GROWTH, FLOWERING, FLORAL BIOLOGY AND SPIKE SHEDDING IN PEPPER *(Piper nigrum L.)*
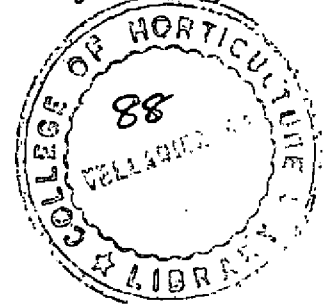
BY

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THESIS

Submitted in partial fulfilment of the requirements

for the degree of

Master of Science in Horticulture

Faculty of Agriculture

Kerala Agricultural University

Department of Horticulture (Plantation Crops)

COLLEGE OF HORTICULTURE

Vellanikkara :: Trichur

1981

DECLARATION

I, hereby declare that this thesis entitled "Growth, flowering, floral biology and spike shedding in pepper (*Piper nigrum* L.)" is a bonafide record of research work done by me during the course of research work 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,
7ᵗʰ April, 1981.

Rema Menon

CERTIFICATE

Certified that this thesis entitled "Growth, flowering, floral biology and spike shedding in pepper (Piper nigrum L.)" is a record of research work done independently by Smt. Rema Menon under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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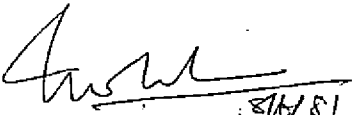
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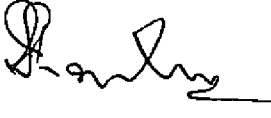
CERTIFICATE

We, the undersigned members of the Advisory Committee of Smt. Rema Menon, a candidate for the degree of Master of Science in Horticulture agree that the thesis entitled "Growth, flowering, floral biology and spike shedding in pepper (Piper nigrum L.)" may be submitted by Smt. Rema Menon in partial fulfilment of the requirement for the degree.

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Vellanikkara,
    April, 1981.

REMA MENON

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INTRODUCTION

INTRODUCTION

Pepper (_Piper nigrum_ L.) is the most popular
among the spices. India's share in world production
of pepper used to be substantial. But when other
producing countries took up pepper cultivation exten-
sively, with scientific management, their production
increased considerably and India's share in export came
down drastically. The world trade in black pepper was
estimated to be about 125.34 thousand tonnes during
1977. During that year, India had 55.5 per cent of
the total world area under pepper, which accounted for
20.5 per cent of the world production. On the other
hand Brazil and Malaysia with 5.9 per cent and 5.2
per cent of the area shared 28.6 and 22.4 per cent
production respectively. Indonesia with 27.5 per cent
of the area accounted for 24 per cent of the total
production.

During 1978-79, India produced 26.10 thousand
tonnes in an area of 111.97 thousand hectares. Pepper
is essentially an export oriented crop in India,
accounting fr about 50 per cent of the total export
earnings from all spices. During the year 1978-79*,

*Source: Directorate of Cocoa., Arecanut & Spices
Development, Calicut.

the export earnings was to the tune of Rs.280 million.

Among the pepper producing states in India, Kerala ranks first both in area and production. During 1978-79, the area under pepper in Kerala was 108.26 thousand hectares and production was 25.12 thousand tonnes.

Considering the importance of this spice in the economy of India and Kerala, very little work has been carried out during the past years. The production in a perennial crop depends upon the growth and flowering behaviour, which in turn is influenced by the interaction of genetic and environmental factors. Pepper is not an exception to this. Hence, in order to exploit the full potential of crop production in pepper, the detailed understanding of the growth and flowering pattern is quite important. A knowledge on the mode of pollination and pollen viability are also important for successful crop production. Though certain work on these aspects have been carried out both in India and abroad, they are neither specific nor exhaustive (Hasan, Iljas, 1960; Martin and Gregory, 1962; De Waard, 1967; Nambiar et al., 1978). Another important factor that hinders the production of pepper is spike shedding, which is

found to vary from 14.5 to 65.2 per cent in different
cultivars (Pillai et al., 1977). The factors respon-
sible for spike shedding are yet to be clearly under-
stood. An understanding of the pattern of spike shedding
will be of use to identify the factors responsible for
the same which will in turn help to arrive at effective
control measures.

In view of the above facts, the present studies
have been undertaken in pepper at the College of
Horticulture, with the following objectives.

To study (i) the pattern of growth and flowering

(ii) the floral biology

(iii) the pattern of spike shedding.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Piper nigrum,L,the black pepper of commerce is systematically placed under the family Piperaceae of the order Piperales.

Engler and Prantle as quoted by Benson (1970) regarded the Piperales as representing one of the most primitive type of dicotyledons. Rendle (1971) related Piperales to Polygonales in the trimerous relation of the flower and the orthotropous solitary ovule. Contrary to the views of Rendle and Engler, it is now considered that the family Piperaceae, though of undeterminate origin, is not one of the most primitive dicots, but an independent and terminal offshoot of direct Ranalian ancestry (Shukla and Misra, 1979).

1. GROWTH STUDIES

Growth studies are important for understanding the cropping behaviour of a plant which is evident from the works of Gustafson (1926), Reed (1929), Barnard (1932) and McMunn (1939).

In pepper, growth studies have not been reported so far. But the relation between vegetative growth and

fruitfulness has been studied in various other crops,
such as apple (Barnard and Reed, 1933), mango (Naik
and Rao, 1942; Spencer and Kennard, 1955;
Krishnamurthi et al., 1961; Teotia et al., 1970),
citrus (Raimund, 1949; Krishnamurthi et al., 1960;
Randhawa and Sinha, 1963; Singh and Ghose, 1965;
Hariano and Marioko, 1975), sapota (Sundararajan, 1961)
and guava (Aravindakshan, 1964).

