LEAF AND SPADIX PHENOLOGY OF COCONUT
(*Cocos nucifera* L.)

By

SHAJEESH JAN, P.

THESIS

submitted in partial fulfilment of the requirement for the degree of

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Department of Agricultural Meteorology

COLLEGE OF HORTICULTURE

KAU P. O., THRISSUR - 680 656

KERALA, INDIA

DECLARATION

I hereby declare that the thesis entitled **"Leaf and spadix phenology of coconut** *(Cocos nucifera* L.*)*" is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other university or society.

Vellanikkara

Date: 21-2-2004

Shajeesh jan, P

CERTIFICATE

Certified that the thesis entitled **"Leaf and spadix phenology of coconut** *(Cocos nucifera* L.)" is a record of research work done independently by **Sri. Shajeesh jan, P** under my guidance and supervision and that it is not previously formed the basis for the award of any degree, diploma, associateship or fellowship to him.

Vellanikkara

Date: 21.2.2004

Dr. G.S.L.H.V. Prasada Rao

(Major Advisor, Advisory Committee)

Professor - in- Charge
Associate Dean
College of Horticulture
Vellanikkara

CERTIFICATE

We, the undersigned members of the advisory committee of **Sri. Shajeesh jan, P**, a candidate for the degree of **Master of science in Agriculture**, with major field in Agricultural Meteorology, agree that the thesis entitled **"Leaf and spadix phenology of coconut (*Cocos nucifera* L.)** may be submitted by Sri. Shajeesh jan, P. in partial fulfillment of the requirement for the degree.

19/3

Dr. G.S.L.H.V. Prasada Rao

Professor - in - Charge
Associate Dean
College of Horticulture
Vellanikkara

19/3/04

Dr. E.K. Lalitha Bai

Associate Professor
Department of Agricultural Meteorology
College of Horticulture
Vellanikkara.

19/3.04

Dr. E.V. Nybe

Associate Professor and Head
Department of Plantation Crops and Spices
College of Horticulture
Vellanikkara.

19-03-04

Dr. V.K.G. Unnithan
Associate Professor and Head
Department of Agricultural Statistics
College of Horticulture
Vellanikkara.

19/3

EXTERNAL EXAMINER
DR. H. S. RAM MOHAN,
PROFESSOR,
DEPT. OF ATMOSPHERIC SCIENCES

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Shajeesh jan, P

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Almighty God

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INTRODUCTION

1. INTRODUCTION

Coconut (*Cocos nucifera* L.) is one of the most important and beautiful palms in the world, which provides food, livelihood and shade for millions of people in the tropical areas. Epigraphical, literary and sculptural evidence provide proof that coconut had served the humanity for more than three millennia. The palm is looked upon with reverence and affection and is referred to by such eulogistic epithets as "Kalpavriksha", tree of heaven, the tree of abundance, nature's super market, king of palms and the tree of life. Considering the importance of coconut tree in the world, Asian and Pacific Coconut Community (APCC) has declared to celebrate 2nd September as 'World Coconut Day'.

India is one of the largest coconut producing countries in the world with an area of about 1.89 million hectares and annual production of 12812.7 million nuts (CDB, 2003). The Country ranks third on the world map of coconut after Philippines and Indonesia. It provides livelihood to small and marginal farmers, scattered in18 states and three Union Territories in the country. The State of Kerala ranks first in coconut area (49.6%) and production (44.7%) within this country. The very name 'Kerala' is derived from its association with the coconut palm, called *kera vriksha* in Sanskrit. No other tree in the State can match coconut in its versatility. Coconut is essentially a crop of the humid tropics and the cultivation of the same is confined between the Tropic of Cancer and Tropic of Capricon. Within this zone, it is mentioned that coconut palm has not been found very fastidious or exacting in its climatic requirements.

The word phenology owes its origin to the two Greek words namely "phainesthai" means to appear and "logos" means to study or it is "the study of appearances". Phenology, in its simplest term, is the study of cyclic events of nature usually the life cycles of plants and animals which respond to seasonal changes. In other words, phenology is the study of the response of living organisms to seasonal and climatic changes in which they live. Seasonal changes include variations in the duration of sunlight, precipitation, temperature, and other life- controlling factors. The present investigations are to elucidate the various biotic events of the leaf and spadix phenological characters of coconut. In the case of coconut, there exists not only a long reproductive phase of three-and-a-half years but also has crop growth and development in different stages at a given point of time. Salter and Goode (1967) in their review of "crop response to water" sum up the position with regard to coconut by stating that "with so great a time lapse between the initiation of leaf and inflorescences primordia and flowering and with many other inflorescences in various stages of development present at the same time, it has been found difficult to relate accurately growth, flowering or yield responses to any particular climatic condition."

In order to study the leaf and spadix phenology of coconut, evolution and development of the leaf, inflorescence and female flowers during different seasons of the year have to be traced. The effect of seasonal factors on the yield of perennial crop like coconut cannot be easily assessed unlike in the case of annual crops. In annual crops, the effect is manifested immediately or during course of the year while in the case of perennial crops, the effect on floral and yield characters is discernible only after some time lag. The effect of a particular season on phenological characters of coconut may be noticed in the same season or following season due to prolonged reproductive phase. At present, the information on the above aspects is seen in the literature mainly based on the data generated a few decades ago from the northern zone of Kerala.

Therefore, the data on biotic events of leaf and spadix phenology of coconut will be an additional information if it is generated systematically as it is varies from one agroclimatic region to another. It will also be an updated one on the leaf and spadix phenology of coconut since the current literature is scarce and sporadic after 1950s. The information generated on coconut phenology could probably be used in crop improvement and management programmes. Keeping the above in view, the present investigations on "Leaf and spadix phenology of coconut (*Cocos nucifera* L.)" were proposed with the following objectives:

1. To understand the seasonal influence on leaf and spadix production and their interval in coconut
2. To understand the seasonal influence on the duration of spadix emergence
3. To compare the seasonal influence on leaf and their interval among different varieties/cultivars of coconut
4. To study the effect of weather on leaf and spadix phenology of coconut.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The reproductive phase of coconut takes about 44 months, starting from primordium initiation to harvest unlike other perennial crops. Aberrations in weather during the development process of spathe will affect the final nut size, yield and oil content. Among the weather variables, air temperature (maximum and minimum), rainfall, rainy days, relative humidity, vapour pressure deficit, wind speed and sunshine hours are found to have direct effect on the crop growth and yield. Though the literature on crop weather relationships of coconut is scarce, studies on the effect of rainfall on crop yield have been attended by several workers in and outside India. It is also an established fact that rainfall distribution alone can determine the yield to a greater extent. In this chpter, the literature available on crop weather relationship and phenology of coconut has been briefly reviewed.

Abeywardena (1955) reported that weather parameters of different months of an year did not contribute to the yield of next successive years production to the same degree because in the cycle of development of bunches, there are certain periods (phases) which are extremely susceptible to weather.

Marar and Pandalai (1957) in a study opined that it was not possible to explain the influence of seasonal changes in terms of individual weather parameters.

Nambiar *et al.* (1969) distinguished three distinct phases of fruit development. The first phase of slow progressive growth is for about three months after fertilization, followed by the next phase of rapid growth for about four months and finally the rapid decline in growth rate in about two months. They observed that the rate of growth during the second phase of development is highly correlated with the final volume and weight of unhusked nut and copra content. Any weather aberration coinciding with active period of development will adversely affect the rate of growth and final size of the nut and copra content. Rao *et al.* (1986) observed a negative relationship between heat units (which is a function of temperature) during the second phase of development (4-7 months after fertilization) and husked nut weight. There was a marked decline in nut size from July to December in response to an increase in total heat units, indicating that the total heat units above 2100 day° C were not congenial for nut development.

According to Abeywardena (1971), the yield variations due to weather factors are more pronounced in coconut than in other tree crops, the reason being the long reproductive cycle of coconut obviate from vagaries of weather in its external manifestations.

Bai *et al.* (1988) in their study on effect of weather variables on stress development in coconut showed that when the palms were exposed to environmental situation wherein the radiation was around 265 W/m^2, temperature 33°C and VPD 26 m bars, the stomatal closure set in. Thus the significance of both soil moisture level and agrometeorological parameters on stress in coconut has been understood.

Nair and Unnithan. (1988) studied the influence of climatic factors on coconut yield variation from season in different lag periods. The most important climatic factors influencing the annual yield of coconut were sunshine hours, evaporation and relative humidity. Sunshine hours and evaporation showed a positive correlation with yield while relative humidity showed a negative correlation. Rainfall and number of rainy days did not shed much light on the pattern of influence.

Vijayakumar *et al.* (1988) in a study of the relationship between 11 weather variables and coconut yields, identified 7 lag periods, which corresponds to various growth stages. Among the variables selected, rainfall had positive influence consecutively on five of the seven lag periods, while temperature and relative humidity had their influence on two or three lag periods.

2.1 EFFECTS OF DIFFERENT WEATHER ELEMENTS ON COCONUT

2.1.1 Rainfall

Copeland (1931) reported that a mature coconut palm loses as much as 6-16 gallons of water daily by transpiration. It was also reported that it is the distribution pattern of which is more important than the quantum of rainfall.

Park (1934) observed that a severe drought lasting for 8 months affected the coconut palm even two years later after the cessation of drought period.

Patel and Anandan (1936) pointed out that yield in particular year were influenced by the January to April rain during the years of harvest and preceeding two years.

In another study, Patel (1938) observed that primordia of inflorescence get aborted due to drought. Menon and Pandalai (1958) noticed that a period of drought occurring 15-16 months before opening of inflorescence leads to abortion of spadices.

Abeywardena (1968) observed a harmful effect of heavy rainfall during southwest monsoon (Sri Lanka) causing high relative humidity, low temperature and low insolation. He observed that coconuts are more moisture sensitive in the period from May to August than in the rest of the periods. It assumed a wide variation in moisture sensitivity in the other two periods. From January to April no harmful effect due to heavy rainfall was observed, whereas in the period from September to December it clearly indicated that any rainfall in excess of 355mm/month was extremely harmful to the crop as temperature is low and humidity is high.

Cooman (1975) observed a negative correlation between fruit set and accumulated water deficit over 5 months, one year earlier. He concluded that influence of water availability period on fruit set was the highest in the period between the appearance of the flower primordia and the ovary differentiation

Rao (1982) attempted to find out a relationship between the annual coconut yield and rainfall trend in Pilicode region of the northern Kerala using twenty years moving average. The study indicated that high rainfall during monsoon as well as the absence of pre and post monsoon showers adversely affected the subsequent years coconut yield.

Beyond a certain maximum rainfall, the precipitation may not be useful and increase in yield may not be manifested in coconut according to Thampan (1982).

Rao (1985) had assessed the extent of damage to coconut palm by drought on the basis of aridity index.

Rethinam (1987) reported that drought effects of adult palm are characterised by bending of leaves, wilting in lower whorls, reduction in female flowers, shedding of buttons, immature nut fall and drastic decline in nut production.

In an unique study, Rao (1988) has reported that the effect of drought on monthly nut yield was seen in the 8^{th} month with maximum reduction during the 13^{th} month after the drought and fall in the nut yield continued for 12 months after the drought period was over.

Vijayaraghavan *et al.* (1988) were of the opinion that very high rainfall interferes with pollination thus affecting the nut yield.

Varghese and Kunju (1988) reiterate the fact that monsoon rainfall and the first and third annual nut yields exhibits significant positive correlation in the backwater areas of Kuttanad.

Rainfall during March and May three year prior to harvest of coconut had a positive contribution to yield, whereas rainfall during January and November had a significant negative influence. As such, the monthly rainfall during the rest of the months was found to have no significant influence on coconut productivity (Babu *et al.* 1993).

In the dry intermediate zone, Peiris (1993) observed the influence of rainfall in two monthly sub periods in the year prior to harvest on the coconut. The most influential period is January and February and least influential period is July to August. The rainfall during May –June has a depressing effect and rainfall in excess of 450 mm was not utilized by the palm. High rainfall during September/ October has discernible effect while high rainfall during October/November showed significant effect to the palm.

Rajagopal *et al.* (1996) revealed that the length of dry spells influence the coconut production under rainfed conditions. The initiation of primordium, ovary development and button-size nuts are more sensitive to coconut production.

2.1.2 Temperature

This is another important factor, which has profound influence on the distribution and performance of coconut palm. Infact it is temperature that sets a limit to the latitude and of altitude up to which coconut can be successfully cultivated. The coconut palm likes equable temperature of neither very hot nor very cold. The optimum mean annual temperature for best growth and maximum yield was found around 26-27°C and with a diurnal variation of 7-8°C (Marar and Pandalai, 1958).

According to Child (1964), the ideal mean annual temperature is usually put at around 27°C, and the average diurnal variation between 5° C and 7 °C. Low temperature seemed to be more limiting than high temperature.

Louis and Annappan (1980) obtained a negative correlation of the yield with temperature and relative humidity.

Thampan (1981) found that yield of coconut was reduced if the average minimum temperature was below 21^{0}C.

Vijayaraghavan (1988) reported that mean minimum temperature during northeast monsoon in Tamil Nadu and winter season were low and very low respectively. The nut yield was also low and very low during the above seasons. Between the southwest monsoon and summer season period when the minimum temperature was high (around 20^{0}C) the nut yield was higher during the above period.

2.1.3 Relative humidity

Relative humidity is one of the factors determining the transpiration rate and consequently the water and nutrient uptake by the palm. Even in the case of sufficient water supply from the soil, low ambient relative humidity may induce stomatal closure in the palm thereby reducing its photosynthetic capacity.

Copeland (1931) observed that relative humidity obviously related to rainfall, temperature and insolation should be such as to permit the most active transpiration with the palm suffering from loss of water. He had established that cloudiness arrests rate of transpiration considerably. According to him the prevalence of high humid conditions throughout are not favourable for the palm. He opined that humidity reduces transpiration and there by reduces the uptake of nutrients. Marar and Pandalai (1957) cited that coconut palm likes a warm humid climate.

2.1.4 Insolation

Sunshine is another critical weather factor affecting the biological function and photosynthetic activity of the plants.

Copeland (1931) made an extensive observation on the effect of sunlight and transpiration, which influence the vital growth process in the plant. He established that cloudiness arrests the rate of transpiration considerably. Sunlight has also been shown to raise temperature of leaf surface thereby promoting better activity.

Wickramasurya (1968) observed that spadix initiation and production of coconut in Sri Lanka are greater in March – September, when average day length is greater than during the rest of the year.

Cooman (1975) observed a positive correlation between the rate of insolation 29 and 30 month before harvest and the female flower produced.

Rao *et al.* (1995) reported that percentage decline in net radiation (around 30 per cent) was high during the southwest monsoon season when compared to that of summer. The potential photosynthesis may be reduced during the rainy season as the decline in solar radiation and net radiation was significant .De wit (1965) has reported that there could be 50 per cent of reduction in potential photosynthesis when the light intensity gets reduced to only 20 per cent of the intensities on clear days in the tropical areas at 10° N.

2.1.5 Wind

According to Copeland (1931) the effects of wind on the coconut palm depend upon soil moisture condition. Strong winds are not desirable as they do considerable damage to coconut plantation. It is more so in case of surface planting.

2.2. PHENOLOGY OF COCONUT

The effect of seasonal factors on the yield of perennial crop like coconut cannot be assessed unlike in the case of annual crop. In annual crops, the effect is manifested immediately or during the course of the year whereas in the case of perennial crops the effect on yield characters is discernible only after some time lag. The effect of a particular season noticed may be due to the delayed effect of earlier seasons. This is due to particular growth characters of the perennial crop.

The evolution and development of inflorescence of the palm has been traced by Patel (1938). The primordium of the inflorescence is reported to develop in the leaf axils about 32 months before the opening of the inflorescence. The primordia of the branches of florescence develop in about 16 months and male and female flowers in about 11 and 12 months respectively before the opening of the inflorescence. The ovary is first differentiated about 6-7 months before the opening of the inflorescence. Seasonal factors prevailing during the developmental stages during the period of 32 months before the inflorescence opens do affect the yield of nut.

Louis and Annappan (1980) revealed two allied factors one is that the inherent nature of the individual or group of palm for higher and lower yield of nuts remain constant, inspite of the uniform treatment received by all the palms. The factor is that all the palms are being influenced by the environmental factors irrespective of their potentiality to yield. The study showed that the number of nuts harvested per palm during April –May (second half summer) is significantly higher and distinct while the lower during the first half of southwest monsoon (May-June).

2.2.1 Rate of leaf production and shedding

The rate of production of leaves is the lowest during summer and most rapid during September-October (Patel, 1938).

Sampson (1923) states that the rate of leaf development slows down during the rainy season. It was also pointed out that more leaves fall from the tree during the rainy season than in the dry weather due to the moist atmospheric conditions, favouring the growth of the fungus *Pestalotia palmarum*. However, who observed that the shedding of leaves is the least in the southwest monsoon when compared to that of hot weather season. Also, the shedding of leaves varies from season to season depending upon locality. It was also pointed out that it is not possible to say whether the variation in seasonal leaf shedding is due to the differences in the age of palms or soil conditions.

Marar and Pandalai (1957) reported that coconut leaves are produced at shorter interval during November to December than the other parts of the year and shedding of leaf was found influenced by season; being least in southwest monsoon season.

Kutty and Gopalakrishnan (1991) reported that the morphological characters like number of leaves retained by the palm, length of leaves, length of petiole, number of leaflets per leaf and girth of stem at collar region had positive correlation with yield and it was also stated that the periodicity of leaf emergence computed in terms of number of days elapsed between two successive leaf emergence had a negative correlation with yield.

2.2.2. Spadix emergence

Patel (1938) reported that the opening of bunches is very low during October, November, December and January while high during March, April and May. The interval between the successive spadices appears to remain the same for the main seasons even in different years. It varied between 27.8 and 33.4 days between Kasaragod and Nileswar-I, respectively. This is mainly due to the fact that the trees at Nileswar-I are very young.

In coconut palms that come to normal bearing stage, every leaf axil will normally produce an inflorescence (spadix). Larger number of spadices are produced in the hot weather season than in the other seasons or the interval in days between the opening of successive spadices was the least in hot weather season when compared to other seasons Marar and Pandalai (1957).

Menon and Pandalai (1958) observed that the production rate of spadices was dependent on the rate of production of leaves. About11-15% of total number of spadices produced during a year emerges during the month of March, April and May.

Bhaskaran and Leela (1983) reported that spadix production was maximum during hot weather period in Tall x Dwarf and WCT. Production of spadices and female flowers in WCT x CDO hybrid was high during March-May and absent during October-December.

Kalathiya and Sen (1991) observed that the nut yield was found significantly and positively correlated with number of spadix produced and duration of female phase whereas number of leaves produced and length of spadix exhibited significant positive correlation with number of spadices. It is, therefore, suggested that the number of leaves, spadix production, length of spadix and duration of female phase should be considered as selection criteria for nut yield improvement in coconut variety 'Dwarf Green'.

Sreelatha and Kumaran (1991) observed that the spadix emergence was observed to commence by early January and it gradually increased reaching a peak in the middle of March with a total of 29 spadices in the population studied during the standard week from 12th to 18th March. Thereafter, the production decreased slowly and attained zero by the next October.

