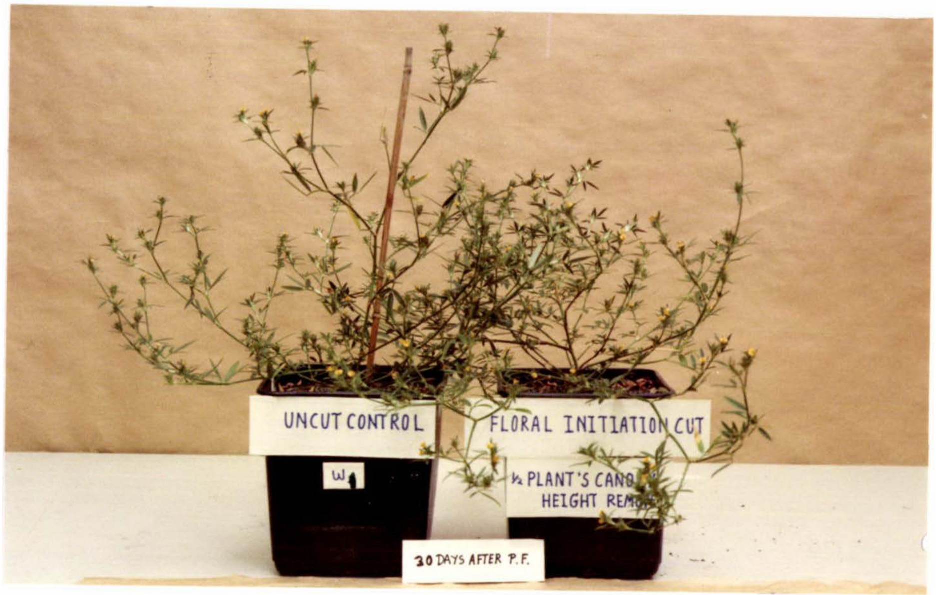
b3

Plate 3.9c Late and heavy cut at floral initiation growth stage (½FI) of Verano stylo

c.1 Early stressed plants at vegetative growth stage (W1)

c.2 Stressed plant at peak flowering stage (W2)

c.3 Non-stressed plant (W3)


UNCUT CONTROL
FLORAL INITIATION CUT
½ PLANT'S CANO
HEIGHT REMO
30 DAYS AFTER P.F.

C1


FLORAL INITIATION CUT
½ PLANT'S CANOPY
HEIGHT REMOVED
30 DAYS AFTER P.F.

C2


½ F.I.
30 DAYS AFTER P.F.

C3

APPENDIX 3.11 EFFECT OF WATER AND CUTTING ON SEED MOISTURE CONTENT PERCENTAGE AT SUCCESSIVE HARVESTS OF VERANO STYLO UNDER THE CONTROLLED ENVIRONMENT CONDITIONS.

Cutting Treatment	15 DAPF			20 DAPF			25 DAPF			30 DAPF		
	W1	W2	W3	W1	W2	W3	W1	W2	W3	W1	W2	W3
Co	55.9	52.6	54.4	48.4	45.3	45.3	37.3	35.4	35.2	32.4	31.9	34.3
¼ VG	55.2	53.1	54.4	47.4	45.3	46.8	38.9	35.2	36.9	33.2	31.8	33.6
½ VG	54.5	52.5	55.2	49.1	47.1	48.9	38.9	35.3	37.0	33.3	32.1	32.1
¼ FI	55.9	53.1	53.3	47.3	45.5	48.7	37.8	35.4	37.9	33.3	32.5	33.1
½ FI	55.6	52.4	53.3	47.5	45.6	48.2	39.0	35.3	37.2	33.7	32.1	33.5

APPENDIX 3.12 EFFECT OF WATER AND CUTTING ON 100 SEED WEIGHT AT SUCCESSIVE HARVEST OF VERANO STYLO UNDER THE CONTROLLED ENVIRONMENT CONDITIONS.

Cutting Treatment	15 DAPF			20 DAPF			25 DAPF			30 DAPF		
	W1	W2	W3	W1	W2	W3	W1	W2	W3	W1	W2	W3
Co	0.23	0.22	0.23	0.24	0.23	0.24	0.24	0.24	0.24	0.24	0.24	0.24
¼ VG	0.23	0.23	0.23	0.23	0.23	0.23	0.24	0.24	0.24	0.24	0.24	0.24
½ VG	0.23	0.23	0.23	0.23	0.24	0.23	0.24	0.24	0.24	0.24	0.24	0.24
¼ FI	0.23	0.22	0.22	0.23	0.23	0.23	0.24	0.24	0.24	0.24	0.24	0.24
½ FI	0.23	0.22	0.22	0.23	0.23	0.23	0.24	0.24	0.24	0.24	0.24	0.24

APPENDIX 3.13 EFFECT OF WATER AND CUTTING ON SEED MOISTURE CONTENT PERCENTAGE AT SUCCESSIVE HARVESTS OF VERANO STYLO UNDER THE CONTROLLED ENVIRONMENT CONDITIONS.

Cutting Treatment	15 DAPF			20 DAPF			25 DAPF			30 DAPF		
	W1	W2	W3	W1	W2	W3	W1	W2	W3	W1	W2	W3
Co	55.9	52.6	54.4	48.4	45.3	45.3	37.3	35.4	35.2	32.4	31.9	34.3
¼ VG	55.2	53.1	54.4	47.4	45.3	46.8	38.9	35.2	36.9	33.2	31.8	33.6
½ VG	54.5	52.5	55.2	49.1	47.1	48.9	38.9	35.3	37.0	33.3	32.1	32.1
¼ FI	55.9	53.1	53.3	47.3	45.5	48.7	37.8	35.4	37.9	33.3	32.5	33.1
½ FI	55.6	52.4	53.3	47.5	45.6	48.2	39.0	35.3	37.2	33.7	32.1	33.5