In mango, growth in a particular season influen-
ces greatly the capacity for flower production in the
succeeding season. The nature of shoot growth in mango
is cyclic as described by Naik and Rao (1942) and
Krishnamurthi et al. (1961). They observed that a period
of growth alternated with a period of quiescence. During
the course of one year, five cycles of growth were re-
corded. Teotia et al. (1970) concluded that tree vigour
could be taken as a criterion for yield in mango.

Halma and Compton (1936) studied the importance
of growth flushes in citrus. Krishnamurthy et al. (1960)
distinguished five cycles of shoots growth for one year.
The maximum total growth was observed to be in the month
of March, followed by that in July, August and September

in the descending order. Similar observations were made by Randhawa and Sinha (1963) and Singh and Ghose (1965).

In citrus, Saur (1951) classified flowering shoots as (i) shoots bearing flowers but no leaves (ii) shoots bearing flowers and few leaves (iii) shoots with leaves and solitary flowers (iv) shoots with several flowers and several large leaves and (v) vegetative shoots with no flowers. In mango, Naik and Rao (1942) classified them as shoots with flowered leaders, non-flowered leaders and current year's leaders. In guava Dasarathy (1951) distinguished the current season shoots as flowering and vegetative types. They were classified into three as shoots which produced flowers and ceased growth, shoots which continued growth producing flowers and shoots purely vegetative (Aravindakshan, 1964).

In pepper the inflorescence is produced on the fruiting branches also known as the laterals. The lateral branches are plagiotropic with a sympodial growth habit and showing a periodical growth (De Waard and Zeven, 1969).

2. SEX AND SEX RATIO

Koorders (1908) reported that most wild _Piper_ species and some wild forms of _Piper nigrum_ in the Western Ghats were dioecious. But surveys conducted in the forests of the Western Ghats revealed the frequent occurance of hermaphroditism among the wild types, as pointed out by Nambiar et al. (1978).

In pepper, majority of the cultivated varieties are reported to be hermaphrodite (Hasan Iljas, 1960; Nambiar and Sayeed 1962; Martin and Gregory, 1962), but there are few exceptions like Uthirankotta, Karuvilanchi and Mundi, which are predominantly pistillate.

Hasan Iljas (1960) observed that stamens may be present in a rudimentary form embedded in the tissues below the surface, which provided on explanation for the restricted hermaphroditism in some of the female cultivars. Male plants though rare could be easily recognised by their vigorous vegetative growth (Koorders, 1908; Marinet, 1953; Hasan Iljas, 1960; Cobley and Steele, 1976).

Nambiar et al. (1978) found wide variation among the cultivars with respect to the proportion of male,

female and hermaphrodite flowers in a spike. The
male flowers in a spike varied from 0 to 19 per cent,
while bisexual flowers showed a wider variation of 2
to 93 per cent. The proportion of female flowers has
been found to increase with an increase in the intensity
of shade. Spikes produced during the off-season were
also characterised by more number of female flowers than
in those produced during the normal flowering season.

Shanmugavelu and Rao (1977) have also reported
the influence of season on the sex of pepper vines.
According to them, in the Travancore cultivars the heavy
rains during March to May provide a favourable atmosphere
for exhibiting hermaphroditism. On the other hand, lack
of rain for six months from October have an unfavourable
influence on the Malabar cultivars.

Cramer (1907), Anandan (1924), Blacklock (1954)
and Nambiar et al. (1978) stressed that a high ratio of
hermaphrodite flowers was essential for increased
production.

3. FLOWER PRODUCTION AND BLOSSOM STUDIES

The inflorescence in pepper develops simultaneously
on the current season growth, opposite to a leaf. De Waard

and Zeven (1969) reported the presence of two successive primordials of a raceme within a single bud giving rise to abundant flowering.

The inflorescence of pepper has been variously described as a catkin supporting 50 to 150 small sessile flowers by De Waard and Zeven (1969), a long slender pendulous spike by Cobley and Steele (1976).

De Waard and Zeven (1969) studied the development of the inflorescence in detail. They observed that the spike exhibited positive geotropism several days after emergence. After about 15 days when the immature raceme has increased in length, flowers appeared from the basal portion. A protogynic stage developed and existed for five days, subsequently followed by the appearance of the stamens from the base. Four or five days later each stigma was accompanied by one or two stamens. The development was fundamentally centripetal, but an irregular appearance or dominancy was frequently observed.

From studies conducted at the Pepper Research Station, Panniyur, by Nambiar et al. (1978) the following observations were made. The spike emerged covered in a sheath, the colour of which varied from green to pinkish

or even violet. It took about 20 to 25 days for
the full emergence of the spike from the sheath.
The flowers opened 8 to 14 days after the emergence
of the spike, starting from the base and progressively
advancing towards the tip. The complete opening of
the flowers on a spike took about 6 to 9 days.

The period of existence of the protogynic stage
was found to vary. Anandan (1924) and Cobley and
Steele (1976) reported that in India protogyny exten-
ded over a period of 7 to 8 days. In Puerto Rico 3 to
8 days passed before anther dehiscence was observed
(Martin and Gregory, 1962). According to Hassan Iljas
(1960) protogyny was a varietal character, which some
times did not exist. From recent reports it is seen
that though protogyny is seen in majority of the cases,
the simultaneous opening of the male and female flowers
and protandry are found as exceptions (Nambiar et al.,
1978).

In pepper, the naked flowers are more or less
sunk in the fleshy axis of the spike on which they
closely occur (Benson, 1970; Rendle, 1971). They
described the flowers as minute, bracteate, usually

bisexual, sometimes unisexual with no perianth.
Purseglove (1977) described the bracts as ovate
and fleshy.