Vanaja and Amma (2002) reported that maximum number of spadix and bunch production was noticed during summer months (March to May). While it was low during post monsoon period (October to December) in both Komadan and WCT.

2.2.3 Production of female flowers

Marechal (1928) reported that female flower production was high during November to March in dwarf palms in Fiji

Number of female flower production in different seasons may be due to the differences in the number of spadices opened during periods (Patel, 1938)

Marar and Pandalai (1957) noted that number of female flowers in general, is more in the inflorescences that are produced in the hot weather than in other seasons of the year.

Shylaraj *et al.* (1991) observed that Komadan mother palms were found significantly superior in girth of stem, number of fronds, number of bunches per palm, number of female flowers per spadix, percentage of fruit set and annual nut yield per palm when compared to that of west coast tall.

Maximum number of female flowers was produced during the summer months (March-May) and minimum during winter (Rao, 1988).

Vanaja and Amma (2002) reported that about 62 per cent of annual female flower production was observed during hot weather period (February to May). According to them, female flower production per spadix was found maximum during September to February and minimum during May to July in both Komadan and WCT.

2.2.4 Seasonal variations in spathe emergence

Vijayaraghavan *et al.* (1993) studied the seasonal variations in the spathes produced. It indicated that the reproductive phase was much active during April to September during which period 65-70 per cent of spadices were opened. The traditional tall (ECT) had two peaks, one during March and the other during August. Among the dwarf types, Malayan Yellow dwarf (MYD) and Malayan Green dwarf (MGD) had single peak during August while Ayiramkachi (AY) had two peaks during August and June.

2.2.5 Button shedding

Shedding of button or female flower in an inflorescence is a common phenomenon in coconut and has great economic bearing on the yield of coconut.

Gadd (1923) reported that water deficiency affected not only the setting of nuts in coconut plantation but also resulted in severe shedding of nuts especially after prolonged period of drought and particularly after the onset of rain.

Patel (1938) reported that shedding of button is high during August, September and November and slightly less during the other months. There does not appear any relationship between the shedding and rainfall and the drought

Shedding is found high in southwest monsoon season and low in cold weather (Marar and Pandalai, 1957)

During heavy rainfall, pollination is hampered which eventually depressed the yield during November- December of ensuing year (Davis and Gosh, 1982).

Rao (1988) highlighted that if intensity of rainfall is high, the button shedding is also high. It is probably due to lack of pollen and pollinating agents during the heavy rains as well due to waterlogging in coconut garden leading to physiological drought, resulting to hypodermal thickening up to the root cap reducing the area of absorption of nutrient from the soil. The study also indicated a significant correlation between button shedding and minimum temperature. Sudden alteration in soil temperature and soil moisture leads to heavy button shedding and immature nut fall in coconut (Karunanithi *et al.* 2002).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study on "Leaf and spadix phenology of coconut" (*Cocos nucifera* L.) was undertaken at the Department of Agricultural Meteorology, College of Horticulture, Vellanikkara from February 2002 to June 2003. The experimental site is located in Seed Production-Cum- Demonstration Farm, Coconut Development Board, Vellanikkara (10^0 31'N and 74^0 13'E). Presently, it is under the control of Central Nursery, Kerala Agricultural University, Vellanikkara (Plate 3.1).

3.1 EXPERIMENTAL MATERIAL

Eight- year- old of ten coconut palms each of the four cultivars were randomly selected for the study (Fig 3.1). Thus altogether forty palms formed the material for recording phenological observations. The palms selected were grown under uniform management conditions. The cultural and management practices were followed as per the package of practices recommendations of the Kerala Agricultural University (KAU, 1996).

3.1.1 Cultivars

The four test cultivars viz., Tiptur Tall, Kuttiadi (WCT), Kasargod (WCT) and Komadan (WCT) were selected for taking up the field experiment.

3.1.2 Soil characteristics: - soil of the location was clay loam in texture. The physico- chemical properties of experimental sites are as detailed below:

Gravel (%)	- 54.45	pH	- 5.4
Sand (%)	- 39.84	EC (dS/m)	- 0.033
Silt (%)	- 27.49	Org.C (%)	- 1.12
Clay (%)	- 32.67	Available P (ppm)	- 1.86

The soil type was clay loam in texture.

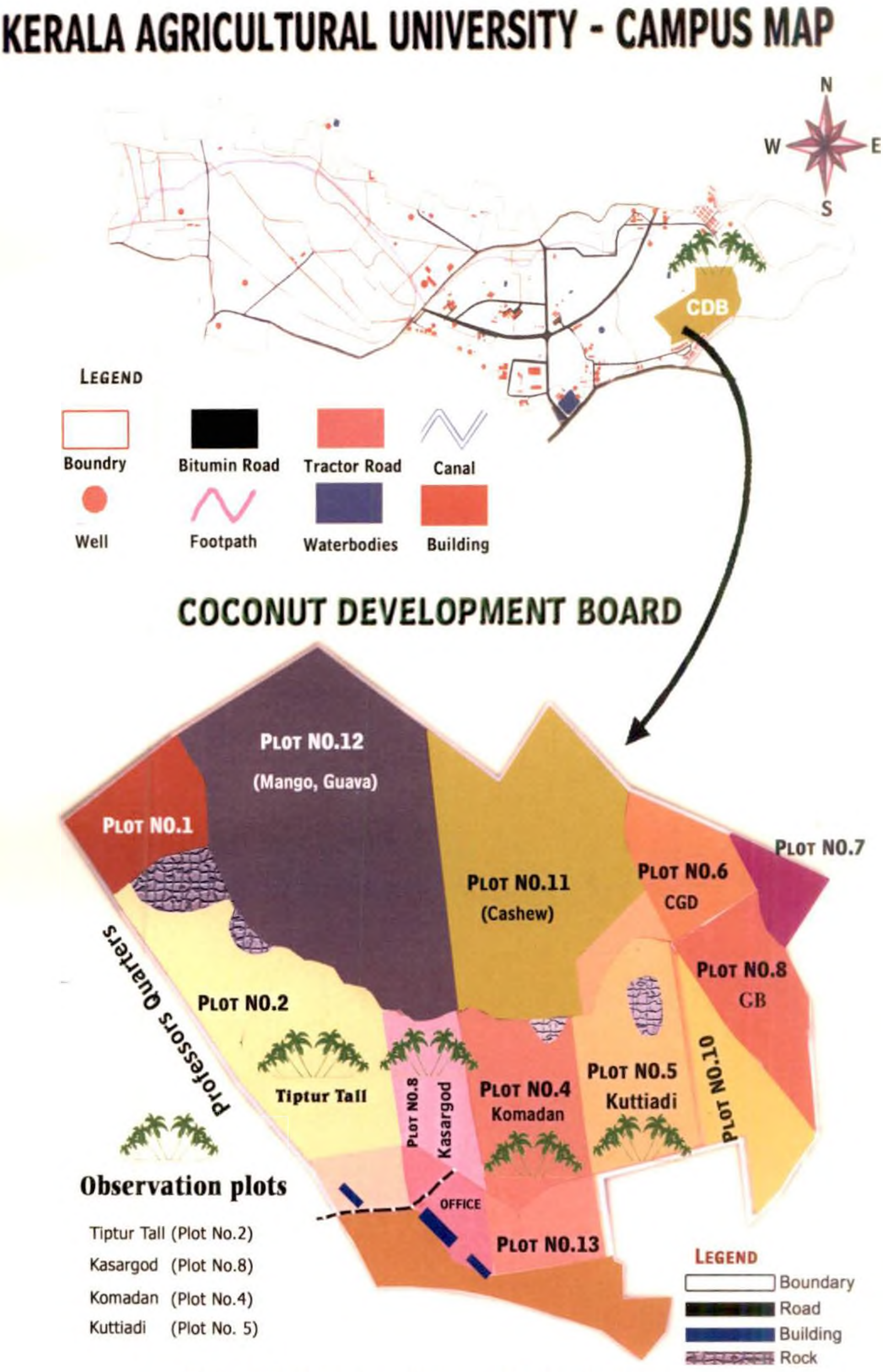

Plate 3.1. Location Map of the Study Area

TIPTUR TALL

1-2	
3-4	
5-9	78-87
10-12	88-98
13-15	99-116
16-21	117-133
23-31	134…***138:137***...150
32-38	151…***154:160***...168
39-47	169..***171:176:177***..18
48-53	185…***188:198***...201
54-60	202…***205***...220
69-77	221-235

KASARGOD

1-15
16-36
37-49
50…***55***...56
57…***61***...68
69…***71:73:75:76***…77
78…***79***...85
86...***87:89:92***…94
104-112
113-121

KOMADAN

1-16
17…***21***…35
36…***41***…53
54…***59***...72
73-93
94-114
115…***117:121:124***...13
135...***140:141:146***…151
152…***162***…168
169-185

KUTTIADI

1…***16:17***…26
27…***38:41:42***…53
54…***59:60:61***…68
69…***71:72***...82
83-90
91-97
98-105
106-127
128-143

Figure in red indicate observational palms

Fig. 3.1 Observation palms of the study area

3.1.3 Climate: - The experimental location falls under humid tropics (B4- type) as per Thornthwaite (1948) climatic classification. The weekly meteorological data for the study were collected from the weekly records maintained at the Dept. of Agricultural Meteorology, College of Horticulture, Vellanikkara (Appendix I.)

3.1.4 Phenological observations

The biotic events viz., leaf, spathe and floral characters were recorded once in a week mostly from February 2002 to June 2003.

3.1.4.1 Leaf characters

1) Number of functional leaves produced monthly
2) Number of leaf shedding monthly

3.1.4.2 Spathe characters

1) Number of spathe presented on the crown at the time of observation.
2) Date of spathe emergence.
3) Date of spadix emergence
4) Duration of spathe emergence to spadix emergence

3.1.4.3 Floral characters

1) Number of female flowers produced
2) Number of buttons set and
3) Button shedding

3.1.5 Meteorological data

Daily meteorological data on maximum and minimum temperatures, relative humidity (morning and evening), rainfall and rainy days, bright sunshine hours, evaporation and cloud amount were collected. The mean values of air temperature, relative humidity and vapour pressure were worked out weekly and monthly and thus the derived weather variables are as followed:

Growing Degree Days (Day °C)

Helio-Thermal unit and

Vapour pressure deficit (hPa)

3.2 METHODS

The phenological data collected from ten palms of each cultivar were pooled in Standard- Meteorological- Week wise to get the mean phenological data of a particular week of a test cultivar. The observations on number of spathes produced, duration of spathe, monthly leaf production and seasonal button shedding, spathe emergence and spathe opening were processed

3.2.1 Spathes duration

The spathes that were emerged in the same standard week were pooled to get the mean duration of spathes of each cultivar. Weather parameters were also averaged in the same way and correlations were worked out using Pearson's Bi-variate correlation technique.

3.2.2 Number of spathe emergence

The number of spathes emerged monthly was worked out for correlation analysis with weather parameters 29 months prior to the spathe emergence since the primordia for spathe would have developed 32 months before the spadix emergence (Patel, 1938). The average duration for spathe to spadix emergence is considered as three months in the present study.

3.2.3 Female flower production

The number of female flowers collected from the observational palms of each cultivar was pooled in Standard- Meteorological- Week- wise and worked out monthly female flower production. The correlations were worked out between mean monthly female flower production and weather parameters at two critical stages viz., primordia initiation (32 months prior to spadix emergence) and ovary development (6-7 months prior to spadix emergence) as suggested by Rajagopal *et al.* (1996).

3.2.4 Button shedding

The mean button shedding was worked out corresponding to spathes, which were opened during the same standard week and it was correlated with weather parameters.

$$BS = 1 - \left[\frac{NFF_1}{NFF_2} \right] \times 100$$

Where,

BS- Button shedding (%)

NFF_1- Number of female flowers retained at the end of third month

NFF_2- Number of female flowers at the time of spathe opening.

3.2.5 Seasonal average

The whole year was divided into four seasons as suggested by the India Meteorological Department

In this study four seasons have been identified as follows

Season	Period
Summer	March-May (3 months)
Southwest monsoon	June- September (4 months)
Post monsoon	October-November (2 months)
Winter	December-February (3 months)

As the phenological observation may vary with the length of seasons, the seasonal monthly means were worked out to maintain uniformity for correlation studies.

3.2.6 Growing Degree Days (GDD)

Growing Degree Days (Day °C) for various phonological events were worked out. A thermal day / Growing Degree Days (GDD) / heat unit is the departure from the mean daily temperature above the minimum threshold temperature (°C). Thermal days for the each phonological event were worked out from the following:

$$GDD = \sum_{i=1}^{n} \frac{(Tmax+Tmin)}{2} - T\ base$$

GDD= Growing Degree Day (Day °C)

T max= Maximum temperature of the day (°C)

T min=Minimum temperature of the day (°C)

$\sum_{i=1}^{n}$ =Summation for day '1' to day 'n' when the event occurred.

The base temperature (T-base) is assumed as 13° C for adult coconuts (Rao, 2003).

3.2.7 Helio-Thermal Unit (HTU)

The product of Growing degree day and the number of actual bright sunshine hours of any day is called Helio- Thermal Unit (HTU). It can be measure for day temperature.

HTU= GDD X Number of actual bright sunshine hours

3.2.8 Vapour Pressure Deficit (VPD)

The difference between the saturation vapour pressure (SVP) and its actual vapour pressure (AVP) is termed as saturation vapour pressure deficit (VPD).

VPD=SVP-AVP

Where,

AVP= Saturation vapour pressure at dew point temperature

SVP=AVP/RH x 100

RH = Relative humidity

The observations on SVP computed using the AVP values which were obtained from the hygrometric table.

3.2.9 Statistical Analysis

Crop-weather relationships were worked out in leaf and spadix phenology of coconut using different statistical tools.

3.2.9.1 Analysis of Variance

To study the influence of season on different leaf and spadix phenology of coconut the experimental data were analysed as Randomised Block Design (RBD) using the ANOVA technique. The significance is tested by F test and the treatments were compared by Duncan's Multiple Range Test (Snedecor and Cochran, 1983).

3.2.9.2 Estimation of Correlation

The simple correlation (bivariate) was worked out using SPSS package.

3.2.9.3 Stepwise Regression

To facilitate the prediction of indices, reduction in number of variables is imperative. Hence, stepwise regression procedure was used to identify major character which can be used to predict the duration of spathe and button shedding. Further, adoption of stepwise regression has been established scientifically to reduce multi-colliniarity among independent variables and to arrive at the best subset of variables (Draper and Smith, 1966).

RESULTS AND DISCUSSION

4. RESULTS AND DISCUSSION

The results obtained on various phenological characters are summarised based on the statistical analysis and presented in this chapter.

4.1 VARIETAL AND SEASONAL VARIATION OF FUNCTIONAL LEAVES IN COCONUT

The mean annual number of functional leaves present on the crown was high (32.76) in Tiptur Tall, followed by Kasargod (29.35) and Kuttiadi (28.92) while the least (27.33) in Komdan. It indicated that Tiptur Tall appears to be better among the four test cultivars in terms of functional leaves (Table 4.1). On an average, the annually functional leaves present on the crown were about thirty in number. The seasonal variations in number of functional leaves present on the crown were significant at one per cent level in all the four cultivars (Table 4.1).

Table 4.1 Seasonal variations in number of functional leaves

Seasons	Tiptur Tall	Kuttiadi	Kasargod	Komadan	Mean
Summer 2002 (Mar-May)	32.29 ^{ab}	28.17 ^{b}	29.00 ^{ab}	26.43 ^{b}	28.97
SWM (June-Sep)	32.07 ^{b}	28.67 ^{b}	28.94 ^{b}	26.67 ^{b}	29.09
PM (Oct-Nov)	33.30 ^{a}	29.90 ^{a}	30.15 ^{a}	27.75 ^{a}	30.28
Winter (Dec-Feb)	33.39 ^{a}	28.92 ^{b}	29.30 ^{ab}	28.48 ^{a}	30.02
Mean	32.76	28.92	29.35	27.33	29.59
Summer 2003 (Mar-May)	31.46 ^{b}	27.10 ^{c}	27.52 ^{c}	26.94 ^{b}	28.26

4.1.1 Tiptur Tall: - The number of functional leaves present on the crown was maximum (33.39) in winter and statistically on par with post monsoon (33.3) and summer 2002 (33.29). The minimum number of leaves (31.46) was observed in summer 2003, which did not differ significantly from southwest monsoon (32.07) and summer 2002 (32.29).

4.1.2 Kuttiadi: - Post monsoon recorded the highest number (29.9) of functional leaves, followed by winter (28.92), southwest monsoon (28.67) and summer 2002 (28.17). They were statistically on par. The summer 2003 recorded the lowest number (27.1) of functional leaves.

4.1.3 Kasargod: - The number of functional leaves present on the crown was maximum (30.15) during post monsoon, followed by winter (29.3) and summer 2002 (29). The number of functional leaves present during winter and summer 2002 was on par with the number of leaves presented during southwest monsoon (28.94). The summer 2003 recorded the minimum (27.52) number of functional leaves.

4.1.4 Komadan: - The highest number of functional leaves was observed during the winter season (28.48), which was on par with post monsoon (27.75). The number of functional leaves was lowest during summer 2002 (26.43) and on par with summer.2003 (26.94) and southwest monsoon (26.67).

Among the cultivars, the number of functional leaves produced was maximum during winter in Tiptur Tall and Komadan while post monsoon in Kuttiadi and Kasrgod. The minimum number of functional leaves was observed during summer 2003 in all the cultivars except in Komadan, in which it was during summer 2002. The functional leaves appear to be low during summer 2003 when compared to summer 2002. It was due to more leaf shedding in summer 2003. The results obtained were in agreement with that of Patel (1938) and Marar and Pandalai (1957) but not in conformity with Sampson (1923).

The reason for more number of leaves during the post monsoon and winter seasons can be attributed to the fact that the food materials that stored in the palm during the southwest monsoon season would not have fully been utilized during the monsoon season because of unfavourable weather conditions such as high rainfall (1518.3 mm), low surface air temperature, less vapour pressure deficit (4.5 hPa), low wind speed (3.8km/h) and low sunshine hours (4.3), which restrict optimum evapotranspiration it may result in poor uptake of nutrients during the monsoon. Once the southwest monsoon period is over, palms are exposed to favourable weather/atmospheric conditions for greater photosynthesis. The assimilation of food material and translocation of assimilates into the vegetative part- leaf lead to more leaf development.

The low number of leaf production during summer and southwest monsoon seasons can be attributed to the fact that the food material stored in the palm would have been assimilated in the same season itself because of the conducive weather condition, favouring better photosynthetic assimilation and translocation of the assimilated material.