According to Rendle (1971), in Piperaceae,
the number of stamens varied from 1 to 10, but most
of the flowers may be derived from a trimerous type
with two whorls, each of 3 stamens, as occurs in
Piper amalago; Piper nigrum has only two stamens
the posterior one of the inner whorl having aborted.
Cobley and Steele (1976) and Purseglove (1977) reported
the number of stamens as 2 to 4, occuring on either
side of the ovary in hermaphrodite flowers. De Waard
(1967) observed that the stamen pushed its way through
the catkin tissue and appeared as a white spherical
body on the top of a short thick filament.

The ovary has been described as ovate, uni-
locular and superior (Cobley and Steele, 1976;
Purseglove, 1977; Shukla and Misra, 1979). The number
of carpels varied from 1 to 4 as reported by Benson
(1970) and 1 to 5 reported by Shukla and Misra (1979).
The ovule is single, solitary and orthotropous with two
or sometimes one integument (Benson, 1970; Shukla and
Misra, 1979). Shukla and Misra (1979) also described
the placentation as basal.

Benson (1970) reported the number of stigma as 2 to 5, while De Waard (1967) and Purseglove (1977) found the number as 3 to 5. Cobley and Steele (1976) described the stigma as star shaped and sessile, the number corresponding to the number of carpels. Martin and Gregory (1962) reported that the succulent papillae of 10 μ in diameter were extremely sensitive to mechanical damage.

3.1 Anthesis

Nambiar et al. (1978) reported that anthesis in pepper commenced from 19.30 hours. Flower opening started from the base of the spike and continued towards the tip.

3.2 Anther dehiscence

In Sarawak, works by De Waard (1967) indicated that dehiscence of anther usually took place between 12.00 and 14.00 hours on days when a relative humidity approximately 60 per cent was attained at a temperature of 32°C and under conditions of bright sunshine. The mass of pollen spilled freely over adjascent stigmas and other parts of the spike. He also observed that

dehiscence within pairs was not simultaneous as a
rule. Nambiar et al. (1978) suggested that in case
of protogyny the anthers dehisced at anytime, within
four days after the stigma became receptive. It was
also reported that temperature and relative humidity
controlled partially the longitudinal dehiscence of
the pollen sac (Hasan Iljas, 1960; Martin and Gregory,
1962).

3.3 Receptivity of stigma

De Waard (1967) associated a viscous condition
of the stigma with receptivity. He also found that
increased relative humidity extended the receptive
period. Nambiar et al. (1978) observed that the period
of receptivity of stigma varied based on the position
of flowers on the spike. The flowers at the base of
the spike had a receptive period of 7 to 9 days, while
it was only 3 to 5 days for those towards the tip.

4. POLLINATION

4.1 Mode of pollination

In pepper several modes of pollination have been
suggested.

Hasan Iljas (1960) has pointed out that the
flower structure of pepper does not facilitate insect
pollination. But Martin and Gregory (1962) had
viewed that wingless insects occassionally occuring on
the recemes may be potential pollinators, which was
supported by De Waard (1967) from similar observations
in Sarawak.

Wind pollination was considered to be as in-
effective as insect pollination by Hasan Iljas (1960).
He found that pollen transportation by wind was negli-
gible. Contrary to this, studies in Puerto Rico by
Martin and Gregory (1962) indicated that 32 to 64 per
cent of the pollen on the spike may be dispersed to the
air within 24 hours of dehiscence and on release the
small grains may be subject to wind transporation.
Insect and wind pollination can evidently be considered
to be accidental in majority of the cases.

Geitonogamy has been suggested as an effective
mode of pollination by Hasan Iljas (1960) and De Waard
(1967). This is a composite mode of self pollination
involving the combined effects of rainwater alternating
with prolonged periods of sun and wind. Dispersed

pollen grains move along the spike by gravity. Free
hanging recemes inside polyethylene isolation bags
displayed an unrestricted fruitset irrespective of
insects or rainwater supporting the occurance of
geitonogamy. According to both the authors, the
factors stimulating geitonogamic fertilisation are
positive geotropism, spiral arrangement of the flowers,
sequential ripening of the stigma and non-chronological
dehiscence of anthers.

De Waard (1967) had also suggested that true
self pollination or autogamy could be effective in
hermaphrodite cultivars, wherein stigma branches curved
very close to the fresh cluster of pollen during
dehiscence. Autogamy was favoured particularly when
environmental conditions promoted the extended period
of receptivity of the stigma.

Nambiar et al. (1978), who could find large number
of pollen grains in dripping water suggested that rain
water was the chief pollinating agent in pepper. The
evidence for this was drawn from an observational trial,
wherein a few vines were protected from rain, half of
which were sprayed with water and the other half left

unsprayed. Normal setting was found in vines sprayed with water, while the vines left unsprayed gave only a very low fruit set.

4.2   Artificial Pollination

Martin and Gregory (1962) described two diffe- rent methods of hand pollination in pepper. In one method ripe anthers were opened by means of a scalpel and the pollen mass scooped up, which was applied to the appropriate stigma. The efficacy of this method was low. The other method consisted of brushing both donor and receptive spikes using a camel hair brush where fertilization was successful.

De Waard (1967) developed a method of hand pollination, in the cultivar Kutching, making use of the extended period of protogyny. Prior to hand pollination all spikes present on the receiving vine were removed to prevent geitonogamy between neighbouring spikes. At three or more locations branches which exhibited actively growing apical buds were selected and isolated in a bag of cheese cloth streched around a strong wire frame. No other spikes were allowed to develop. As soon as the stigma appeared on the proximal

portion of the spike, a number of these, usually two or three per spike were marked. From the donor vine ripe anthers were selected and placed at the end of a long pin. Subsequently the entire pollen cluster was gently brought into contact with the young stigma. This method was found to be successful in 50 to 75 per cent of routine pollinations.

Nambiar et al. (1978) suggested that it was convenient to restrict pollination to a few flowers in a spike which would open within the next one or two days. In the method developed by them, anthers from the flowers of the selected portion of the spike, were removed with a dissecting needle without causing injury to the ovary and the remaining portion of the spike cut off with a pair of scissors. The emasculated flowers were covered with a paper bag, preferably with paraffin coated paper bag. Pollen grains from selected spikes were collected by washing them with distilled water and collecting the washings or by extracting mature anthers and crushing them in distilled water. The pollen suspension thus obtained was used to pollinate flowers using a fountain pen filler, which was carried out at 20.00 hours. For ensuring maximum set the process was repeated for 3 to 5 successive evenings.

The pollinated spikes were kept covered till fruits started developing.

5. POLLEN STUDIES

Study of pollen grains is of great significance in floral biology and in interpreting taxonomic relationships and the origin of plants. The storage and germination of pollen grains play an important role in assisted pollination and hybridisation programmes.

5.1 Pollen production

Oberle and Geortzen (1952) and Rao and Khader (1962) suggested the use of a haemocytometer for estimating the pollen produced by a flower. In pepper, the number of pollen per anther is found to vary with cultivars. In Indian cultivars, the pollen yield per spike was estimated to be 5,00,000 to 7,00,000 by Marinet (1955) and 1,00,000 to 3,00,000 by Martin and Gregory (1962).

The influence of atmospheric conditions on pollen production has been reported by Brooks and Puri (1963), which was supported by results obtained by Sharma and Singh (1970) in mango. Higher temperature and drier climate appeared to be associated with increased pollen

production per anther. According to Stanley and
Linskens (1974) it is possible to derive a regres-
sion coefficient to predict the day of maximum
pollen shed for any one species at a given location,
from the degree hour heat sums if sufficient data is
available.

5.2 Pollen morphology

Pollen morphology as an expression of phylogeny
and evolution of plants has been stressed by various
workers (Wodehouse, 1935; Rao, 1961; Nair,1965).
According to them the form of pollen grains was as
useful as any other characteristic in the classifica-
tion of plants. As a general rule, they served best
in distinguishing between higher groups of plants such
as tribes, families, genera and some species. This
view was supported by the works of Fogle (1977) and
Maas (1977) who have suggested pollen ultrastructure
as a means to identify the tree fruit species and even
clones within species. Nair (1965) classed the pollen
grains of the family Piperaceae as monocolpate. Several
investigators (Hasan Iljas, 1960; Martin and Gregory,
1962) reported that pollen grains of pepper were small
with a mean diameter of 10 µ irrespective of cultivars.

5.3   Pollen viability

Stanley and Linskens (1974) have classified the methods for testing the viability of pollen grains as germination and non-germination assays. In pepper, pollen viability studies have not been reported so far. However, in many other crops this has been pursued in detail.

5.3.1   Stain tests.

Zirkle (1937) suggested a method for testing the viability of pollen grains, by mounting them in aceto-carmine. The grains which stained well, looked plumpy and well shaped were taken by him as fertile and the unstained shrivelled ones as nonviable or sterile. This method have been adopted by Balasubramanyam (1959) in guava, Nirmalendunath and Randhawa (1959) in pomegranate, Singh (1961) in mango, Singh (1962) in litchi, Nalawadi et al. (1977) in sapota and Thankammapillai et al. (1978) in ginger to find out the percentage of fertility.

The staining properties of various other compounds, suggestive of pollen fertility have been reported. They are iodine (Barnett and Carver, 1964; Brooks and Brooks, 1967), tetrazolium salts (Aslam et al., 1964) and propino-carmine (Deshmukh et al., 1978).

The different stains possess specific staining
properties as explained by Stanley and Linskens (1974).
According to them acetocarmine preferentially stained
chromosomes, iodine stained starch and tetrazolium
salts changed their colour in the presence of enzymes
occuring in the viable pollen. They further observed
that the use of stains was not sufficiently accurate
when compared to germination tests because the immature
and aborted pollen grains contained levels of constitu-
tive chemicals enough to yield positive results in the
stain tests.

5.3.2 <u>Pollen germination</u>

Compared to stain tests, in vitro germination
of pollen can give a more accurate index of pollen
viability. The level of germinability determined in
vitro is some what inacurate according to Nair (1977).
Addicott (1943) and Visser (1955) viewed pollen germina-
tion and pollen tube growth as two distinct physiological
processes independent of each other.

5.3.2.1 <u>Role of sucrose in pollen germination.</u>

The role of sucrose in pollen germination and
tube growth have been much debated. Many workers believed

that the externally supplied sugars had only an
osmotic role and were not utilized by the tube for
any nutritional purpose (Jost, 1905; Martin, 1913;
Anthony and Harlan, 1920; Visser, 1955). This view
was contradicted by others (Brink, 1924; O'Kelly, 1955;
Vasil, 1958), who pointed out that apart from having
an osmotic role the externally supplied sugars in the
medium or in the style definitely served as a nutrient
material for the growing tubes. However the work of
O'Kelly (1955) has shown that germination was neither
an osmotic or turgor phenomenon nor did sugars serve
merely as a source of nutrition.