4.2 VARIETAL AND SEASONAL INTERACTION IN LEAF SHEDDING

Table 4.2 Seasonal leaf shedding in different cultivars of coconut during 2002-2003

cultivar	Summer (Mar-May)	SWM (June-Sep)	PM (Oct-Nov)	Winter (Dec-Feb)	Total
Tiptur Tall	4.6	3	1.5	4.1	13.2
Kuttiadi	3.6	2.4	1.9	4.9	12.8
Kasargod	3.7	2.9	2.3	3.9	12.8
Komadan	4.3	2.4	1.2	3.8	11.7
Mean	4.05	2.68	1.73	4.18	12.63

The annual number of leaf shedding was maximum (13.2) in Tiptur Tall, followed by Kuttiadi (12.8) and Kasargod (12.8) while minimum (11.7) in

Komadan (Table 4.2). On an average, the number of leaves shed annually was about thirteen.

The seasonal variations of leaf shedding was significant at one per cent level in all the cultivars studied (Table 4.3).

Table 4.3 Mean monthly leaf shedding in different seasons

Seasons	Tiptur Tall	Kuttiadi	Kasargod	Komadan
Summer 2002 (Mar-May)	1.58 [a]	1.50 [ab]	1.42 [ab]	1.65 [ab]
SWM (June-Sep)	1.38 [a]	1.15 [bc]	1.25 [b]	1.30 [b]
PM (Oct-Nov)	0.75 [b]	0.75 [c]	1.00 [b]	0.60 [c]
Winter (Dec-Feb)	1.47 [a]	1.68 [a]	1.68 [a]	1.29 [b]
Summer 2003 (Mar-May)	1.71 [a]	1.87 [a]	1.71 [a]	1.76 [a]

4.2.1Tiptur Tall: - The maximum number (1.71) of leaf shedding was noticed during summer 2003 which was statistically on par with summer 2002 (1.58), winter (1.47) and southwest monsoon (1.38). The minimum leaf shedding was noticed during post monsoon season (0.75).

4.2.2 Kuttiadi: - The highest (1.87) leaf shedding was noticed during summer 2003, followed by winter (1.68) and summer 2002 (1.50). The leaf shedding was lowest number of leaf shedding was observed during post monsoon season and on par with southwest monsoon.

4.2.3 Kasargod: - The leaf shedding was maximum (1.71) during summer 2003. It did not differ significantly from winter (1.68) and summer 2002 (1.42). The minimum number of leaf shedding was observed during post monsoon and on par with southwest monsoon season.

4.2.4 Komadan: - The maximum (1.76) leaf shedding was observed during summer 2003, followed by summer 2002 (1.65). The leaf shedding during summer 2002 (1.65), southwest monsoon (1.30) and winter did not differ significantly. The minimum (0.60) number of leaf shedding was noticed during post monsoon period.

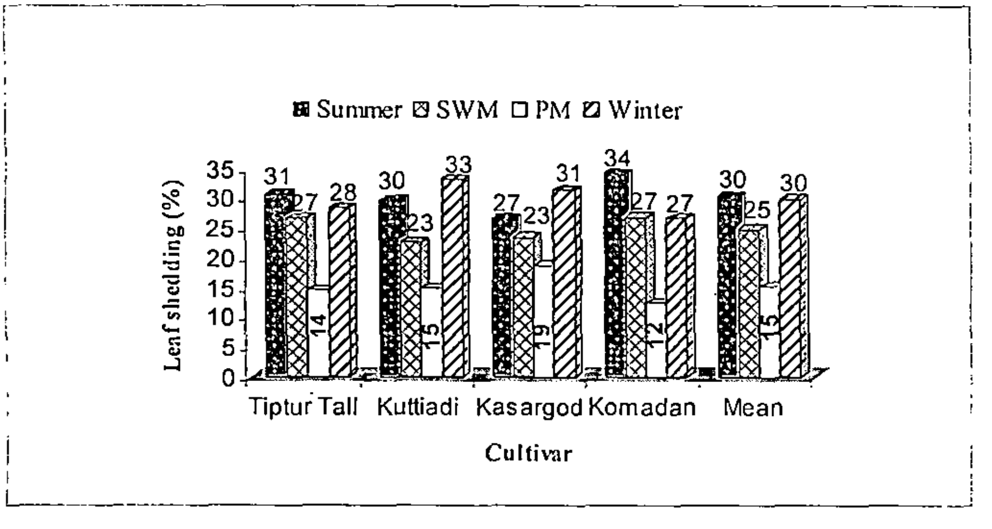

Fig. 4.1 Percentage leaf shedding in coconut during different seasons

As a whole, the leaf shedding was maximum during summer (30 %) and winter (30 %) while minimum (15%) during post monsoon season. Leaf shedding was intermediary (25%) during southwest monsoon season (Fig. 4.1). The results obtained were in accordance with Patel (1938) but not in agreement with Sampson (1938).

The rise in ambient air temperature, temperature range, vapour pressure deficit, low rainfall coupled with high evapotranspiration and high solar radiation prevailed during the summer season might have enhanced the drying rate of older leaves on the crown under the rainfed condition. The palms selected for the study were grown under rainfed conditions. This may be one of the reasons, why, the shedding of leaves was maximum during summer season. Shedding of leaves was low during summer 2002 when compared to summer 2003 as the dryness was high during summer 2003 due to prolonged dry spell when compared to that of 2002. In contrast, the leaf shedding was low during southwest and post monsoon. It can be attributed to less drying rate of older leaves due to high rainfall and relative humidity, lower temperature, wind speed, sunshine hours and evapotranspiration. The above factors lead to very low vapour pressure deficit in micro-environment of the crop.

4.3 SEASONAL SPATHE EMERGENCE IN COCONUT

The annual number of spathes emerged in Tiptur Tall was high (11.9), followed by Kuttiadi (11.0) and Komdan (10.1) while the least (9.7) in Kasargod (Table 4.4). It indicated that Tiptur Tall appears to be better among the four test cultivars in terms of spathe emergence. On an average, the number of spathes emerged annually was eleven.

Table. 4.4 Seasonal spathe emergence in different cultivars of coconut during 2002-2003

Cultivar	Summer (Mar-May)	SWM (June-Sep)	PM (Oct-Nov)	Winter (Dec-Feb)	Total
Tiptur Tall	3.2	1.8	3.3	3.6	11.9
Kuttiadi	3.1	2.5	2.9	2.5	11.0
Kasargod	2.8	1.6	2.4	2.9	9.7
Komadan	2.8	2.2	2.6	2.5	10.1
Mean	3.0	2.0	2.8	2.9	10.7

It also revealed that the influence of season on spathe emergence was significant at 1 per cent level (Table 4.5).

Table 4.5 Mean monthly spathe emergence in different seasons

Seasons	Tiptur Tall	Kuttiadi	Kasargod	Komadan
Summer 2002 (Mar-May)	1.06 [b]	1.03 [bc]	0.93 [a]	0.94 [b]
SWM (June-Sep)	0.46 [c]	0.63 [d]	0.43 [b]	0.57 [c]
PM (Oct-Nov)	1.65 [a]	1.45 [a]	1.20 [a]	1.30 [a]
Winter (Dec-Feb)	1.19 [b]	0.83 [cd]	0.97 [a]	0.85 [bc]
Summer 2003 (Mar-May)	1.29 [b]	1.24 [ab]	1.19 [a]	1.46 [a]

4.3.1 Tiptur Tall: - The mean number of spathes emerged was maximum (1.7) in post monsoon season followed by summer (1.06 and 1.29) and winter (1.19). It was on par in the seasons viz., summer and winter. The number of spathe emergence during southwest monsoon was the minimum (0.46).

4.3.2 Kuttiadi: - The mean number of spathe produced during the post monsoon season was found to be maximum (1.45) and on par with summer 2003 (1.24) while it was not the case with summer 2002. However, the number of spathes emerged during the summer 2002 and summer 2003 did not differ significantly. The number of spathe emerged during southwest monsoon (0.63) and winter (0.83) was found to be lowest and they were on par.

4.3.3 Kasargod: - The number of spathe emerged was maximum (1.2) during post monsoon, followed by summer 2002 (0.93), summer 2003 (1.19) and winter (0.97) while minimum (0.44) during southwest monsoon.

4.3.4 Komadan: - The spathe emergence was high (1.46) in summer 2003 and post monsoon (1.3). The spathe emergence was low (0.57) during southwest monsoon season.

The seasonal influence on spathe emergence in all the four cultivars showed that it was maximum (36%) during post monsoon season while minimum (14%) during southwest monsoon season. The spathe emergence was intermediary in summer (26%) and winter (25%). However, varietal variation in spathe emergence was also noticed (Fig. 4.2)

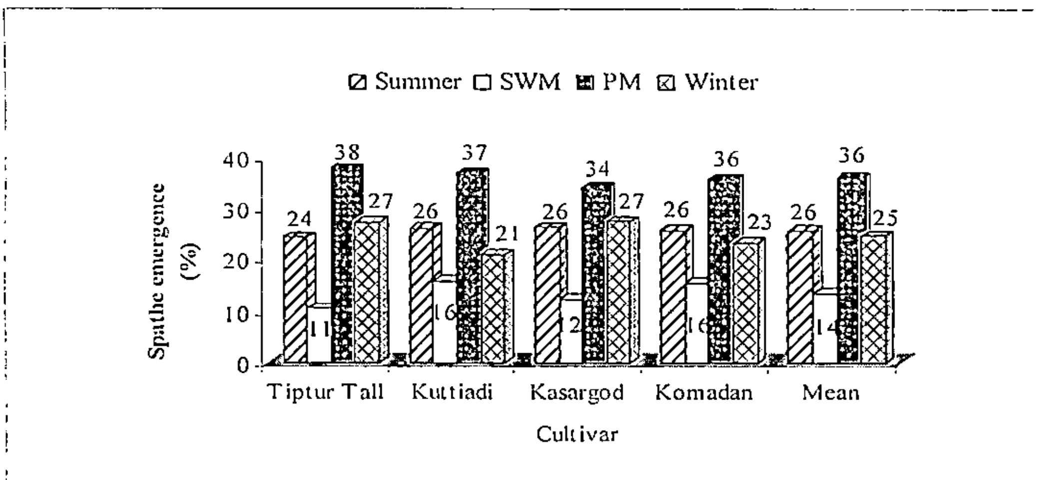

Fig. 4.2 Percentage spathe emergence in coconut during different seasons

4.4 EFFECT OF WEATHER ON SPATHE EMERGENCE

An attempt was made to work out cause-effect-relationship through correlations between the monthly spathe emergence and weather parameters of 29 months lag period (Table 4.6). The salient results are detailed below:

Table 4.6 Correlations between monthly weather variables 29 months prior to spathe emergence and number of spathes produced

Cultivars / Weather variables	Tiptur Tall	Kuttiadi	Kasargod	Komadan
Tmax	-.655**	-0.473	-.610**	-.508*
Tmin	-0.423	-0.174	-0.392	-.553*
Trange	-.633**	-.523*	-.591*	-0.378
V PI	0.059	0.028	-0.094	-0.192
V PII	0.148	0.136	0.068	-0.068
RH I	0.211	0.093	0.075	-0.113
RH II	0.443	0.368	0.329	0.175
VPD	-0.424	-0.307	-0.29	-0.117
WS	0.049	0.068	0.175	0.251
SSH	-.597*	-.532*	-.643**	-0.392
RD	.622**	.540*	.572*	0.349
RF	.580*	.542*	.568*	0.301
EVP	-0.22	-0.148	-0.241	-0.165

4.4.1 Maximum surface air temperature: - The relationship between the maximum temperature and the emergence of spathes was significantly negative in Tiptur Tall, Kasargod and Komadan while no such correlation in the case of Kuttiadi. Similar was the relationship between the mean surface air temperature and spathe emergence.

4.4.2 Minimum surface air temperature: - The correlation coefficient was non-significant between spathe emergence and minimum temperature except in Komadan in which it was significant and negative.

4.4.3 Temperature range: - The relationship between the spathe emergence and temperature range was siginificant and negative in Tiptur Tall, Kuttiadi and Kasargod while non significant in Komadan.

4.4.4 Sunshine hours: - A highly significant negative correlation was observed between sunshine hours and spathe emergence in Kasargod, Tiptur Tall and Kuttiadi while no significant correlation in case of Komadan.

4.4.5 Rainy days and rainfall: - In contrast to the surface air temperature and bright sunshine hours, the relationship was positive between spathe emergence and rainy days in Tiptur Tall, Kuttiadi and Kasargod while no significant correlation in Komadan. Similar was the case with rainfall.

The correlation studies between weather parameters and spathe emergence indicated that rainfall (positive), surface air temperature and sunshine hours (negative) 29 months prior to spathe emergence only influence spathe emergence in coconut.

The maximum emergence of spathe during post monsoon season can be attributed to the fact that rainfall, temperature and bright sunshine hours 29 months before the spathe emergence (Table 4.7) coincide with the receipt of pre monsoon and monsoon rainfall were optimum, which results in better availability of soil moisture. It may favour congenial environment for the primordia initiation and thus maximum spathe emergence during post monsoon season.

The unfavourable weather conditions such as low rainfall, number of rainy days and high temperature coupled with more sunshine hours 29 months prior to the spathe emergence (January- April) would have played a major role in low emergence of spathes during the southwest monsoon season. The amount of rainfall received from January to April was only 73 mm in four rainy days during 2000. It is obvious that the low rainfall was the major factor in low spathe emergence during southwest monsoon of 2002 (Fig. 4.3).

Table 4.7 Weather variables during the primordial initiation stage of the spathe (29 months prior to spathe emergence) at Vellanikkara

Seasons	Temperature (°C)			VP (hPa)		RH (%)		VPD (hPa)	WS (Km/h)	SSH	RD	RF (mm)	EVP (mm)
	Max	Min	Range	Morning	Evening	Mor-ning	Even-ing						
Summer 2002	31.2	22.9	8.3	19.3	19.2	83	60	7.7	4.0	7.3	16	515.3	380.5
SWM	34.0	23.6	10.4	20.3	19.0	84	50	9.5	4.1	8.7	4	72.5	587.7
PM	31.7	23.6	8.1	22.9	21.7	91	72	5.1	3.1	5.8	29	719.2	247
Winter	29.9	22.7	7.2	21.9	21.6	93	73	4.6	3.5	4.6	44	1070.7	301
Summer 2003	31.3	22.6	8.7	18.9	18.6	80	57	8.8	5.4	6.7	17	311.5	382.3

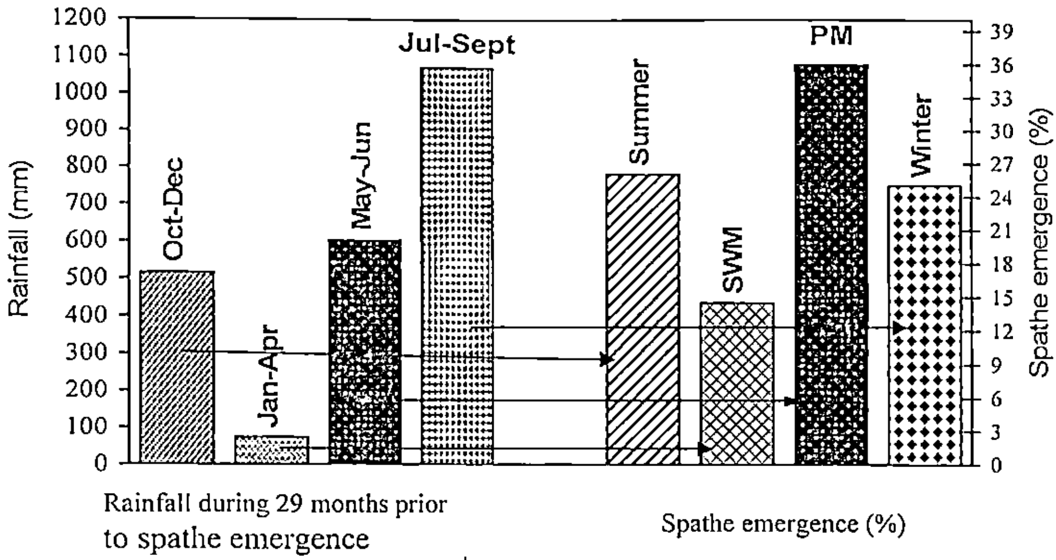

Fig. 4.3 Rainfall during 29 months prior to the spathe emergence and seasonal variation in spathe emergence

The low spathe emergence during winter season coincides with 29 months lag period, corresponding to southwest monsoon period. During the above period, high rainfall beyond a critical value might have affected the spathe emergence adversely as it results in waterlogging and lack of aeration to coconut root zone.

4.5 SEASONAL SPATHE PRESENT ON THE CROWN

Table. 4.8 Seasonal spathe present on the crown in different cultivars of coconut

Cultivar	Summer (Mar-May)	SWM (June-Sep)	PM (Oct-Nov)	Winter (Dec-Feb)	Total
Tiptur tall	2.68	1.52	2.03	3.98	10.21
Kuttiadi	2.34	1.76	2.32	3.22	9.65
Kasargod	2.44	1.31	1.41	3.33	8.50
Komadan	1.95	1.08	1.67	3.01	7.71
Mean	2.35	1.42	1.86	3.39	9.02

The mean annual number of spathes presented on the palm in Tiptur Tall was high (10.21), followed by Kuttiadi (9.65) and Kasargod (8.50) while the least (9.02) in Komadan. It indicated that Tiptur Tall appears to be better among the four test cultivars in terms of number of spathes present on the crown (Table 4.8). On an average, the number of spathes presented on the crown was nine during the year 2002-2003.

The seasonal differences in average number of spathes were found to be significant at one per cent level in all the four cultivars studied. The seasonal influence on the number of spathes present on the crown in different cultivars is described below (Table 4.9).

Table 4.9 Mean monthly spathe present on the crown in different seasons

Seasons	Tiptur Tall	Kuttiadi	Kasargod	Komadan
Summer 2002 (Mar-May)	2.68 [b]	2.33 [b]	2.44 [b]	1.96 [b]
SWM (June-Sep)	1.53 [d]	1.77 [c]	1.31 [c]	1.09 [c]
PM (Oct-Nov)	2.01 [c]	2.31 [b]	1.41 [c]	1.66 [b]
Winter (Dec-Feb)	3.98 [a]	3.20 [a]	3.34 [a]	3.01 [a]
Summer 2003 (Mar-May)	3.16 [b]	2.66 [b]	2.69 [b]	2.49 [a]

4.5.1 Tiptur Tall: - The number of spathes present on the crown was the high (3.98) during winter season and significantly superior, followed by summer 2002 (2.67) and summer 2003 (3.16). They were statistically on par. The number of spathes present on the crown was low (1.53) during southwest monsoon season.

4.5.2 Kuttiadi: - The number of spathes present was maximum (3.20) in winter and significantly superior, followed by summer 2003 (2.32), post monsoon (2.66) and summer 2002 (2.31). The number of spathes present on the palm was on par in summer (2.33 and 2.66) and post monsoon season (2.33). The number of spathes noticed in southwest monsoon season was low (1.76).

4.5.3 Kasargod: - The number of spathes on the crown was maximum (3.34) in winter, followed by summer 2002 (2.44) and summer 2003 (2.69) while minimum (1.41) during post monsoon and southwest monsoon (1.31). The number of spathes present on the crown during the above seasons was statistically on par.