Adams (1916) obtained good pollen germination
at various concentrations of cane sugar for different
crops such as 2.5 to 10 per cent for apple, 4 to 8
per cent for pear and 8 per cent for black currants.
Successful pollen germination in many other crops have
been reported. This include 20 per cent sucrose and
1.5 per cent agar for plum (Randhawa and Nair, 1960),
16 per cent sucrose and 0.7 per cent agar for sapota
(Rao and Khader, 1960), 25 per cent sucrose and 0.5
per cent agar for mango (Singh, 1961), 30 per cent
sucrose for cashew (Damodaran et al., 1966) and 15 per
cent sucrose for cocoa (Ravindran, 1977).

Brink (1924) observed that when pollen was
cultured in sugar or sugar agar medium the pollen
tubes were as long or even longer than those formed
in nature.

5.3.2.2 Effect of boric acid in pollen germination.

Schumucker (1935) discovered the stimulative
role of boric acid in pollen germination and tube
growth. In Nymphaea and in many other species studied
by him, the element was found to occur in the pistil-
late tissues. Since then the role of boric acid in
germination and tube growth had been studied by various
workers in many plants. Thompson and Batjer (1950) in
their studies on the pollen of different species of
fruit trees, found that boron or boric acid in low
concentrations of 25 to 40 ppm stimulated both germina-
tion and tube growth. Resnik (1956) observed that the
addition of boric acid at concentrations ranging from
10 to 100 ppm improved germination by 10 to 15 per cent
in 'Mayer' lemon. He obtained similar results with many
other varieties and species of citrus.

Studies by Munzer (1960) revealed that 1 to 10
per cent boric acid stimulated pollen germination and
tube growth in more than 60 species of angiosperms.

Singh (1961) obtained increased pollen germination and tube elongation in mango with 20 ppm boron or boric acid. Rao and Khader (1960) found that germination of sapota pollen could be enhanced appreciably by the addition of 100 ppm boric acid to the sucrose-agar medium. Jose and Magoon (1972) could improve germination and tube growth with 200 ppm boric acid added to 5 per cent sucrose medium. Ravindran (1977) also emphasised the need of boric acid (100 ppm) for proper germination and tube growth of cocoa pollen.

5.3.2.3 Effect of calcium nitrate in pollen germination.

The influence of calcium nitrate on pollen germination and tube growth, though not as effective as boric acid, is reported by various workers. It has been found that the addition of electrolytes to pollen culture hinder growth or inhibits it entirely. Lidforss (1896) and Brink (1924) observed that calcium nitrate even in small amounts were toxic to pollen. Contrary to this, works by Brewbaker and Kwack (1963), Kwack and Brewbaker (1963), Kwack (1965), Jose and Magoon (1972) and Ravindran (1977) have revealed the essential role of calcium in pollen germination and tube growth. The action of calcium

appeared to be based on the non-metabolic incorporation
of calcium into pectic substances of the pollen wall.
It has also been suggested that the presence of calcium
resulted in increased resistance against the bursting
of pollen tubes.

5.4   Pollen storage

Pollen being a very delicate material, its
handling requires great care. Various workers have
described the methods of collecting pollen in detail
(Fletcher, 1906; Barrett and Arisumi, 1952; Stanley
and Linskens, 1974).

The term "pollinicuration" has been proposed
by King (1962) to refer to procedures as collection,
drying, testing viability, storage and shipment, parti-
cularly as those inclusive in the techniques of plant
breeding.

A proper combination of factors such as low
temperature, relation humidity and light have great
bearing on pollen storage, as is evident from various
reviews made by Pfundt (1910), Knowlton (1922),
Doroshenko (1928), Nebel and Ruttle (1937), Maheshwari
(1944), Visser (1955) and Singh et al. (1961).

5.4.1   <u>Storage by controlling temperature and humidity.</u>

King and Hesse (1938) studied the pollen storage
requirements of 16 deciduous fruits and found the optimum
temperature for storing pollen to be about 30°F. Nebel
(1939) could successfully store the pollen of apple,
pear, plum, peach and apricot for 2 to 5½ years in
desiccator over sulphuric acid with 50 per cent. R.H.
at 28°C. Gollmick (1942) was able to extend the via-
bility of grape pollen for a year at 1°C and 40 to 50
per cent R.H. Similar successful pollen storage studies
by controlling temperature and humidity were conducted
in papaya (Traub and O'Rork, 1936), coconut palm
(Liyanage, 1949), olive (Nicolaissen, 1953), stone fruits
(Remy, 1953), grapes (Nagarajan et al., 1965) jack
(Sinha, 1972) and lime (Shukla and Misra, 1975).

5.4.2   <u>Storage by freezing.</u>

Griggs et al. (1953) were able to store the
pollen of plum, peach, almond, apple, pear, cherry and
olive for 1 to 3 years in a home freezer at - 18°C.
They observed that there was no difference in the germina-
tion percentage of pollen at the time of collection and
almost after one year of storage. Singh (1962 a) reported

the viability of mango pollen to be 14 months, when stored in deep freeze condition in a desiccator. In citrus, 50 per cent viability after 90 days storage in deep freeze was recorded by Sachan and Patro (1970). In Kagzi lime, Shukla and Misra (1975) reported 40 to 64 per cent fruit set with pollen stored in deep freeze for 15 days. Lyophilization or freeze drying of pollen has been reported to be one of the efficient method of pollen storage (Stanley and Linskens, 1974; Nair, 1977).

5.4.3 Storage by drying and dehydration.

Sedov (1955) made a comparative study of the shade dried and sun dried apple pollen and found that shade dried pollen gave better germination. Pollen dried in shade and stored in a desiccator over calcium chloride in darkness was found to be most viable. Good storage life over calcium chloride had been reported in various fruit crops by Tatarincev and Ostrowhova (1950, 1956), Soost and Cameroon (1954), Singh (1960, 1961, 1962) and Satjan and Kleeva (1964). In apple Satjan and Kleeva (1964) observed that pollen stored in desiccator for one year failed to germinate in artificial media, but showed germination on the stigmatic surface.