4.5.4 Komadan: - Winter recorded the maximum (3.01) number of spathes as in the case of above three test cultivars, followed by summer 2003 (2.49). The number of spathes present on the crown in both the seasons was statistically on par. It was intermediary during summer 2002 (1.96) and post monsoon (1.66). The number of spathes presented on the crown during southwest monsoon season was found to be the lowest (1.09).

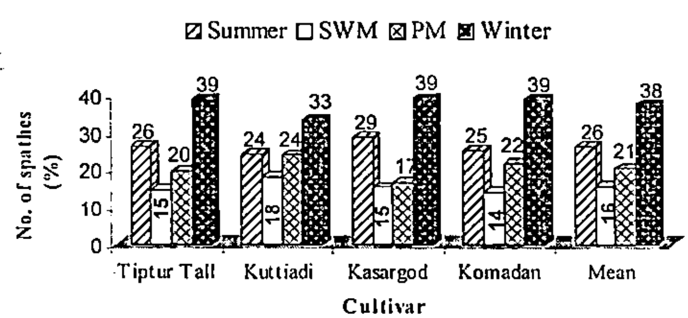

Fig. 4.4 Varietal and seasonal variation in spathes present on the crown

The number of spathes present on the crown was maximum (38 %) in winter, followed by summer (26%) while low (16 %) in southwest monsoon. It was intermediary (21%) during post monsoon season (Fig. 4.4).

The study revealed that the number of spathes present on the crown and spathe emergence followed the same trend seasonally except their peak appearance during winter and post monsoon, respectively.

The number of spathes present on the crown in coconut was maximum in winter due to cumulative effect of high spathe emergence in post monsoon season, followed by winter. As the spathe duration takes about three months, the emergence of spathes during post monsoon season completes its phase only during winter.

The low spathe emergence in the same and previous season (summer) resulted in poor number of spathes during southwest monsoon.

4.6 SPATHE DURATION IN DIFFERENT CULTIVARS OF COCONUT

The number of weeks taken from initiation of spathe at leaf axil to spadix emergence was high (11.34) in WCT (Kasargod), followed by Kuttiadi (11.26) and Tiptur Tall (10.59) while the least (9.64) in Kasargod. On an average, the mean annual spathe duration was eleven weeks (Table 4.10).

Table 4.10 Seasonal variation in spathe duration in coconut

Seasons	Tiptur Tall	Kuttiadi	Kasargod	Komadan	Mean
Summer 2002 (Mar-May)	10.68 [a]	11.25 [b]	11.40 [ab]	8.69 [bc]	10.53
SWM (June-Sep)	9.29 [b]	9.890 [c]	10.21 [c]	8.06 [c]	9.38
PM (Oct-Nov)	10.82 [a]	11.85 [ab]	11.60 [ab]	10.80 [a]	11.30
Winter (Dec-Feb)	11.52 [a]	11.92 [a]	12.04 [a]	11.01 [a]	11.61
Mean	10.59	11.26	11.34	9.64	10.70
Summer 2003 (Mar-May)	11.46 [a]	10.51 [c]	10.87 [bc]	9.22 [b]	10.52

The seasonal variations in spathe duration were significant at one per cent level in all the four cultivars (Table 4.10)

4.6.1 Tiptur Tall: - Among all the seasons, spathe duration was maximum in winter (11.52), followed by summer 2003 (11.46), post monsoon (10.82) and summer 2002 (10.68). It was statistically on par in all the above seasons. The spathe duration was found to be minimum (9.29) in southwest monsoon season.

4.6.2 Kuttiadi: - The duration of spathe was maximum (11.92) during winter, followed by post monsoon (11.85), which was also on par with summer 2002 (11.25). The minimum (9.89) spathe duration was seen in southwest monsoon season, which was on par with summer 2003.

4.6.3 Kasrgod: - The spathe duration was maximum (12.04) during winter, followed by post monsoon (11.60) and summer 2002 (11.40) and the least (10.21) in southwest monsoon like in case of Kuttiadi. The spathe duration in summer 2003 (10.51) was on par with post monsoon and summer 2002.

4.6.4 Komadan: - The spathe duration in Komadan took more number of weeks (11.01) during winter and post monsoon (10.80), which were on par followed by summer (9.22 and 8.69). The least (8.06) spathe duration was found in southwest monsoon season.

The duration of spathe in all the cultivars was minimum (9.38) if it is emerged in southwest monsoon while maximum (11.61) in winter, followed by post monsoon (11.30). The spathe duration during summer took more than ten weeks on an average, which was intermediary.

4.7 EFFECT OF WEATHER ON SPATHE DURATION

The relationship between the influence of different weather variables and spathe duration was worked out (Table 4.11) and described below:

Table 4.11 Correlations between spathe duration and weather variables

Cultivars / Weather variables	Tiptur Tall	Kuttiadi	Kasargod	Komadan
T max	.331*	-0.177	0.151	0.118
T min	-.302*	-.678**	-.469**	-.442**
T range	.565**	0.123	.432**	.345*
VPI	-.643**	-.691**	-.681**	-.433**
VPII	-.585**	-.529**	-.670**	-.603**
RHI	-.631**	-.451**	-.599**	-.635**
RHII	-.628**	-0.254	-.511**	-.476**
SSH	.625**	0.237	.443**	.498**
WS	.544**	.606**	.661**	.627**
VPD	.607**	0.207	.485**	.487**
RF	-.441**	-0.129	-0.215	-.364**
RD	-.439**	-0.084	-0.224	-.289*
EVP	.780**	.599**	.763**	.814**
GDD	.851**	.803**	.859**	.928**
HTU	.681**	.426**	.638**	.702**

4.7.1 Maximum temperature: - Correlation between maximum temperature and spathe duration were non significant in all cultivars except Tiptur Tall.

4.7.2 Minimum temperature: - In contrast to maximum temperature, a highly significant (1% level) and negative correlation was observed between the minimum temperature and spathe duration in all the cultivars except in Tiptur Tall.

4.7.3 Temperature range: - A highly significant positive correlation between the temperature range and duration of spathe was obtained in Tiptur Tall and Kasargod. In Komadan, correlation was significant at five per cent level. In Kuttiadi, no significant correlation was noticed.

4.7.4 Morning vapour pressure: - The study indicated a highly significant negative correlation between the duration of spathe and morning vapour pressure in all the cultivars observed.

4.7.5 Evening vapour pressure: - There was a highly significant and negative correlation between the spathe duration and evening vapour pressure.

4.7.6 Morning relative humidity: - A highly significant and negative correlation was noticed between the morning relative humidity and duration of spathe studied in all the cultivars.

4.7.7 Evening relative humidity: - It showed a highly significant and negative correlation between the evening relative humidity and spathe duration in all the cultivars except Kuttiadi.

4.7.8 Sunshine hours: - It showed that a highly significant and positive correlation between the sunshine hours and duration of the spathe except in Kuttiadi.

4.7.9 Wind speed: - The study indicated a highly significant and positive correlation between the wind speed and duration of the spathe in all the cultivars studied.

4.7.10 Vapour pressure deficit: - A highly significant and positive correlation was observed between spathe duration and vapour pressure deficit in all the cultivars studied except in Kuttiadi in which correlation was not significant.

4.7.11 Rainfall: - There was significant negative correlation between the spathe duration and rainfall in Tiptur Tall and Komadan. But the correlation was not significant in Kuttiadi and Kasargod.

4.7.12 Rainy days: - Highly significant negative correlation was noted in Tiptur Tall and Komadan it was significant at five percent level. In Kuttiadi and Kasargod, no significant correlation was obtained.

4.7.13 Evaporation: -A highly significant positive correlation was obtained between the spathe duration and evaporation in all the cultivars under study.

4.7.14 Growing Degree Days: -The study indicated highly significant positive correlation between the duration of spathe and GDD in all the cultivars

4.7.15 Helio Thermal Unit: - It indicted highly significant positive correlation between HTU and duration of spathe in all the cultivars.

From the correlation studies, it is understood that spathe duration is dependent on weather variables either positively or negatively. This could be explained due to multicolinearity effect among the weather variables. For example, a positive correlation with VPD will be similar to that of evaporation since the evaporation is more when the VPD is more. Similarly in case of rainfall and number of rainy days too. Keeping the above in view, the relationship between temperature and duration of spathe was worked out based on the growing degree days, which is dependent on air temperature.

4.8 GROWING DEGREE DAY VERSUS SPATHE DURATION

Growing degree day versus spathe duration indicated that there is a close linear relationship between them in all the cultivars. The spathe duration was high if GDD was also high and vice versa. It revealed that coconut spathe took more number of days to open as the GDD was more. In contrast, it took less number of days to open as the GDD was less and hence it took less number of days to open in southwest monsoon while more in winter (Fig. 4.5).

The result indicated that there exists a negative correlation in the case of minimum temperature, vapour pressure and relative humidity. In contrast, correlation was positive in the case of sunshine hours, wind speed and evaporation.

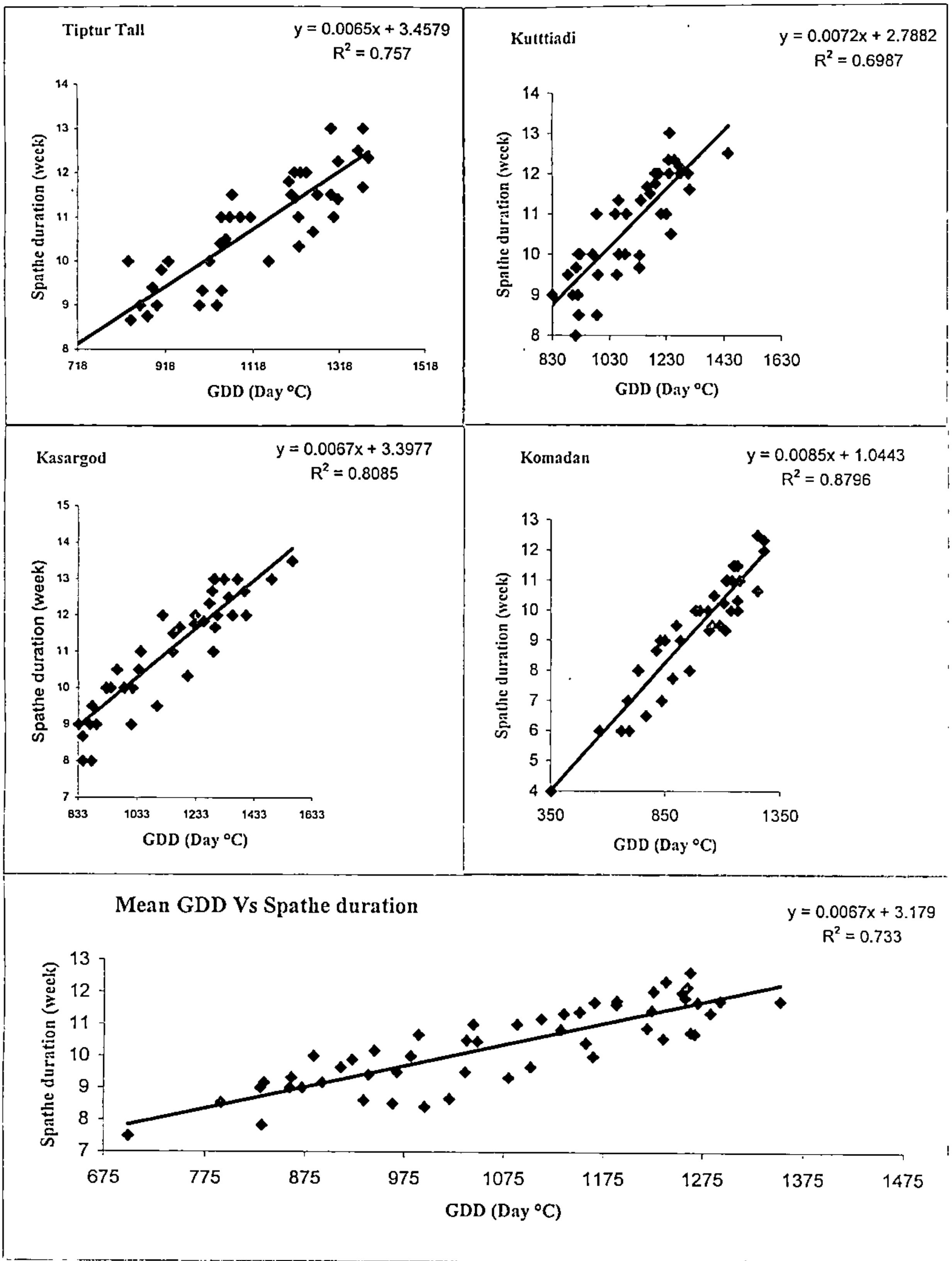

Fig 4.5 Growing Degree Day versus spathe duration

The reasons for the maximum spathe duration during winter season can be attributed to low minimum temperature, relative humidity and low vapour pressure and high temperature range, wind speed, vapour pressure deficit, evaporation and sunshine hours prevailed during winter season when compared to other seasons (Table 4.12).

The lowest spathe duration during southwest monsoon season can be attributed to the high minimum temperature, low temperature range, high vapour pressure, low vapour pressure deficit, high relative humidity, low wind speed, low sunshine hours and low evaporation. In addition to low temperature range, rainfall during southwest monsoon after a prolonged dry spell may stimulate for early break of spathe. These relationships hold good for the other seasons also.

4.9 VARIETAL AND SEASONAL VARIATIONS IN SPADIX EMERGENCE IN COCONUT

The annual number of spadices emerged in Tiptur Tall was high (11.8), followed by Kuttiadi (11.0) and Komdan (10.0) while the least (9.7) was in Kasargod. It indicated that Tiptur Tall appears to be better among the four test cultivars in terms of spadix emergence (Table 4.13). On an average, the number of spadices emerged annually was eleven.

Table 4.13 Varietal and seasonal variation in spadix emergence in 2002-2003

Cultivar	Summer (Mar-May)	SWM (June-Sep)	PM (Oct-Nov)	Winter (Dec-Feb)	Total
Tiptur tall	4.40	3.50	0.50	3.40	11.80
Kuttiadi	3.40	3.60	0.60	3.40	11.00
Kasargod	3.60	3.00	0.40	2.70	9.70
Komadan	4.00	2.60	0.50	2.90	10.00
Mean	3.85	3.18	0.50	3.10	10.63

Table 4.12 Weather variables from summer 2002 to summer 2003 at Vellanikkara

Seasons	Temperature (°C)			VP (hPa)		RH (%)		VPD (hPa)	WS (Km/h)	SSH	RD	RF (mm)	EVP (mm)
	Max	Min	Range	Morning	Evening	Mor-ning	Even-ing						
Summer 2002	34.6	24.5	10.1	22.7	20.7	86	54	9.3	4.4	7.2	18.	375.5	466.2
SWM	29.9	23.1	6.9	22.4	22.0	93	73	4.5	3.8	4.3	70	1518.3	406
PM	31.3	23.3	8.0	21.2	21.4	87	67	6.5	4.0	5.4	22	409.8	221.1
Winter	33.4	22.9	10.5	17.0	15.3	73	41	12.2	7.3	9.0	5	162.1	588.2
Summer 2003	34.4	24.9	9.5	22.9	21.1	87	54	9.4	3.6	7.4	10	158.1	471.3

The seasonal influence on spadix emergence or spathe opened was significant at one per cent level in all the four cultivars (Table 4.14)

Table 4.14 Mean monthly spadix emergence in coconut

Seasons	Tiptur Tall	Kuttiadi	Kasargod	Komadan
Summer 2002 (Mar-May)	1.47 [a]	1.12 [ab]	1.19 [a]	1.32 [a]
SWM (June-Sep)	0.88 [b]	0.91 [b]	0.77 [b]	0.68 [c]
PM (Oct-Nov)	0.25 [c]	0.30 [c]	0.20 [c]	0.25 [d]
Winter (Dec-Feb)	1.12 [b]	1.12 [ab]	0.90 [b]	0.96 [b]
Summer 2003 (Mar-May)	1.65 [a]	1.25 [a]	1.35 [a]	1.50 [a]

4.9.1 Tiptur Tall: - The mean number of spadices emerged was maximum (1.654) during summer 2003 and summer 2002 (1.47), followed by winter (1.12) and southwest monsoon (0.88) while minimum (0.25) during post monsoon season.

4.9.2 Kuttiadi: - In case of Kuttiadi, the spadix emergence was maximum (1.25 and 1.12) during summer as well as in winter (0.94), followed by southwest monsoon (0.91) while minimum (0.30) during post monsoon.

4.9.3 Kasargod: - The mean number of spadices emerged was maximum during summer 2003 (1.35) and summer 2002 (1.50), followed by winter (0.96) and southwest monsoon (0.68) while minimum (0.25) during post monsoon season.

4.9.4 Komadan: - The mean number of spadies emerged was maximum (1.5) in summer 2003 and summer 2002 (1.320), followed by winter (0.960) and southwest monsoon season (0.68). The minimum (0.25) spadix emergence was noticed during post monsoon season.

As a whole, the spadix emergence is maximum (38%) during summer in all the cultivars unlike in case of spathe emergence (Fig. 4.6). The minimum spadix emergence was invariably low (7%) during post monsoon season. The spadix emergence was intermediary during winter (31%) and southwest monsoon season (24%).

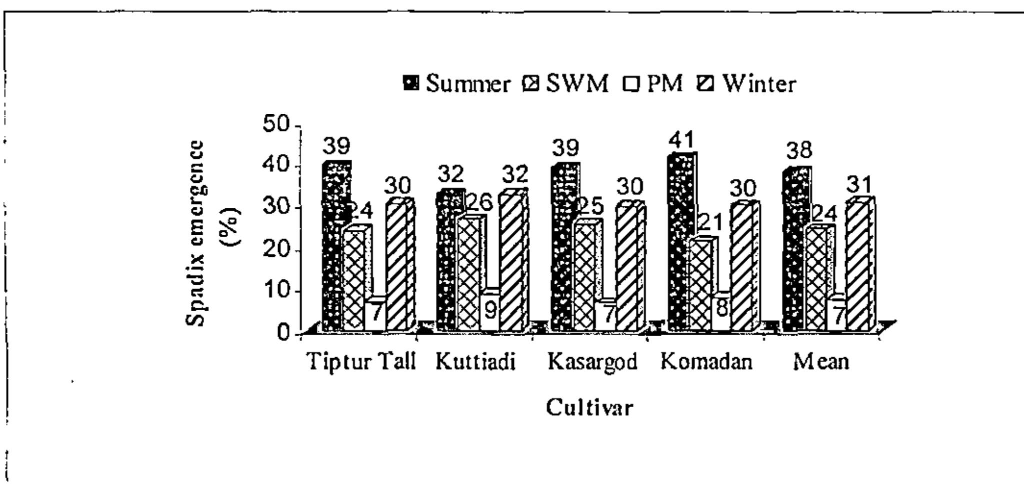

Fig. 4.6 Varietal and seasonal variations in spadix emergence

The results of the study were in agreement with Marar and Pandalai (1957). They observed that spadix emergence was maximum during summer March-May and minimum during (October-November) post monsoon, followed by (December-January) winter. Same results were obtained by Menon and

Pandalai (1958). The above results were in conformity with Bhaskaran and Leela (1983), Sreelatha and Kumaran (1991) and Vanaja and Amma (2002).

The reasons for maximum spadix emergence during summer season can be attributed to the maximum number of spathes present on the crown during winter in which the duration from spathe to spadix was also more. When coconut spathes were exposed to range of higher atmospheric temperature (32-36°C) it may caused for early opening of spathe which is nothing but spadix emergence. The number of spathes present on the crown was less during the southwest monsoon, and hence the opening of spathe during the ensuing post monsoon was less. The same explanation holds good in case of other seasons too.

4.10 SEASONAL FEMALE FLOWER PRODUCTION IN COCONUT

The annual female flowers production per bunch was high (28.3) in Tiptur Tall, followed by Komdan (23.9) and Kasargod (22.5) while the least (20.9) in Kuttiadi. It indicated that Tiptur Tall appears to be better among the four test cultivars in terms of female flower produced (Table 4.15). On an average, per bunch female flowers produced annually were 24.

Table 4.15 Female flower production per bunch in coconut cultivars during 2002-2003

Cultivar	Summer (Mar-May)	SWM (June-Sep)	PM (Oct-Nov)	Winter (Dec-Feb)	Mean
Tiptur tall	42.1	24.4	12	34.7	28.3
Kuttiadi	32.0	15.8	5.5	30.1	20.9
Kasargod	38.2	18.1	7.7	26	22.5
Komadan	38	18.4	5.6	33.7	23.9
Mean	37.6	19.2	7.7	31.1	23.9

Table 4.16 Mean monthly female flower production in different seasons.

cultivar	Summer 2002 (Mar-May)	SWM (June-Sep)	PM (Oct-Nov)	Winter (Dec-Feb)	Summer 2003 (Mar-May)
Tiptur Tall	60.1	20.9	8	41.7	90.2
Kuttiadi	38.8	13.9	3.4	34.6	52.1
Kasargod	43.8	14.5	7.5	28	58.3
Komadan	53.1	12.2	4.67	37.7	89.8

4.10.1 Tiptur Tall: - The number of female flowers produced was maximum (90.2) in summer 2003, followed by summer 2002 (60.1). There was a gradual decline in the number of female flower production during the southwest monsoon (20.9), reaching to minimum (8) during post monsoon, thereafter a gradual increase (41.7) was noticed during the winter.

4.10.2 Kuttiadi: - The female flower production was maximum in (38.8) in summer 2002 while minimum (3.4) in post monsoon. A sharp increase (34.6) was seen in winter reaching to a peak (52.1) during summer 2003.

4.10.3 Kasargod: - The seasonal variation in number of female flowers showed a declining trend from summer 2002 (43.8) to post monsoon (7.5). An increasing trend was noticed thereafter in winter (28), followed by summer 2003 (58.3).

4.10.4 Komadan: - The maximum female flower production (89.8) was recorded during summer 2003, followed by summer 2002 (53.1). A decreasing trend was noticed during southwest monsoon (12.2) and post monsoon season (4.65). The number of female flowers during winter was intermediary (37.7).

The various stages of spathe emergence to female flower development in coconut (Komadan) are shown in Plate 4.1

a) At spathe emergence

b) One week after spathe emergence

c) One month after spathe emergence

d) Two months after spathe emergence

e) At spadix emergence

f) One week after spadix emergence

g) One month after spadix emergence

h) Two months after spadix emergence

i) Three months after spadix emergence

Plate 4.1. Spathe emergence to female flower development in coconut (Komadan)

The number of female flowers produced was high (46%) during summer and less (6%) in post monsoon season (Fig. 4.7). A gradual decline in female flower production was noticed from summer to post monsoon season and thereafter an increase was noticed during winter in all the cultivars. It revealed that the trend in female flower production was uniform in all the season despite the varietal difference.

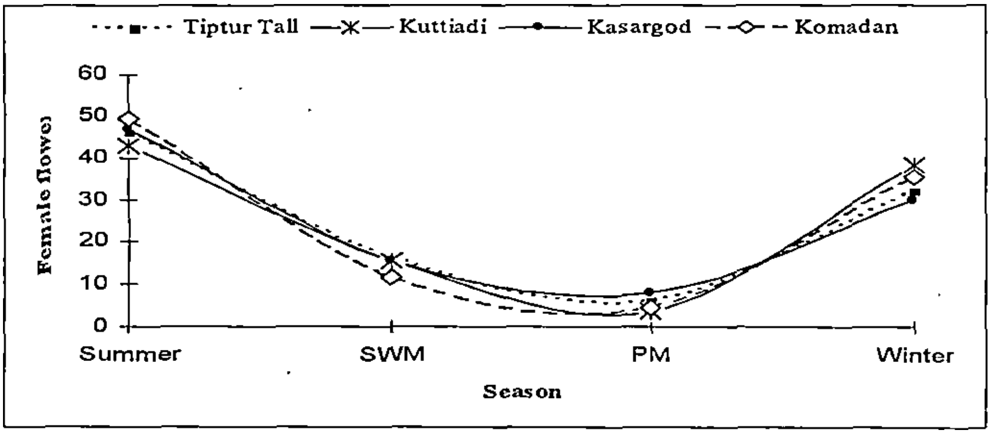

Fig. 4.7 Seasonal percentage female flower production in different cultivars of coconut

The results obtained were in agreement with that of Marar and Pandalai (1957), Rao (1988) and Vanaja and Amma (2002).

To study the association between the weather variables and number of female flowers produced, correlations were worked out in two critical stages (Fig. 4.8) viz., primordia initiation and ovary development as these biotic phases are vital for final female flower production. These above phases coincide with 32 months and 6-7 months, respectively prior to the spadix emergence.

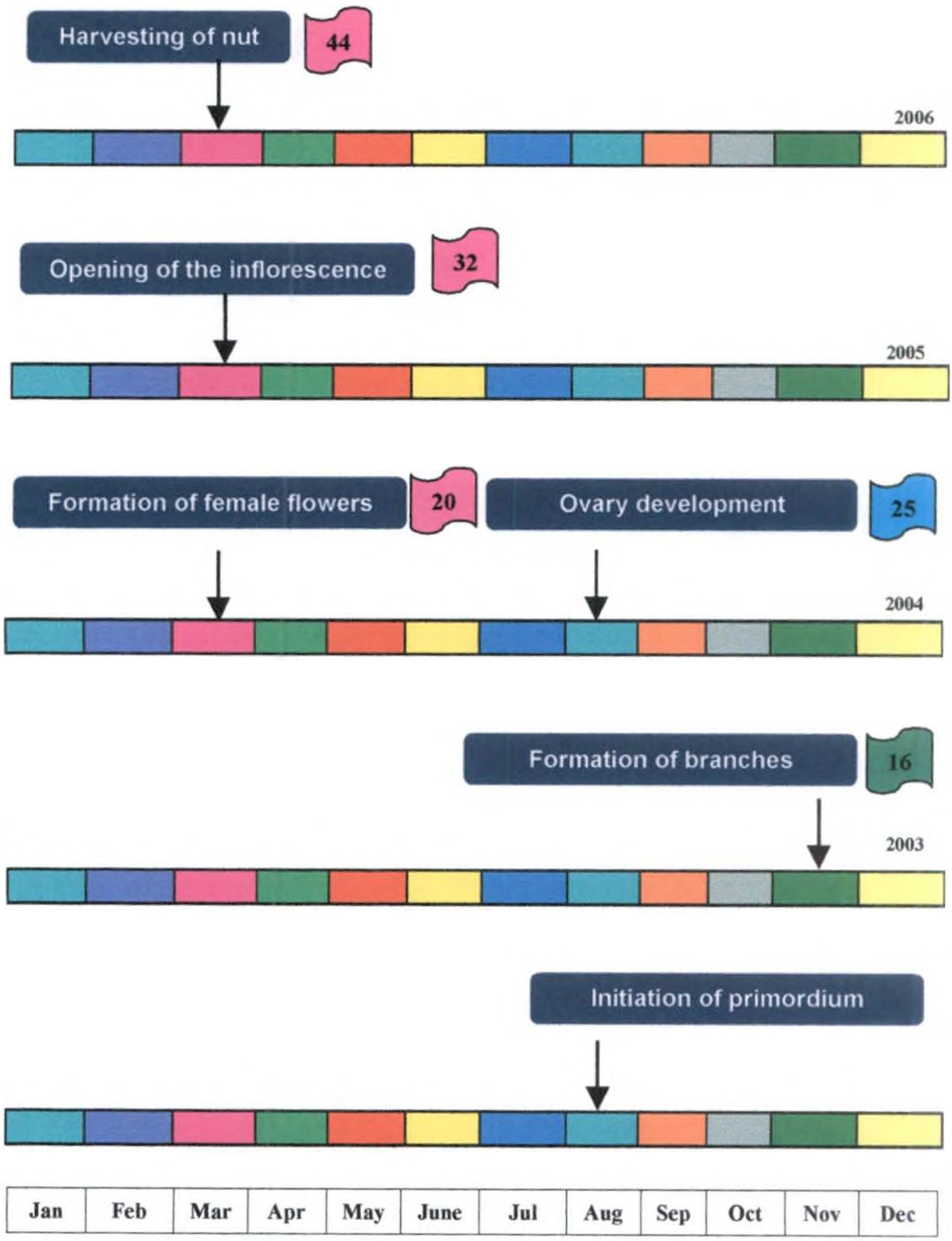

Fig. 4.8 Schematic representation of different phenological stages from primordium initiation to final harvest of coconut

4.10 INFLUENCE OF WEATHER ON CRITICAL STAGES

4.11.1 Weather during primordia initiation (32 months prior to the spadix emergence)

Correlations were worked out between monthly female flower production and different weather variables at 32 months prior to spadix emergence (Table 4.17) and results are discussed below:

Table 4.17 Correlations between female flower production and weather variables during the primordia initiation stage (32 months prior to the spadix emergence).

Weather variables / Cultivars	Tiptur Tall	Kuttiadi	Kasargod	Komadan
Tmax	-.669**	-.770**	-.829**	-.632**
Tmin	-0.36	-0.344	-0.411	-0.253
Trange	-.665**	-.792**	-.837**	-.661**
VP I	0.368	0.429	0.384	.485*
VP II	0.458	.594*	.571*	.582*
VPD	-.659**	-.787**	-.807**	-.694**
WS	-0.168	-0.288	-0.252	-0.269
SSH	-.662**	-.790**	-.814**	-.723**
RD	.592*	.863**	.822**	.684**
RF	.518*	.771**	.743**	.617**

** Significant at 1 % level *Significant at 5 % level

4.11.1.1 Maximum temperature: - A highly significant negative correlation was obtained between maximum temperature and female flower production.

4.11.1.2 Minimum temperature: -No significant correlation was obtained in any of the cultivars.

4.11.1.3 Temperature range: - A highly significant negative correlation was obtained between temperature range and female flower production.

4.11.1.4 Morning vapour pressure: - In Tiptur Tall, Kuttiadi and Kasargod cultivarscorrelations between the morning vapour pressure and female flower production were not significant .While in Komadan, it was significant and positive.

4.11.1.5 Evening vapour pressure: - Significant positive correlations were obtained in all the cultivars except Tiptur Tall.

4.11.1.6 Vapour pressure deficit: - A highly significant negative correlation was obtained between female flower production and vapour pressure deficit in all cultivars studied.

4.11.1.7 Wind speed: - No significant correlations were obtained between the female flower production and wind speed in any of the cultivars studied.

4.11.1.8 Sunshine hours: - It was highly significant negative correlation between sunshine hours and female flowers produced.

4.11.1.8 Rainy days: - Highly significant positive correlations were obtained between number of rainy days and female flowers produced in all the cultivars except Tiptur Tall. In Tiptur Tall correlation was significant only at five percent level.

4.1.1.9 Rainfall: - Highly significant positive correlations were obtained between rainfall and female flowers produced in all the cultivars except Tiptur Tall. In Tiptur Tall correlation was significant only at five percent level.

4.11.2 Weather during ovary development stage (6-7 months prior to spadix emergence)

Correlations were worked out between female flower production and different weather variables at 6-7 months before the opening of the inflorescence i.e. at the ovary development stage. (Table 4.18) and results are discussed below:

Table 4.18 Correlation between monthly female flower production and weather variables during the ovary development stage (6-7 months prior to spadix emergence)

Weather variables \ Cultivars	Tiptur Tall	Kuttiadi	Kasargod	Komadan
Tmax	-.753**	-.864**	-.815**	-.757**
Tmin	-0.405	-0.417	-0.457	-0.217
T range	-.730**	-.855**	-.784**	-.803**
VP I	0.295	0.346	0.287	0.412
VP II	0.475	.557*	.488*	.592*
VPD	-.704**	-.762**	-.699**	-.710**
WS	-0.469	-.506*	-.503*	-.527*
SSH	-.630**	-.799**	-.694**	-.676**
RD	.654**	.800**	.721**	.742**
RF	.631**	.733**	.633**	.679**

** Significant at 1 % level *Significant at 5 % level

4.11.2.1 Maximum temperature: - Highly significant and negative correlation was obtained between maximum temperature and female flower production.

4.11.2.2 Minimum temperature: -No significant correlation was obtained in any of the cultivars.

4.11.2.3 Temperature range: - The study revealed that a highly significant negative correlation existed between the range of temperature and number of female flowers produced in all the cultivars observed.

4.11.2.4 Morning vapour pressure: - No significant correlation was obtained between morning vapour pressure and female flower produced.

4.11.2.5 Evening vapour pressure: - Significant correlation was obtained between evening vapour pressure and female flowers produced in all the cultivars except Tiptur Tall.

4.11.2.6 Vapour pressure deficit: - Highly significant negative correlations were obtained between the number of female flowers produced and vapour pressure deficit in all the test cultivars.

4.11.2.6 Wind speed: -A significant negative correlation was observed between female flowers and wind speed in the case of Kuttiadi, Kasargod and Komadan. In Tiptur Tall, no significant correlation was observed.

4.11.2.7 Sunshine hours: - Highly significant negative correlation was observed between sunshine hours and female flowers in all the test cultivars.

4.11.2.8 Rainy days: - The study showed a highly significant positive correlation between rainy days and number of female flowers produced.

4.11.2.9 Rainfall: - There existed a highly significant positive correlation between rainfall and number of female flowers produced.

4.12 REGRESSION MODEL FOR ESTIMATING OF FEMALE FLOWER PRODUCTION USING THE WEATHER VARIABLES AT CRITICAL STAGES

Linear regression equations were evolved for estimating the female flower production using the step-wise regression procedure. The equations were developed based on the mean weather variables and mean monthly female flower production during the two critical stages viz., primordium initiation (32 months before the opening of the inflorescence) and at the ovary development stage (6-7 months before the opening of the inflorescence). The regression equations obtained based on the analysis are presented in Table 4.19 The maximum temperature and temperature range during ovary development could explain the variability in female flowers production between 57 and 65% in Tiptur Tall and Komadan respectively while in the case of Kuttiadi and Kasargod, the production in number of female flower could be explained up to 99 per cent due to weather that prevailed during the primordium initiation and ovary development.

Table 4.19 Regression model for female flower production using the weather variables at critical stages

Cultivar	Regression equation	Weather variables selected	R^2
Tiptur Tall	$Y= 375.75-10.42\ x_1$	x_1 is the maximum temperature during ovary development stage	0.57
Kuttiadi	$Y= 361.10-4.25\ x_1+3.37x_2-7.56x10^{-2}\ x_3-1.43x_4-4.7979x_5+0.55x_6-5.88_{x7}+2.02x10^{-2}\ x_8$	x1, x6 and x8 are maximum temperature, morning relative humidity and rainfall during ovary development stage and x2, x3, x4, x5 and x7 are the rainy days, rainfall, evening relative humidity, sunshine hours and minimum temperature respectively during the primordia initiation stage.	0.995
Kasargod	$Y= 291.945-5.53\ x_1+1.3\ x_2-9.73\ x_3$	x_1 and x_3 are the temperature range and minimum temperature respectively during the primodia initiation stage and x_2 is the number of rainy days during the ovary development stage.	0.902
Komadan	$Y= 158.936-13.772\ x_1$	x_1 is the temperature range during the ovary development stage	0.645

Where, Y is the estimated number of female flower and x_1- x_8 are the weather variables selected by the model.

The reasons for variation in female flower production during different seasons of the year were examined based on the significant correlation values coinciding with the two critical phases such as primordia initiation and ovary development.

High female flower production during summer season was attributed to the favourable weather prevailed during primordia initiation (32 months before the opening of the inflorescence) Table 4.20 and ovary development (6-7 months before the opening of the inflorescence) Table 4.21. It showed a strong negative correlation with maximum temperature, temperature range, vapour pressure deficit, sunshine hours and solar radiation while it was positively correlated with vapour pressure, relative humidity, rainfall and rainy days. The maximum temperature and range in temperature at the time of primordia imitation and ovary development were found to be lower than that of the other seasons resulting in high female flower during summer. Relative humidity, vapour pressure, rainfall and rainy days during the lag period were higher than rest of the seasons under the study period. This also would have favoured the female flower production.

The reasons for low female flower production during post monsoon season were also examined. It showed a strong positive correlation with relative humidity, vapour pressure, rainfall and rainy days while it was negatively correlated with maximum temperature, temperature range, vapour pressure deficit, sunshine hours. Higher maximum temperature, mean temperature and temperature range, sun shine hours and high vapour pressure deficit and lower vapour pressure, relative humidity, rainfall and rainy days would have played a role in determining female flower production.

The reasons for high female flower production during summer 2003 were also discussed. The weather parameters such as morning vapour pressure, mean vapour pressure, high rainfall and more number of rainy days were noticed during summer 2003. This might have favoured ovary development during summer 2003 compared to summer 2002.

Table 4.20 Weather variables during the primordia initiation stage of female flower (32 months prior to spadix emergence) at Vellanikkara

Seasons	Temperature (°C)			VP (hPa)		RH (%)		VPD (hPa)	WS (Km/h)	SSH	RD	RF (mm)	EVP (mm)
	Max	Min	Range	Morning	Evening	Mor-ning	Even-ing						
Summer 2002	29.8	23.3	6.6	21.9	21.6	94	73	4.5	2.3	5.0	43	1111.8	281.9
SWM	31.6	23.0	8.6	18.8	18.3	81	55	8.6	4.7	7.7	16	515.3	583.9
PM	34.5	23.3	11.2	20.4	19.1	86	50	9.3	3.5	9.1	1	4.6	255.9
Winter	32.5	23.9	8.5	23.0	21.9	90	68	6.1	3.0	6.3	32	787.1	375.4
Summer 2003	29.9	22.7	7.2	21.9	21.6	93	73	4.6	3.5	4.6	44	1070.7	301.0

Table 4.21 Weather variables during the ovary development stage of the female flower (6-7 months prior to spadix emergence) at Vellanikkara

Seasons	Temperature (°C)			VP (hPa)		RH (%)		VPD (hPa)	WS (Km/h)	SSH	RD	RF (mm)	EVP (mm)
	Max	Min	Range	Morning	Evening	Mor-ning	Even-ing						
Summer 2002	30.3	23.1	7.2	22.0	22.0	92	71	3.7	3.3	4.6	35	677.7	320.6
SWM	32.5	22.7	9.7	18.1	16.7	76	48	10.7	7.7	7.8	6	116.2	671.5
PM	35.6	24.4	11.2	22.4	19.7	85	48	10.6	4.5	8.0	6	67.1	341.7
Winter	30.8	23.6	7.1	23.0	22.7	92	73	4.9	4.0	4.0	55	1196.1	311.6
Summer 2003	30.3	23.1	7.2	22.0	21.7	93	71	4.9	3.6	5.1	46	1018.3	315.1

4.13 SEASONAL VARIATION IN BUTTON SHEDDING

The average annual button shedding was high (58%) in Komadan, followed by Tiptur Tall (55%), Kuttiadi (55%) while the least (53%) in Kasargod (Table 4.22). It indicated that Komadan was more prone to button shedding when compared to other test cultivars. On an average, the mean annual percentage of button shedding was 55 (Table 4.22).