6. FRUIT DROP

Fruit drop is a universal phenomenon exhibited by a wide variety of crops. This problem which is severe in many fruit crops has been much investigated and reviewed as by Coit and Hodgson (1916, 1918), Murneek (1933), Harrold (1935), Srivastava (1938), Naurial (1955), Korrigs and Kester (1959), Singh (1960, 1961), Chadha and Singh (1963, 1964), Singh (1965), Palmer et al. (1968), Pollard and Biggs (1969), Wilson (1969), Rogers (1971), Jawanda et al. (1972) and Harlom et al. (1975).

In pepper, spike shedding has so far been considered as a natural phenomenon. Recently Pillai et al. (1977) have reported that loss of crop due to spike shedding may be as high as 40 per cent, especially during unfavourable years.

6.1 Factors influencing fruit drop

Several theories have been put forward in an attempt to explain the mechanism of fruit drop. Lewis (1946) had postulated that the relative post fertilization production of hormones by the developing embryo determined the further retainment. If embryo failed to develop, the ovulary tissues abscised. If they developed,

the ovulary tissues remained attached until maturity.
In mango degeneration and abortion of ovule as early
as at the four nucleate stage of embryo sac was res-
ponsible for the drop of 40 to 50 per cent of fruits
(Singh, 1965).

Addicott and Lynch (1955) explained the possi-
ble influence of an abscission mechanism, which was
supported by the works of Chadha and Singh (1963) and
Randhawa (1971). A relation between endosperm and
embryo development has been suggested by Leuty and
Bukovac (1968). They observed that fruits about to
abscise and those considered as potential drops were
characterised by a smaller pericarp or no embryo or an
aborting embryo or more than one of these factors.

Hormones are important in that they have a
decisive role in bringing about abscision of flowers
and fruits. Auxin-abscission relationship has been
supported by several workers (Addicott and Lynch, 1955;
Coyne and Al-Yasuri, 1964; Bardwaj, 1975; Hariom et al.,
1975; Varma 1976; Addicott and Wiater, 1977). The
influence of gibberellins, abscisin, cytokinin and
ethylene on abscission had also been explained by various
workers (Gustafson, 1960; Cooper and Henry, 1971;
Varma,1976; Addicott and Wiater, 1977).

According to Bardwaj (1975), the interaction between various growth regulators determine the ultimate abscission. The auxin and gibberellins produced in the seed and the abscision in the pericarp may be transported to and interact at the abscission zone located at the base of the pedicel. If auxin and gibberellin were not available in sufficient amounts so as to neutralize the effect of abscisin, the flower or fruit would be shed. Thus ultimately, the relative balance between various plant growth regulators determines the retention and abscission.

Various external factors are also involved in flower and fruit drop of which temperature (Yamagutchi, 1954) and moisture status of the soil (Carns, 1951) are most important.

6.2   Waves of drop

The abscission of flowers and partially developed fruits is not ordinarily continuous but proceeds in more or less definite waves. The waves of drop have been worke out in different crops. The interval between and the intensity of different waves depend upon several factors such as species, variety, occurance of fertilisation,

position of flowers and prevailing weather conditions
as reported by Randhawa (1971).

In apples, Howlett (1927) recognised two periods
of abscission. The 'first drop' which was heavy, began
shortly after petal fall and lasted for two to three
weeks, while the so called 'June drop' which began a
few days after the completion of the first drop conti-
nued for two to four weeks. This view was shared by
Mc Cown (1938), Vyvyan (1946) and Randhawa (1971).

Chadha and Singh (1964) distinguished three
waves of drop in mango as pinhead drop, post setting
or 'April drop' and unripe fruit drop or 'May drop'.
In citrus Randhawa (1971) recorded three waves of drop
which were during the month following full bloom,
'June drop' and preharvest drop.

In pepper, Pillay et al. (1977) studied the
various aspects of spike shedding and made the follow-
ing observations. The spikes dropped from the plant
at various stages of their maturity beginning from the
time of emergence to the date of harvest. But the
intensity of shedding was found to be high at two
definite stages of maturity of spikes, that is, after

the fertilization of flowers and then in the advanced
stages of fruit development. They found that the per-
centage of setting in spikes dropped at the early stages
of development was very low, varying from 0 to 25 per
cent. Hence they associated poor setting in the spikes
with the drop observed at this stage. Shedding in the
advanced stages of fruit development was thought to be
due to physiological disturbances in the plant, which
was caused by prolonged spells of drought or heavy rains
or the sharp and sudden alteration of the two. This
view was supported by the observation that intensive
shedding occured during years in which heavy North-East
monsoon showers were obtained after a spell of dry period
following the South-West monsoon.

They concluded that, four major factors, that
is, genetic character of the plant, imbalanced nutrient
status of the soil, climatic factors and diseases or
pests were responsible for spike shedding. They further
observed that the influence of these factors were inter-
related and complimentary. In one season one or more
of these factors may have an upper hand, though the
effects of others cannot be ignored. The extent of shed-
ding in different varieties studied by them varied from
14.02 per cent to 65.62 per cent. In the variety Panniyur-I
shedding was observed to be 26.24 per cent.

MATERIALS AND METHODS

MATERIALS AND METHODS

The studies on the growth, flowering, floral biology and spike shedding were carried out at the Pepper Research Scheme, Vellanikkara (attached to the College of Horticulture) for a period of 16 months from May, 1979 to August, 1980. The vines were 4 years old and were under uniform cultural and manurial treatments as per the package of practices of the Kerala Agricultural University.

The details of the materials and methods adopted are as given below:

1. SHOOT GROWTH

Eight standards of the cultivar Panniyur-I were selected for studying the growth of shoots. Twenty lateral shoots were selected at random on each standard. The shoots were tagged and numbered serially. The extension in shoot length was measured in cm at weekly intervals commencing from 20th May, 1979 to 30th May, 1980.

2. FLOWER CHARACTERS

For studying flower characters, six vines of

Panniyur-I were selected. The various aspects studied
were the pattern of flowering, development of the spike,
sex-ratio and floral biology which included anthesis,
anther dehiscence, stigmatic receptivity and mode of
pollination.

2.1   Pattern of flowering

Twenty lateral shoots of each standard were
selected at random, tagged and numbered serially.
Observations were made for the number of shoots flowered
and number of spikes per shoot.

2.2   Spike development

Fifty spikes on each of the six standards were
observed for studying the developmental stages of
inflorescence. Measurements of spike length in cm were
taken at an interval of 2 days from the day of emergence
to the day of attaining full length. Number of days
required for the completion of anthesis and anther
dehiscence in individual spikes were also recorded by
daily observation of mature spikes. Similar observations
were taken from the cultivar Karimunda.

2.3   Sex ratio

A random selection of fifty spikes on each of the

six standards were used for determining the sex-ratio. From the observation on the total number of flowers in a spike and number of hermaphrodite, pistillate and staminate flower per spike, sex-ratio was worked out. The sex-ratio of Panniyur-I was compared with that of Karimunda.

2.4 Floral biology

To study the floral biology, spikes were collected and flowers were described. Drawings were made of spikes, pistillate and hermaphrodite flowers.

2.4.1 Anthesis..

To know the exact time of anthesis, 25 mature spikes were tagged and observed twice daily in the morning and evening. Preliminary observations indicated that anthesis took place during the late evening. Thereafter mature spikes along with the shoot were plucked at 18.00 hours and kept with their basal portion immersed in water. The spikes were observed at bi-hourly intervals to determine the actual time of anthesis.

2.4.2 Anther dehiscence.

The spikes tagged for determining the time of

anthesis were used for acertaining the time of anther
dehiscence. The maturity of the anthers was evident
from their brownish white colour. From initial obser-
vations it was noted that anthers dehisced during the
afternoon hours. To find out the actual time, spikes
with mature anthers were plucked along with the shoot
at 13.30 hours, kept with their basal portion immersed
in water and observed at hourly intervals.

2.4.3 Receptivity of stigma.

The receptivity of stigma was judged by the
fresh, white colour and the shiny appearance. The
confirmation of this was made by pollination studies.
Mature spikes were selected and bagged using polythene
bags. The spikes were observed daily and 15 to 20
flowers of each spike that would open the next day
were emasculated using a needle. The remaining portion
of the spike was cut off using a pair of scissors, after
which the bags were replaced carefully. A pollen sus-
pension prepared from mature anthers (pollen suspension
was prepared in water by gentle crushing of anthers)
was used to pollinate the flowers using a fountain pen
filler. Pollination was done between 09.00 and 10.30

hours on 25 spikes each at different stages starting
from one day prior to anthesis to eight days after
anthesis. Twenty emasculated spikes were left bagged
without pollination to observe if fruit set took
place in pepper in the absence of pollination.

2.4.5 Mode of pollination.

To find out the role of rainwater in pollination,
the following method was adopted. Fifty spikes were
selected and labelled on each of the six standards used
for the study. Twentyfive spikes of each standard were
covered using polythene bags well in advance of anthesis.
The remaining twentyfive were left open. After fruitset
the bags were removed. The number of flowers which had
set fruit were counted on covered as well as open spikes
and the percentage fruitset worked out.

3. POLLEN STUDIES

The pollen grains of pepper being microscopic
cannot be collected as such. Therefore the method
adopted was to collect mature whole anthers from spikes
plucked from individual standards. The maturity of
anthers was judged from the change of colour from white

to brownish white before dehiscence. A pollen sus-
pension prepared by gentle crushing of such anthers
was used for studying the different aspects of pollen
such as morphology, fertility, number of pollen per
flower, pollen germination and pollen viability.

3.1 Morphology and fertility

A drop of the pollen suspension prepared was
transferred to acetocarmine and glycerine kept on a
clean slide using the base of a dissection needle.
After covering with a clean cover glass, the slides
were kept for about 30 minutes to allow the pollen
grains to take stain properly before examining under a
microscope. The diameter of pollen grain was measured
using an occular micrometer and their average was taken
as the diameter of each pollen grain. The diameter of
50 normal, well shaped and well stained pollen grains
at random were recorded from each slide. From the
total number of well stained pollen grains fertility
was calculated. The experiment was repeated using
iodine-potassium iodide (0.1% iodine in 2% potassium
iodide) as stain.

3.2 Estimation of pollen production

A haemocytometer as adopted by Rao and Khader

(1962) was used for estimating the number of pollen grains per flower. Spikes with mature anthers about to dehisce were collected. Hundred anthers were seperated with a dissection needle and taken in a small beaker. The anthers were crushed gently and 2.5 ml of water containing 0.25 per cent Calgon (Oberle and Geortzen, 1952) was added and the contents thoroughly stirred in order to obtain an even dispersion of the grains in the suspension. A drop of this suspension drawn in a fine pipette was transferred to each of the two counting chambers of a haemocytometer. Each chamber had an area of nine square millimeter ruled into square millimeter areas. Each of the four corner square millimeter areas were ruled into 16 while other five square millimeter areas were ruled into smaller divisions. The counting chambers were 0.1 mm in depth so that the volume of solution over 0.1 mm^2 was 0.1 mm^3. The number of pollen per flower was calculated as,

If N = average number of pollen counted per corner square.