Table 4.22 Seasonal variation in button shedding in different cultivars of coconut

Cultivar	Summer (Mar-May)	SWM (June-Sep)	PM (Oct-Nov)	Winter (Dec-Feb)	Mean
Tiptur Tall	62 (77)	52	37	69	55
Kuttiadi	55 (73)	53	46	65	55
Kasargod	59 (71)	50	43	58	53
Komadan	69 (72)	53	39	72	58
Mean	61 (73)	52	41	66	55

( ) Figures in parenthesis indicate the percentage button shedding in summer 2003

4.13.1 Tiptur Tall: -The percentage button shedding was maximum (77) during summer 2003, followed by winter (69) and summer 2002 (62). The minimum (37) button shedding was observed during post monsoon, followed by southwest monsoon (52).

4.13.2 Kuttiadi: - The study indicated that percentage button shedding was high during summer 2003 (73), followed by winter (65) and summer 2002 (55). The button shedding was lowest (46) during post monsoon, followed by southwest monsoon (53).

4.13.3 Kasargod: - The maximum (71) button shedding was noticed during summer 2003, followed by summer 2002 (59) and winter (58). The minimum (45) button shedding was observed during post monsoon, followed by southwest monsoon (50).

4.13.4 Komadan: - The button shedding was maximum (72) in summer 2003, winter (72) and summer 2002 (69). The minimum was during post monsoon (39) and southwest monsoon (53).

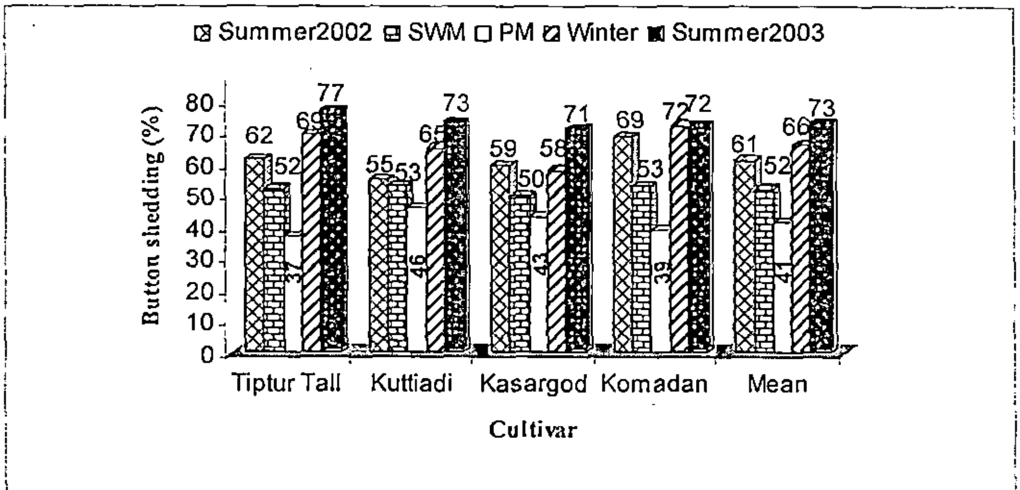

Fig. 4.9 Seasonal variations in button shedding of coconut

The seasonal effect on button shedding was found to be maximum (73%) during summer 2003, followed by winter (66%) and summer 2002 (61%) in all the cultivars studied (Fig. 4.9). The shedding was found to be minimum (41%) in post monsoon season, followed by southwest monsoon season (52%).

The results obtained were not in agreement with those obtained by Marar and Pandalai (1957), Davis (1982) and Rao (1988). The above studies revealed that the button shedding was high in rainy season while not so in the present investigation. It revealed that button shedding might vary from one agroclimatic zone to another as prevailing weather is different. However, the result can be confirmed only after five years, which is now progress.

4.14 BUTTON SHEDDING VERSUS FEMALE FLOWER PRODUCTION

It is understood that the button shedding was more when female flower production was high. Similar trend was very much evident in the present investigation. The seasonal variations were also noticed in button shedding though it follows the number of female flower production (Fig. 4.10).

Hence, the relationship between the button shedding and weather parameters prevailed during the study period was worked out (Table 4.23) and the results are presented below:

Table 4.23 Correlation between button shedding and weather variables

Weather variables \ Cultivars	Tiptur Tall	Kuttiadi	Kasargod	Komadan
Tmax	.580**	.598**	.324*	.477**
Tmin	.718**	.485**	.335*	.433**
Trange	.391**	.527**	0.251	.385**
RH I	-0.045	-.371**	-0.157	-0.182
RH II	-.292*	-.493**	-0.21	-.327*
VPD	.315*	.515**	0.243	.339*
RF	-0.263	-.442**	-0.221	-0.136
RD	-.310*	-.468**	-0.236	-0.198
Radiation	.302*	.467**	0.182	0.239
GDD	.665**	.610**	.350*	.500**
HTU	.422**	.539**	0.238	.360*

** Significant at 1 % level *Significant at 5 % level

4.14.1 Maximum temperature: - A highly significant and positive correlation with button shedding was observed in Tiptur Tall, Kuttiadi and Komadan while significant at five per cent level in the case of Kasargod.

4.14.2 Minimum temperature: - It showed a highly significant and positive correlation between button shedding and minimum temperature in all the cultivars except in Kasargod in which it was significant at five per cent level.

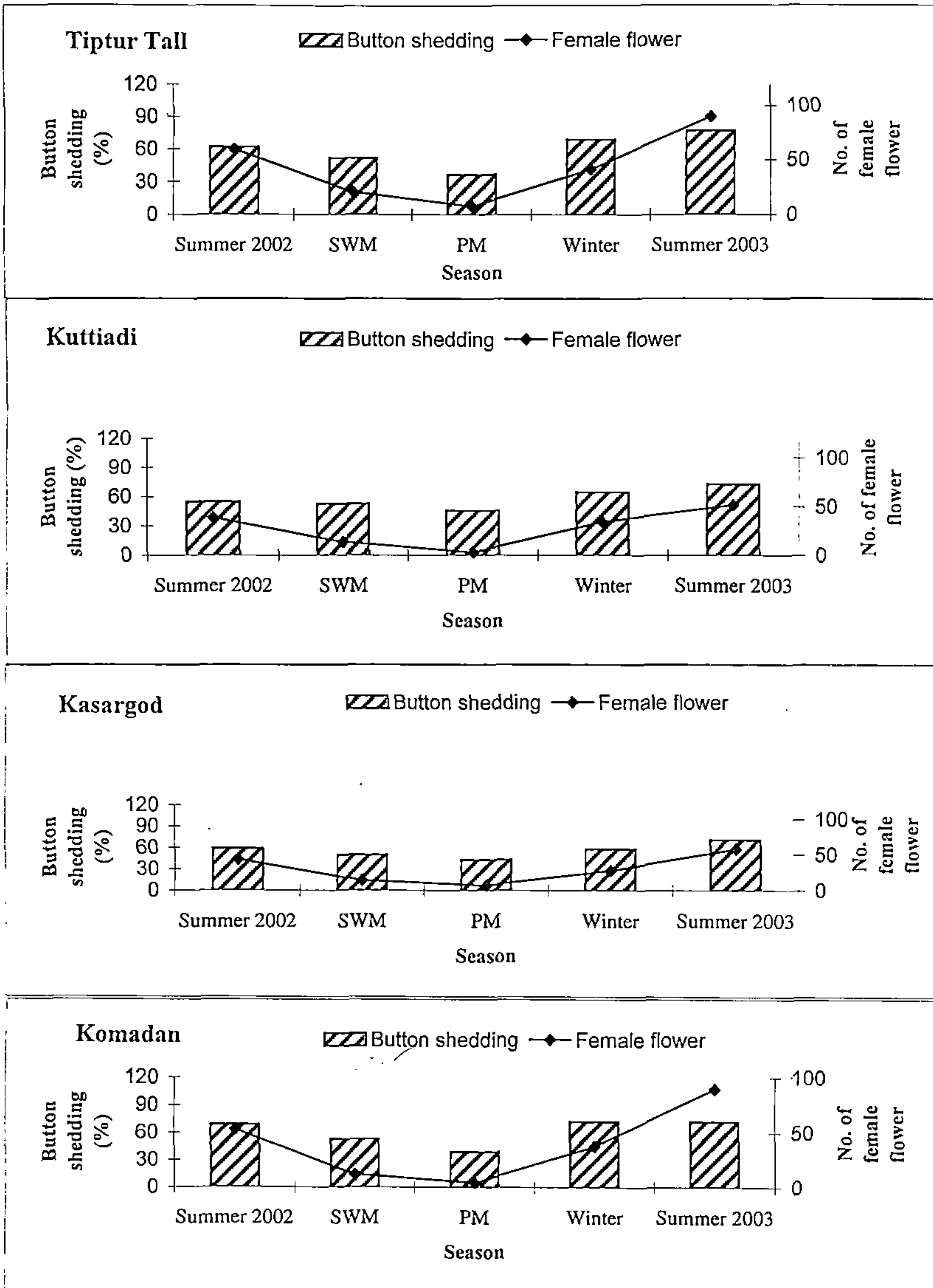

Fig 4.10 Button shedding versus female flower production of coconut cultivars

4.14.3 Temperature range: - The study indicated a highly positive significant correlation between the button shedding in Tiptur Tall, Kuttiadi and Komadan and there was no correlation in the case of Kasargod.

4.14.4 Morning relative humidity: - The study indicated no significant correlation between morning relative humidity and button shedding in Tiptur Tall, Kasargod and Komadan. However, in Kuttiadi it was highly significant and negatively correlated.

4.14.5 Evening relative humidity: - A significant negative correlation was observed between button shedding and evening relative humidity in Tiptur Tall and Komadan. In Kuttiadi, it was highly significant (1% level). In case of Kasargod, no significant correlation was noticed.

4.14.6 Vapour pressure deficit: - A significant positive correlation was observed between button shedding and vapour pressure deficit in Tiptur Tall and Komadan and it was highly correlated in Kuttiadi. There existed no correlation between vapour pressure deficit and button shedding in the case of Kasargod.

4.14.7 Rainfall: - Except in Kuttiadi, other cultivars showed no correlation with rainfall and button shedding. In Kuttiadi, correlation was highly significant.

4.14.8 Rainy days: - Sugnificant negative correlation existed in the case of Tiptur Tall and Kuttiadi. The remaining cultivars showed no significant correlation with button shedding.

4.14.9 Growing Degree Day

There existed highly significant and positive correlations between button shedding and GDD in Tiptur Tall, Kuttiadi and Komadan. In Kasargod, correlations were significant only at 5% level.

The button shedding was high when the growing degree days was high when all the cultivars were pooled. At the same time, the relationship between the growing degree day and percentage button shedding was poor in case of Kasargod, Komadan and Kuttiadi as R^2 values are 0.122, 0.250 and 0.372 respectively (Fig. 4.11).

4.14.10 Helio Thermal Unit

The study showed a highly significant positive correlation between the HTU and button shedding in Tiptur Tall and Kuttiadi and significant correlation with Komadan. No correlation was observed in Kasargod.

The results revealed that positive correlation with respect to button shedding in the case of maximum temperature, minimum temperature, temperature range and vapour pressure deficit and it was negatively correlated with evening relative humidity. Interestingly, the cultivar Kasargod appeared to be tolerant with reference to weather aberrations as the button shedding was relatively low. Rainfall had significant negative effect on Kuttiadi while the number of rainy days together with rainfall had a negative effect in the case of Tiptur Tall though the similar trend was seen in all the cultivars.

A step- wise regression equation based on the weather variables (rainfall, rainy days, temperature range and vapour pressure deficit) revealed that in Tiptur Tall and Komdan, rainfall itself could decide 40.6 % and 30.2 % respectively in variation of the button shedding while in Kuttiadi rainfall, temperature range and vapour pressure deficit explained 52.6%. However, it was not significant with any of the weather variables in the case of Kasargod (Table 4.24).

Table 4.24 Regression model based on weather variables and button shedding in summer seasons

Cultivar	Regression equation	Variables selected	R^2
Tiptur Tall	$Y=87.23-2.15x10^{-2}x_1$	RF	0.406
Kuttiadi	$Y=187.09+7.79x10^{-3}x_1-40.55x_2+29.38x_3$	RF, Temp (range) and VPD	0.526
Kasargod	Not significant	-	-
Komadan	$Y=82.62-1.51x10^{-2}x_1$	RF	0.302

Where, Y is the estimated percentage button shedding and x_1- x_3 are the weather variables selected by the model.

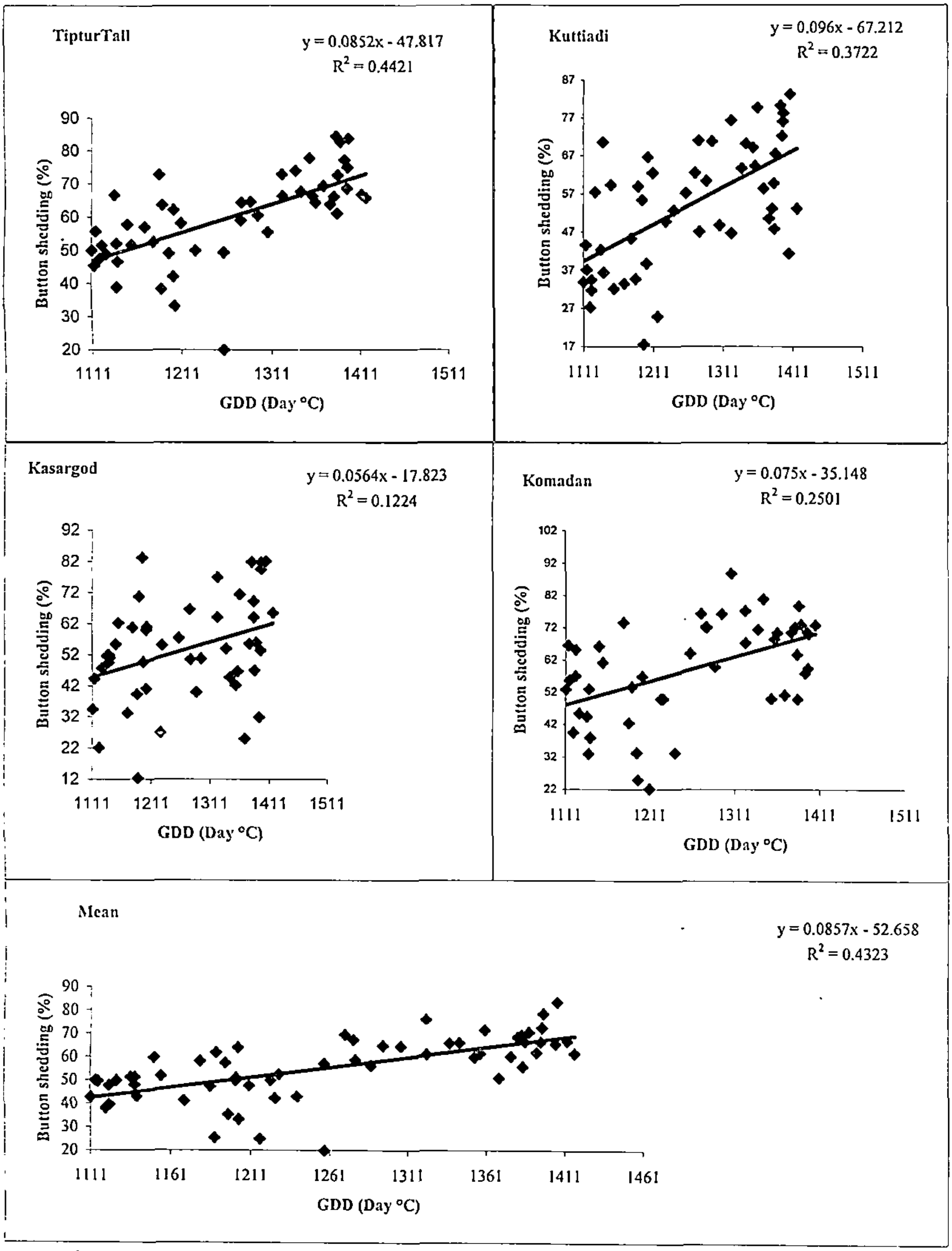

Fig 4.11 Growing Degree Day versus button shedding

Nevertheless, the influence of independent weather variables on button shedding is difficult to establish since it is a complex one as various biotic and abiotic factors influence this phenomenon viz., physiological, defective fertilisation, soil moisture and drought, waterlogging and lack of aeration, nutritional imbalance, diseases and insect pests. In addition, intra-correlations do exist among different weather variables. However, the button shedding was high during summer 2003 when compared to that of summer 2002, which could be attributed to the occurrence of prolonged dry spell (Fig. 4.12). The absence of significant rains from November 2002 to 8^{th} June 2003 (belated monsoon) resulted in abnormal drought situation under which the temperature range (9.8°C) and vapour pressure deficit (11.4 hPa) was also high. The above situation might have resulted in more button shedding during summer 2003. In addition to the prolonged dry spell during the above season, the occasional intermittent rains in the form cloud burst/ summer showers might have caused imbalance in nut setting under severe soil moisture stress resulting in immediate fall of buttons.

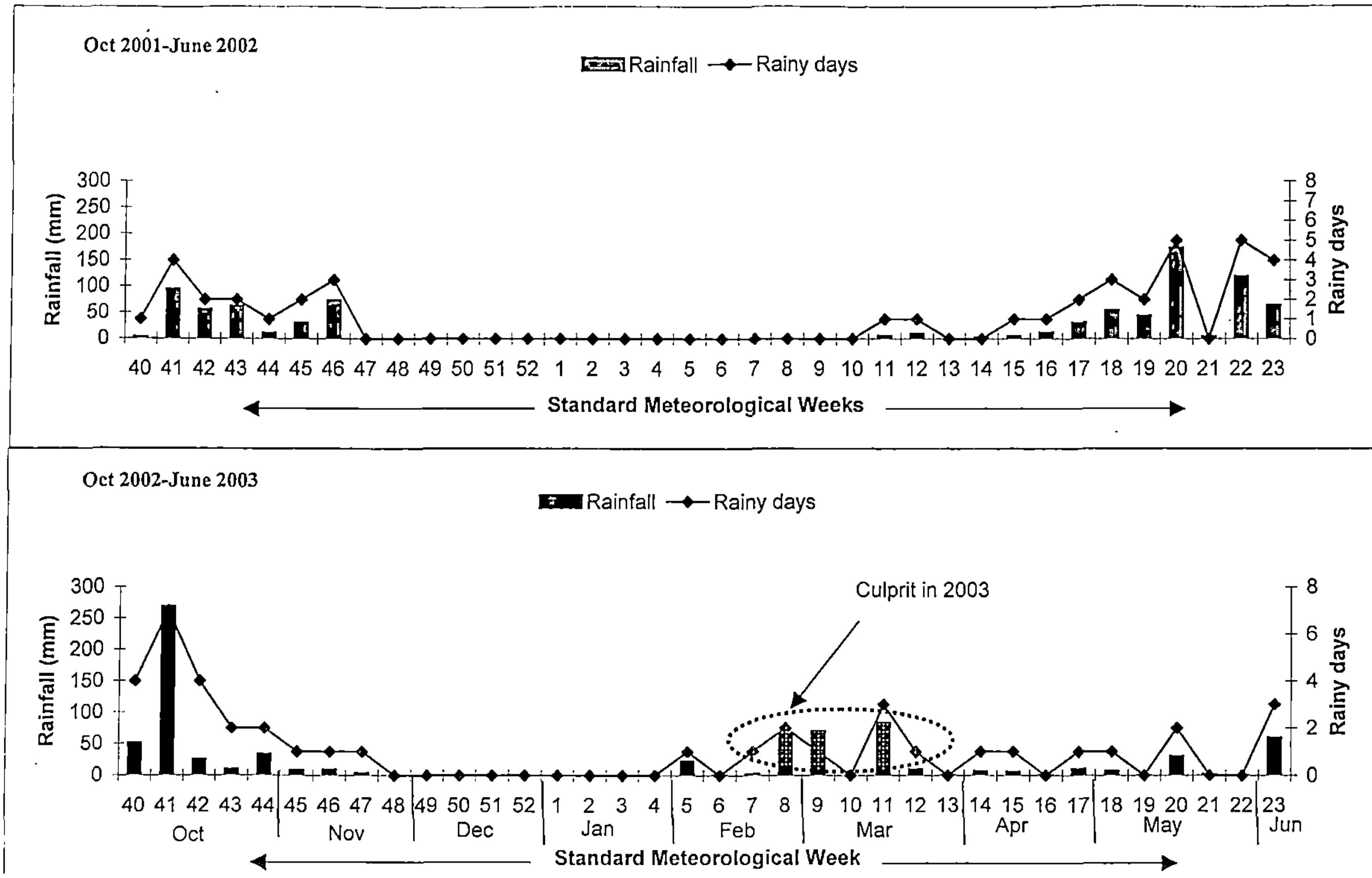

Fig 4.12 Weekly rainfall and number of rainy days from October to June

SUMMARY

5. SUMMARY

The present investigation on "Leaf and spadix phenology of coconut (*Cocos nucifera* L.)" was undertaken at the department of Agricultural Meteorology, College of Horticulture, Vellanikkara. Ten palms each of eight-year-old coconut cultivars viz., Tiptur Tall, Kuttiadi (WCT), Kasargod (WCT) and Komadan (WCT) were randomly selected. The experimental site is located at the Regional Station, Coconut Development Board, Vellanikkara. Presently, it is under the control of Central Nursery, Kerala Agricultural University, Vellanikkara. The biotic events such as functional leaves, leaf shedding, spathe emergence and its duration, spadix emergence, female flowers and button shedding were recorded weekly from February 2002 to June 2003. The salient results of the study were summarised and presented in this chapter.

All the four cultivars behaved uniformly with respect to seasons in terms of functional leaves, spathe and female flower production. Nevertheless, they responded differently to different weather variables. However, Tiptur Tall was tolerant to weather aberrations and superior in terms of its floral and yield characters among the four cultivars.

The total number of functional leaves present on the crown was maximum (30.3) in post monsoon season, followed by winter (30.0) and minimum (28.9) in summer and southwest monsoon (29.1). The maximum number of functional leaves during post monsoon season was attributed to the favourable weather conditions resulting in greater absorption and translocation of nutrients while it was not so in summer and southwest monsoon during which unfavourable weather conditions were noticed.

The leaf shedding was maximum (30.5 %) during summer and winter (29.5 %) while minimum (15.0 %) during post monsoon season. It was intermediary (25.0 %) during southwest monsoon season. High maximum temperature (34.6°C), temperature range (10.1°C), vapour pressure deficit

(9.3hPa), low rainfall (375.5 mm) and rainy days (18) coupled with high evaporation (462.2mm) and high solar radiation (19704 MJ/m^2) during the summer caused to more shedding of older leaves while the above conditions were reverse in post monsoon as well as southwest monsoon and hence low leaf shedding.

The seasonal influence on spathe emergence in all the four cultivars showed that it was maximum (36%) during post monsoon while minimum (14%) during the southwest monsoon. The spathe emergence was intermediary (26%) in summer and winter (25%). However, varietal variation in spathe emergence was also noticed. The favourable weather conditions such as optimum soil moisture through rainfall (719.2 mm), maximum temperature (31.7°C) and bright sunshine hours (5.8) during the primordium initiation (29 months prior to the spathe emergence) resulted in maximum spathe emergence during post monsoon. The unfavourable weather conditions such as low rainfall (72.5 mm), less rainy days (4) and high maximum temperature (34°C) coupled with more sunshine hours (8.7) during the primordia initiation stage (January-April) would have played a major role in low emergence of spathes during the southwest monsoon.

The number of spathes present on the crown was maximum (38%) in winter, followed by summer (26%) while low (16%) in southwest monsoon. It was intermediary (21%) during post monsoon season. The maximum number of spathes present on the crown during winter was attributed to the prolonged spathe duration that took place in post monsoon season (previous season) and the development of spathes in the winter itself. In contrast, the low spathe emergence in summer together with southwest monsoon resulted in less number of spathes during the southwest monsoon season.

The duration of spathe in all the cultivars was minimum (66 days) if it was emerged in southwest monsoon while maximum (81 days) in winter, followed by post monsoon (79 days) and it was intermediary (74 days) during summer. Low minimum temperature (22.9°), high temperature range (10.5°C), wind speed (7.3 km/h), vapour pressure deficit (12.2 hPa), evaporation (588.2 mm) and sunshine hours (9.0) prevailed during winter when compared to other seasons would have resulted in the maximum spathe duration while reverse during southwest monsoon season, which led to low spathe duration. The Growing Degree Day versus spathe duration indicated that there was a close relationship between them in all the cultivars. The spathe duration took more number of days if the GDD exceeds (1150 day °C) and *vice versa.*

The spadix emergence was maximum during summer (38%) in all the cultivars unlike in the case of spathe emergence which was maximum during post monsoon season. In contrast to spathe emergence, the spadix emergence was invariably low (8%) during post monsoon. It was intermediary (31%) during winter and southwest monsoon season (24%). The reasons for maximum spadix emergence during summer season can be attributed to the maximum number of spathes present on the crown during winter in which the duration from spathe to spadix was also more. When coconut spathes were exposed to a range of higher atmospheric temperature (32-36°C) it may caused for early opening of spathe which is nothing but spadix emergence. The number of spathe present on the crown was less during the southwest monsoon and hence the opening of spathe during the ensuing post monsoon was less. The same explanation holds good in case of other seasons too.

The number of female flowers produced was high (46%) during summer and less (6%) in post monsoon season. A gradual decline in female flower production was noticed from summer to post monsoon season and thereafter an increase was noticed during winter in all the cultivars. The female flower production during summer was high, which can be attributed to the favourable weather prevailed during primordia initiation (32 months prior to the spadix emergence, June-August, 1999) and ovary development (6-7 months before the spadix emergence, Jul-Aug to Sept-Oct, 2001). High maximum temperature (34.5°C), temperature range (11.2°C), sun shine hours (9.1) and high vapour pressure deficit (9.3 hPa) and prolonged dry spell during the above critical stages caused the low female flower production during post monsoon season. In the case of Kuttiadi and Kasargod, the number of female flowers produced could be explained up to 99 percent due to weather that prevailed during the ovary development and primordium initiation.

The seasonal effect on button shedding was found to be maximum (73%) during summer 2003, followed by winter (66%) and summer 2002 (61%). The shedding was found to be minimum (41%) in post monsoon and southwest monsoon (52%). The button shedding was high during summer 2003 when compared to that of summer 2002. It can be attributed to the occurrence of prolonged dry spell. The absence of significant rain from November 2002 to 8th June 2003 (belated monsoon) resulted in abnormal drought situation under which the temperature range (9.8°C) and vapour pressure deficit were also high (11.4 hPa). The above situation might have resulted in more button shedding during summer 2003. In addition to the prolonged dry spell during the above season, the insignificant occasional intermittent rains in the form of cloud burst/ summer showers might have caused imbalance in nut setting, resulting in immediate fall of buttons.

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* Original not seen

APPENDICES

APPENDIX I

Weekly weather variables at Vellanikkara in 2002

Week No.	Temperaure(°C)						Vapour pressure (mm)		Relative humidity (%)		Wind Speed (km/hr)	Sun-shine (hrs)	Rainfall (mm)	Number of rainy days	Evapo-ration (mm)
	Dry bulb I	Wet bulb I	Dry bulb II	Wet bulb II	MAX	MIN	I	II	I	II					
1	25.1	21.4	32.1	23.0	32.4	23.7	16.9	15.6	70	44	12.8	9.8	0.0	0	52.1
2	24.3	22.9	32.1	24.8	32.5	23.0	18.7	16.0	81	44	11.0	9.3	0.0	0	47.9
3	23.1	20.3	31.7	22.4	32.5	21.3	16.2	15.1	76	42	5.0	7.8	0.0	0	37.1
4	24.9	23.6	32.6	24.7	33.4	23.4	21.1	18.5	88	50	3.6	4.7	0.0	0	26.3
5	25.3	21.3	30.6	22.9	31.1	23.4	16.6	16.5	69	50	10.6	4.6	0.0	0	37.9
6	25.1	21.7	32.8	23.5	33.6	23.7	17.4	17.4	72	47	6.9	8.0	0.0	0	45.0
7	25.3	21.1	34.3	22.3	34.8	22.8	16.1	12.9	66	32	7.8	9.8	0.0	0	46.7
8	24.7	21.9	34.9	21.9	36.1	22.2	18.1	11.7	77	28	7.0	10.6	0.0	0	51.6
9	25.0	23.2	34.8	26.3	37.3	21.9	18.3	11.7	76	25	4.7	8.7	0.0	0	51.8
10	25.4	23.5	36.2	25.0	36.6	23.6	20.6	17.0	84	38	5.3	8.7	0.0	0	45.0
11	25.7	23.8	35.9	24.2	36.6	24.2	20.9	15.7	84	36	5.4	8.4	6.2	1	42.2
12	26.0	24.2	35.0	24.5	35.6	24.4	21.6	16.9	85	41	5.0	8.0	10.1	1	43.5
13	27.0	25.6	31.8	27.3	35.4	25.6	23.8	22.7	89	55	3.8	6.9	0.0	0	37.9
14	27.1	26.6	34.0	26.3	34.6	24.6	22.9	21.1	86	53	4.1	7.9	2.2	0	33.6
15	27.0	25.1	34.5	26.8	35.1	24.5	22.7	21.7	85	53	4.3	8.0	5.4	1	36.9
16	27.8	26.0	34.3	27.4	35.2	25.4	24.2	23.2	86	57	3.7	7.6	12.2	1	29.6
17	27.8	25.9	34.1	27.2	35.3	24.9	23.8	22.7	85	56	4.4	7.7	31.0	2	38.0
18	27.8	25.9	32.9	26.1	34.6	24.5	23.9	21.7	85	60	4.7	6.2	54.4	3	35.0
19	27.8	25.7	33.0	26.9	33.7	25.3	23.5	22.9	84	60	4.9	7.7	44.2	2	33.6
20	25.8	25.0	29.2	25.7	30.8	24.0	23.3	22.9	93	76	3.3	3.1	173.2	5	19.2
21	27.3	25.5	31.6	26.7	32.2	24.2	23.5	23.3	87	67	3.6	6.9	4.0	0	25.7
22	26.5	25.1	30.1	26.3	30.8	24.0	23.4	23.3	89	73	4.2	3.5	119.0	5	29.6
23	25.9	25.1	29.9	26.1	30.7	23.4	23.2	23.0	94	73	4.0	5.0	64.2	4	24.6
24	24.3	23.7	27.6	25.3	28.9	22.5	21.5	22.8	94	83	3.7	0.6	219.1	5	17.2
25	25.6	24.7	28.5	25.9	29.6	23.3	23.3	23.6	93	81	4.5	1.8	109.8	6	19.5
26	25.8	25.1	29.7	26.2	30.5	23.7	23.5	23.4	94	75	3.7	1.4	74.6	6	21.7
27	25.7	25.0	29.8	25.9	30.3	23.6	23.3	22.7	94	72	3.7	5.2	57.0	4	23.6
28	25.4	24.7	28.5	25.3	29.3	23.1	22.9	22.2	94	77	4.0	3.0	126.1	4	21.4
29	24.6	24.0	29.1	25.4	29.7	22.7	22.2	22.0	95	73	3.8	2.7	58.0	5	21.7
30	24.9	24.1	29.0	25.3	29.9	22.9	21.9	21.8	93	73	3.7	3.8	83.5	5	20.3
31	24.3	23.7	26.6	24.8	28.1	22.5	21.5	22.4	95	86	4.0	0.7	83.6	7	16.6
32	23.9	23.3	27.6	24.9	28.6	22.2	21.3	22.6	95	79	3.8	0.9	94.3	5	19.5
33	24.4	23.7	27.1	24.9	27.9	22.8	21.7	22.2	94	83	3.7	2.6	337.0	7	14.9
34	25.2	24.4	29.8	25.8	30.1	23.4	22.5	22.4	93	72	3.7	5.4	13.8	2	26.6
35	25.3	24.4	30.5	25.5	30.9	24.1	22.3	21.4	93	65	3.8	7.3	3.8	1	30.1
36	24.7	24.0	29.4	25.4	29.8	23.2	22.2	21.8	94	71	3.7	5.5	98.7	5	24.0
37	25.0	38.4	29.5	25.0	30.7	22.9	21.9	20.4	92	63	3.7	8.7	0.0	0	30.8
38	25.4	24.3	31.0	24.8	31.3	22.8	22.1	19.6	91	59	3.6	8.3	0.0	0	30.3
39	25.6	24.4	32.4	25.0	32.5	22.7	22.2	19.8	90	55	3.6	8.2	21.5	2	30.8
40	25.9	24.6	31.1	26.4	32.3	23.3	22.4	22.9	89	67	3.2	5.7	51.0	4	26.0
41	24.8	24.0	26.6	25.2	29.3	23.1	21.9	23.2	93	89	3.5	2.1	268.3	7	12.8
42	25.0	24.1	29.2	25.6	30.1	23.0	21.9	22.3	92	74	2.8	4.3	25.1	4	24.4
43	25.4	24.5	31.0	26.1	31.5	23.5	22.3	22.3	92	66	3.1	6.0	9.9	2	23.0
44	25.6	23.7	30.7	25.1	31.6	23.3	20.8	20.2	84	61	5.1	5.7	33.4	2	30.6
45	25.4	24.1	30.9	25.9	31.8	23.5	21.8	22.0	90	66	3.4	4.7	8.7	1	22.0
46	25.7	23.6	30.9	24.8	31.2	23.4	20.5	19.8	83	59	5.1	4.7	9.4	1	29.1
47	25.5	22.8	31.0	25.2	31.3	23.3	18.8	21.0	78	63	5.4	6.8	4.0	1	30.2
48	24.5	22.0	32.4	24.7	32.9	22.6	18.5	18.6	79	51	4.5	9.2	0.0	0	31.5
49	25.5	22.1	31.5	24.7	32.1	23.2	17.9	19.2	73.1	53	10	7.6	0.0	0	41.6
50	25.5	21.3	31.9	24.0	32.1	24.1	17.0	17.6	69.3	50	12	9.4	0.0	0	61.4
51	23.7	19.9	31.7	21.7	32.2	21.1	15.2	13.5	69.0	39	8	8.0	0.0	0	45.6
52	22.6	19.5	32.0	21.7	32.5	20.5	15.2	13.7	74.4	37	4	9.3	0.0	0	41.7
Mean	25.4	24.0	31.3	25.1	32.1	23.4	21.0	20.0	85.7	60	5	6.1	2316.7	111.0	1659.7

APPENDIX I continued

Weekly weather variables during 2003 (January- June) at Vellanikkara

Months	Week No.	Temperaure(°C) Dry bulb I	Wet bulb I	Dry bulb II	Wet bulb II	MAX	MIN	Vapour pressure (mm) I	II	Relative humidity (%) I	II	Wind Speed (km/hr)	Sun-shine (hrs)	Rainfall (mm)	Number of rainy days	Evapo-ration (mm)
Jan	1	24.3	20.0	32.1	22.0	32.9	22.4	14.9	13.6	66	38	9.0	8.6	0.0	0	48.7
	2	24.9	20.2	32.2	21.8	32.4	23.9	14.9	13.4	63	37	10.0	8.9	0.0	0	57.9
	3	24.8	19.1	32.1	21.7	32.4	23.6	14.2	13.5	62	37	10.2	9.1	0.0	0	62.9
	4	23.1	19.8	34.1	20.9	34.6	22.0	15.3	10.4	72	26	6.9	9.9	0.0	0	48.1
Feb	5	23.7	20.9	33.2	22.9	33.9	22.6	17.0	14.7	77	39	5.4	8.7	23.6	1	38.5
	6	24.7	21.8	34.2	23.5	34.8	23.7	17.9	15.1	77	38	7.0	9.8	0.2	0	44.7
	7	25.6	23.1	35.0	25.0	35.7	24.2	19.9	17.6	80	42	4.9	9.8	2.9	1	37.9
	8	24.9	23.4	34.0	25.1	35.1	23.7	23.1	18.7	78	47	3.7	9.2	65.4	2	37.1
Mar	9	24.6	23.5	33.1	25.5	33.8	23.3	21.1	19.8	91	53	3.2	8.7	70.0	1	31.8
	10	25.7	23.7	34.5	23.5	35.2	24.2	20.8	16.7	84	38	4.0	8.8	0.0	0	40.0
	11	25.6	24.1	34.1	24.2	34.8	24.2	21.8	16.7	88	42	4.0	8.2	83.4	3	36.1
	12	25.4	22.9	33.8	25.5	34.2	23.4	19.4	19.3	80	49	4.2	8.7	10.4	1	38.2
	13	26.5	25.6	33.4	27.0	34.1	24.9	24.1	22.8	92	59	2.7	8.1	1.0	0	33.2
Apr	14	26.9	25.0	32.3	26.0	33.6	24.9	22.6	21.3	86	63	2.8	6.1	6.8	1	27.6
	15	26.9	25.5	33.9	27.0	34.4	25.0	23.6	22.6	87	56	2.8	7.9	5.8	1	37.5
	16	27.1	25.6	34.2	27.5	34.9	25.1	23.7	23.5	88	58	3.1	8.1	0.7	0	35.2
	17	26.9	25.3	34.2	27.1	35.4	25.0	22.7	22.5	81	56	4.1	8.2	10.5	1	42.0
May	18	26.9	24.8	32.9	26.4	33.8	24.7	22.4	21.8	84	58	3.9	5.9	7.2	1	34.2
	19	27.7	25.9	33.7	27.1	34.1	25.6	23.9	22.8	86	58	3.4	5.3	0.5	0	31.8
	20	27.4	26.3	32.6	26.4	33.3	25.5	25.0	21.9	92	59	4.0	5.0	29.8	2	34.7
	21	27.9	26.3	34.0	26.4	34.4	26.0	24.7	21.2	87	53	3.7	7.8	1.8	0	39.9
	22	27.8	26.2	34.3	26.0	34.7	25.7	24.6	20.1	88	48	3.8	7.2	0.2	0	41.2
June	23	26.6	25.4	32.8	26.0	33.4	24.8	23.7	21.0	91	55	3.6	6.8	59.4	3	35.2
	24	26.4	25.0	30.1	25.7	30.9	23.7	22.9	22.7	89	75	3.8	4.3	164.3	5	21.2
	25	24.3	23.7	27.5	25.3	27.7	22.9	21.9	22.9	95	83	2.7	0.4	309.6	6	16.1
	26	24.9	23.8	28.5	25.1	29.7	22.7	21.8	22.1	92	75	2.7	2.9	46.9	6	22.6

APPENDIX II

Weekly biotic events in coconut cultivar (Tiptur Tall)
(Feb 2002 to June 2003)

Month	MW	AFL	NLS	NS	SE	SO	SD	NFF
Feb	5	33.3	1	3.8	5	0		
	6			3.6	0	2		
	7			3.3	3	6		
	8			3.5	3	1		45
Mar	9			3.4	1	2		38
	10	33.1	12	3.3	3	4		50
	11			3.2	2	3		55
	12			3.1	2	3		41
	13			2.9	1	3		46
Apr	14			2.8	3	4		56.5
	15	32.1	20	2.7	2	3	10	41
	16			2.6	3	4	11	47.3
	17			2.3	0	3	12	41
May	18			2.1	2	4	10.5	40.3
	19			2.4	4	1	11	38
	20	31.8	14	2.1	1	4	11	29.5
	21			2.3	3	1	10	24
	22			2.3	5	5	9.8	42
June	23			2.4	2	1	12	28
	24			2.2	3	5	9.2	24.2
	25	31.8	10	2.2	1	1	9	42
	26			2.2	0	0		
July	27			2.4	5	3	9.3	28
	28			2	0	4	12.3	26
	29			1.9	1	2	7.5	24
	30	31.9	10	1.7	0	2	9	18
Aug	31			1.4	1	4	9	21.8
	32			1.4	2	2	8	24
	33			1.1	0	3	10.6	26.7
	34			1.1	0	0		
	35	32.5	4	1	1	2	9	22
Sep	36			0.8	0	2	11	20.5
	37			0.7	1	2	10	20
	38			0.7	0	0		
	39			0.6	1	2	11	17
Oct	40	32.9	6	0.6	1	1	8	6
	41			1.1	5	0		
	42			1.1	2	2	10.5	23
	43			1.4	3	0		
Nov	44			1.9	5	0		
	45	33.7	4	2.5	6	0		
	46			2.9	5	1	11	14
	47			3.4	5	0		
	48			3.4	1	1	9	5
Dec	49	33.5	11	3.6	2	0		
	50			4.2	7	1	13	16
	51			4.2	4	4	9.75	20
	52			4.3	2	1	10	18

Month	MW	AFL	NLS	NS	SE	SO	SD	NFF
Jan	1	33.6	9	4.2	2	3	12	30
	2			4.2	1	1	10	23
	3			4.2	6	6	11.5	32
	4			4.2	2	2	11.5	39
Feb	5			3.8	2	6	11.8	40
	6	33.1	15	3.6	3	5	11.6	39
	7			3.7	3	2	12.5	46
	8			3.6	2	3	12	79
Mar	9			3.3	1	4	11.5	44
	10	32.2	17	3.7	8	4	12.5	69
	11			3.5	1	3	12.3	78
	12			3.2	1	4	12.3	58
	13			3.2	4	4	11.5	62
Apr	14	31.2	20	3.3	3	2	11	30
	15			3.2	0	1	11	62
	16			3.1	4	5	11	64
	17			3.3	5	3	11.3	47
May	18			3.3	1	1	15	30
	19	31	11	3	2	5	11	52
	20			2.7	2	5	11	46
	21			2.9	3	1	11	31
	22			2.6	4	7	10.2	58
June	23	31.1	8	2.7	3	2	10.5	30
	24			2.5	2	4	9.25	39
	25			2.4	0	1	15	71
	26			2.4	3	3	9.2	28

MW-Standard Meteorological Week
AFL-Average functional leaves
NLS-No. of leaf shedding
NS- No. of spathe presented on the crown
SE- Spathe emergence
SO- Spathe opening
SD- Spathe duration
NFF- No. of female flowers (per bunch)

APPENDIX II Continued

Weekly biotic events in coconut cultivar (Kuttiadi)

(Feb 2002 to June 2003)

Month	MW	AFL	NLS	NS	SE	SO	SD	NFF
	5	28.6	0	3.2	4	0		
Feb	6			3.2	0	0		
	7			2.9	3	5		60
	8			2.7	0	3		64
	9			2.8	2	1		53
	10	28.4	12	2.8	4	4		53
Mar	11			2.6	0	2		28
	12			2.5	2	3		41
	13			2.4	3	4		30
	14			2.4		1		24
Apr	15	28	15	2.4	2	2		18
	16			2.3	2	3	10	33
	17			2.2	2	3	11	35
	18			2	2	4	10	23
	19			2	2	2	12	26
May	20	28.1	9	2.3	4	1	11	32
	21			2.1	2	4	11	30
	22			2.2	3	2	8.5	23
	23			2.2	2	2	10.5	19
June	24			2.2	2	2	9.5	20
	25	28.2	8	2.4	4	3	9.6	17
	26			2.3	1	1	9	22
	27			2.1	1	3	9.3	17
July	28			2.3	3	2	9	20
	29			2.2	2	2	9	13
	30	28.7	5	2.1	0	1	10	21
	31			1.9	1	3	9.9	13
	32			1.6	0	3	9.6	14
Aug	33			1.3	0	3	10.3	17
	34			1.1	0	2	9	11
	35	29.1	6	1	2	3	10	19
	36			1.1	1	0		
Sep	37			0.9	0	2	11	9
	38			1.1	3	1	10	6
	39			1.2	3	2	10.5	14
	40	29.6	5	1.3	1	0		
Oct	41			1.4	3	2	12.5	7.5
	42			1.8	4	0		
	43			2.1	3	0		
	44			2.4	4	1	13	4
	45	30.2	4	2.7	3	0		
Nov	46			2.9	2	0		
	47			2.9	3	3	11.6	5
	48			3.5	6	0		
	49	29.7	15	3.5	0	0		
Dec	50			3.6	5	4	11.5	22
	51			3.5	1	2	12.5	14
	52			3.4	1	2	11.5	17

Month	MW	AFL	NLS	NS	SE	SO	SD	NFF
	1	28.8	17	3.4	2	2	12	26
	2			3.1	3	6	11.5	23
Jan	3			3.1	2	2	12	23
	4			3.4	5	2	12	38
	5			3.2	2	4	12	39
Feb	6	28.3	14	3.1	1	2	12.5	45
	7			2.8	1	4	11.8	57
	8			2.7	3	4	11.5	27
	9			2.7	3	3	11	41
	10	27.5	18	2.7	3	3	11.6	50
Mar	11			2.7	2	2	13	55
	12			2.4	1	4	10.3	45
	13			2.9	5	0		
	14	26.8	20	2.6	3	5	10.6	46
Apr	15			2.8	2	0		
	16			2.5	3	6	11	34
	17			2.9	6	2	9.5	29
	18			2.8	1	2	8.5	70
	19	27	9	2.6	1	3	10.3	23
May	20			2.5	3	4	9.25	28
	21			2.5	2	2	9	34
	22			2.4	3	4	8.75	29
	23	27.3	7	2.4	4	4	9	29
June	24			2.4	1	1	9	25
	25			2.4	1	1	9	25
	26			2	1	5	9.4	22

MW-Standard Meteorological Week
AFL-Average functional leaves
NLS-No. of leaf shedding
NS- No. of spathe presented on the crown
SE- Spathe emergence
SO- Spathe opening
SD- Spathe duration
NFF- No. of female flowers (per bunch)

APPENDIX II Continued

Weekly biotic events in coconut cultivar (Kasargod)

(Feb 2002 to June 2003)

Month	MW	AFL	NLS	NS	SE	SO	SD	NFF
	5	29.4	0	3.6	2	0		
Feb	6			3.2	0	4		
	7			3.2	5	5		
	8			3.1	0	1		
	9			3.1	1	1		56
	10	29.5	9	3.1	3	3		38
Mar	11			2.9	3	5		54
	12			3.1	3	1		52
	13			2.9	0	2		45
	14			2.7	1	3		40
Apr	15	28.8	17	2.2	1	6		43
	16			2.2	1	1	9	40
	17			2	2	4	10	32
	18			2	1	1	13	17
	19			2.1	2	1	14	23
May	20	28.7	11	1.9	3	5	10.4	32
	21			1.7	1	3	7.6	25
	22			2.3	6	0		
	23			2	0	2	10	20
June	24			1.7	2	5	11.2	28
	25	28.5	13	1.8	1	0		
	26			1.9	2	1	9	18
	27			2.2	3	0		
July	28			2	1	3	10.3	20
	29			1.7	1	3	9.3	17
	30	29	5	1.7	1	1	11	25
	31			1.4	0	3	9.3	16
	32			1.1	0	2	10	16
Aug	33			1	1	2	11	17
	34			0.9	0	1	10	13
	35	29.3	6	0.7	0	2	10	20
	36			0.7	1	1	9	8
Sep	37			0.5	1	3	11	18
	38			0.4	0	1	9	18
	39			0.6	2	0		
	40	30	5	0.7	1	0		
Oct	41			0.7	1	1	11	6
	42			0.6	0	1	9	10
	43			0.9	3	0		
	44			1.5	6	0		
	45	30.3	7	1.6	1	0		
Nov	46			1.9	5	2	9.5	7
	47			2.2	3	0		
	48			2.6	4	0		
	49	29.7	16	2.7	1	0		
Dec	50			3.2	6	1	11	3
	51			3.3	2	1	12	20
	52			3.4	1	0		

Month	MW	AFL	NLS	NS	SE	SO	SD	NFF
	1	29.6	11	3.6	3	1	13	26
	2			3.7	3	2	12	20
Jan	3			3.6	2	3	11.6	20
	4			3.6	3	3	11.3	26
	5			3.5	1	2	12	18
Feb	6	28.6	19	3.4	3	4	13.3	52
	7			3.2	3	5	11.8	41
	8			2.8	1	5	12	34
	9			2.9	3	2	12	104
	10	27.9	17	2.9	2	2	12	23
Mar	11			2.7	1	3	12.6	35
	12			2.7	4	4	11.3	50
	13			2.6	1	2	11	35
	14	27.6	13	2.9	5	2	12	50
Apr	15			2.8	2	3	12.6	42
	16			2.6	2	4	10.8	44
	17			3	6	2	11.5	51
	18			2.9	3	4	10.5	34
	19	27.1	15	2.5	0	4	10.3	49
May	20			2.6	2	1	9	40
	21			2.3	1	4	9	27
	22			2.3	4	4	9.25	36
	23	27.1	8	2.5	4	2	8.5	27
June	24			2.1	0	4	9.3	30
	25			2	2	3	8	29
	26			2.1	2	1	10	25

MW-Standard Meteorological Week
AFL-Average functional leaves
NLS-No. of leaf shedding
NS- No. of spathe presented on the crown
SE- Spathe emergence
SO- Spathe opening
SD- Spathe duration
NFF- No. of female flowers (per bunch)

APPENDIX II Continued

Weekly biotic events in coconut cultivar (Komadan)

(Feb 2002 to June 2003)

Month	MW	AFL	NLS	NS	SE	SO	SD	NFF
Feb	5	27.4	0	3.3	2	0		
	6			3.2	1	2		
	7			2.9	2	6		
	8			2.9	3	2		
Mar	9			2.7	3	5		50
	10	27.2	12	2.5	3	4		61
	11			2.4	1	2		53
	12			2.2	0	3		37
	13			1.9	1	4		45
Apr	14			2.1	5	2	6.5	66
	15	26	21	2.1	2	2	8	18
	16			1.6	0	5	6.2	27
	17			1.9	3	0		
May	18			1.6	3	6	8.6	32
	19			1.5	0	1	10	38
	20	26.1	10	1.7	5	3	8	23
	21			1.6	1	1	7	18
	22			1.5	2	2	6	26
June	23			1.5	3	3	9.3	20
	24			1.4	1	1	7	30
	25	26.4	8	1.2	0	2	6	14
	26			1.3	1	1	6	23
July	27			1.6	4	1	9	21
	28			1.5	1	2	7.5	33
	29			1.4	2	2	10	21
	30	26.7	6	1.2	1	1	6	15
Aug	31			1.3	2	2	8.5	15
	32			0.9	0	3	9.3	20
	33			0.9	0	0		
	34			0.8	2	3	6.7	13
	35	26.9	8	0.6	2	3	8	15
Sep	36			0.6	0	0		
	37			0.7	2	1	9	8
	38			0.7	0	0		
	39			0.8	2	1	8	9
Oct	40	27.6	2	1.1	3	0		
	41			1	0	1	10	6
	42			1.1	1	0		
	43			1.5	4	0		
Nov	44			1.6	2	1	10	4
	45	28	5	1.7	1	1	9	4
	46			2	4	1	11	8
	47			2.2	3	1	10	6
	48			2.8	5	0		
Dec	49	28.4	7	2.7	1	2	10	25
	50			3	4	2	10	36
	51			3.1	2	1	11	15
	52			3.4	4	1	6	54

Month	MW	AFL	NLS	NS	SE	SO	SD	NFF
Jan	1	28.7	6	3.2	0	2	10.5	22
	2			3.1	3	3	12.3	24
	3			3.3	2	1	11	31
	4			3.2	4	4	11	47
Feb	5			3.1	2	3	12	27
	6	28.3	14	3.1	1	1	10	24
	7			2.5	1	7	11.4	61
	8			2.4	1	2	12.5	38
Mar	9			2.7	7	4	10.3	69
	10	27.4	18	2.6	2	3	10.6	76
	11			2.3	2	4	11.8	68
	12			2.4	5	5	9.4	63
	13			2.3	1	1	10	78
Apr	14	26.5	19	2.5	5	3	9.6	49
	15			2.5	2	2	10	71
	16			2.7	3	2	7.5	56
	17			2.5	4	5	8.2	41
May	18			2.7	2	1	9	78
	19	26.9	5	2.4	3	5	8.6	45
	20			2.7	4	2	8	64
	21			2.3	0	4	8.8	43
	22			2.3	5	4	7	32
June	23	27.2	7	2.1	1	3	8.3	33
	24			2.1	1	1	8	69
	25			2.1	4	3	8.6	29
	26			2.2	4	3	7.6	46

MW-Standard Meteorological Week
AFL-Average functional leaves
NLS-No. of leaf shedding
NS- No. of spathe presented on the crown
SE- Spathe emergence
SO- Spathe opening
SD- Spathe duration
NFF- No. of female flowers (per bunch)

LEAF AND SPADIX PHENOLOGY OF COCONUT
(*Cocos nucifera* L.)

By

SHAJEESH JAN, P.

ABSTRACT OF THE THESIS

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Department of Agricultural Meteorology

COLLEGE OF HORTICULTURE

KAU P. O. THRISSUR - 680 656

KERALA, INDIA

ABSTRACT

The field experiment entitled "Leaf and spadix phenology of coconut (*Cocos nucifera* L.) was conducted at Department of Agricultural Meteorology, College of Horticulture, Vellanikkara, during the period from February 2002 - June 2003. The investigations were undertaken with the following objectives such as to understand the seasonal influence on leaf and spadix production and their interval on different cultivars of coconut namely Tiptur Tall, Kuttiadi (WCT), Kasargod (WCT) and Komadan (WCT) including the duration of spadix emergence and on leaf and spadix phenology of coconut.

All the four coconut cultivars behaved uniformly with respect to seasons in terms of functional leaves, spathe and female flower production. Nevertheless, they responded differently to different weather variables. However, Tiptur Tall was tolerant to weather aberrations and superior in terms of its floral and yield characters.

The study indicated that favourable weather conditions during post monsoon season might have resulted in maximum absorption and translocation of food material during the same season in which maximum number of functional leaves were noticed whereas the rise in temperature, vapour pressure deficit coupled with low rainfall and bright sunshine hours led to higher leaf shedding during summer.

The favourable weather conditions such as optimum soil moisture, maximum temperature and bright sunshine hours during the primordium initiation (29 months prior to the spathe emergence) resulted in maximum spathe emergence during post monsoon. The unfavourable weather conditions such as low rainfall, less rainy days and high maximum temperature coupled with bright sunshine during the primordia initiation stage would have played a major role in low emergence of spathes during the southwest monsoon.

The study also indicated that low minimum temperature, and optimum temperature range, wind speed, vapour pressure deficit, evaporation and sunshine hours resulted in maximum spathe duration during winter.

The reasons for maximum spadix emergence during summer season can be attributed to the maximum number of spathes present on the crown during winter in which the duration from spathe to spadix was also more. When coconut spathes were exposed to a range of higher atmospheric temperature it may cause for early spadix emergence. In contrast, the number of spathes present on the crown was less during the southwest monsoon and hence the opening of spathe during the ensuing post monsoon was less.

The high female flower production during summer can be attributed to the favourable weather prevailed during primordia initiation (32 months prior to the spadix emergence) and ovary development (6-7 months before the spadix emergence,). High maximum temperature, temperature range, sun shine hours and high vapour pressure deficit and prolonged dry spell during the above critical stages caused to the low female flower production during post monsoon season. The number of female flowers produced could be explained up to 99 percent due to weather prevailed during the above two critical stages in the case of Kuttiadi and Kasargod.

The relationship between the female flower production and button shedding revealed that when female flower production was high button shedding was also high, while not in the case of Tiptur Tall. It also revealed that button shedding was more in summer 2003 when compared to that of summer 2002. It was attributed to the occurrence of prolonged dry spell from November 2002 to 8^{th} June 2003 when compared to that of summer 2002. In addition to the prolonged dry spell during the above season, the occasional intermittent rains in the form of cloud burst/ summer showers might have caused imbalance in nut setting resulting in immediate fall of buttons. The spathe duration and button shedding in coconut responded positively to the growing degree days. It revealed that that both the above phenological events may respond to thermal regime.

Future line of work

Such studies, if undertaken for at least five years, will be quite useful in understanding the response of biotic events to weather variations. In addition, the information can be used in crop improvement programmes of coconut.