X = number of grains per anther.

N : X = 0.1 : 25.

0.1 = 25 N

X = 250 N

The pollen grains in each of the four corner squares of each counting chamber were counted with the help of a hand tally counter and by using the low power objective of the microscope.

For each standard, ten such estimates were made and the total flowers examined per standard was 250 numbers.

3.3   Effect of sucrose in pollen germination

The experiment was conducted initially using varying concentrations of sucrose (5, 10, 20, 25 and 30%) with 1 per cent agar and incubating in a moist chamber. There was no germination even after 48 hours. Repeating the experiment with lower concentrations did not better the results. Thereafter the concentration of agar was lowered to 0.5 per cent and the experiment carried out with 0, 2, 4, 6, 8 and 10 per cent sucrose where good germination was noticed.

3.4   Effect of boric acid and calcium nitrate in pollen germination

Effects of boric acid and calcium nitrate were determined at 0, 2, 4, 6, 8 and 10 per cent sucrose with 0.5 per cent agar. After incubating in a moist chamber for 4 hours, the growth was arrested with

Carnoy's fluid and observations were made. The concentrations of boric acid and calcium nitrate tried were 10, 20, 30 and 40 ppm. The independent as well as the combined effects were studied.

For estimating germination, on an average, 400 pollen grains were counted from twenty microscopic fields and for tube length 100 pollen tubes were measured using an occular micrometer. Germination was expressed in percentage and tube length in μ . The average value for the experiment repeated thrice was taken.

3.5   Pollen storage

Mature anthers were extracted from spikes with a dissection needle. The anthers were crushed gently in distilled water and tap water so as to get a pollen suspension. Both suspensions were stored as follows:

1. In a deciccator at room temperature.

2. At 4°C.

The viability of pollen under each treatment was determined at daily intervals by staining with aceto-carmine and percentage fertility worked out.

4. SPIKE SHEDDING

For studying the pattern of spike drop, twenty standards of the cultivar Panniyur-I were used. The base of these standards were kept clean and daily counts were made of the spikes shed by each till harvest. The yield of each standard at harvest was determined. The total number of spikes shed by each standard was estimated. The percentage shed during different months was also worked out.

Another trial was conducted to study the different stages of spike drop starting from emergence to harvest. For this, twenty shoots were labelled on each of the six standards. The spikes produced on each shoot were observed at 3 day intervals from emergence.

5. STATISTICAL ANALYSIS

The data on the different characters studied were subjected to statistical analysis, following the methods suggested by Snedecor and Cochran (1967). Transformations were done wherever needed and the data analysed by the analysis of variance technique. Significant results were compared after finding out the critical differences.

RESULTS

RESULTS

The results of the study on growth, flowering, floral biology and spike shedding are presented below. The analysis of variance tables for the different aspects are given in appendices II to IX.

1. SHOOT GROWTH

The extension growth of pepper shoots at weekly intervals from 20-5-1979 to 19-8-1979 is presented in Table 1a. The data showed that shoot growth started at the end of May and continued upto the middle of August. Statistical analysis showed significant variation in the mean extension growth and the percentage of shoots showing growth between weeks at one per cent level.

The maximum mean growth was recorded during the period between the third weeks of June and July (5.55 cm) which accounted to 63.68 per cent of the total growth for the year. The percentage of shoots that showed growth was also maximum during this period, which ranged from 71.25 per cent to 86.25 per cent. This was followed by growth during the period between the third week of May and second week of June (2.37 cm) which accounted to 26.28 per cent of the total growth and when 7.5 to

Table 1a. Weekly growth of pepper shoots (c.v. Panniyur-I)
(Mean of 160 shoots)

Week	Mean extension in cm	Mean growth expressed on percentage of the total	Percentage of shoots showing growth	
20-5-79	0.16	1.39	7.50	(15.89)*
27-5-79	0.30	2.97	18.75	(25.70)
3-6-79	0.50	5.51	37.50	(37.76)
10-6-79	0.61	6.87	50.00	(45.00)
17-6-79	0.80	9.54	62.50	(52.24)
24-6-79	1.01	11.70	71.25	(57.61)
1-7-79	1.05	12.11	82.50	(65.27)
8-7-79	1.11	13.19	85.00	(67.21)
15-7-79	1.25	14.51	86.25	(68.28)
22-7-79	1.11	12.17	78.75	(62.58)
29-7-79	0.64	6.83	56.25	(48.62)
5-8-79	0.32	2.96	37.50	(37.76)
12-8-79	0.06	0.51	12.50	(20.70)
19-8-79	0	0	0	
F value	32.25**		35.00**	
CD (0.05)	0.20		9.81	

** Significant at one per cent level

* Values in parenthesis indicate angular transformed ones

to 62.5 per cent of the shoots showed growth.
Minimum growth (1.02 cm), accounting to 10.30 per
cent of the total was recorded for the period between
the fourth week of July to the second week of August.
During this period growth was observed in 12.50 to
56.25 per cent of the shoots. Thereafter no growth
was observed. The total extension growth for the
year was 10.27 cm.

Considering the months, maximum growth occured
in July (46.70%) followed by June (35.73%), May (4.36%)
and August (3.47%). The percentage of shoots that
showed growth followed the same trend with the maximum
in July (76.32%) and minimum in August (50.00%). Shoot
growth in relation to temperature rainfall and relative
humidity is illustrated in Fig.1.

During the months of June and July, when shoot
growth was maximum, the average temperature was 28.55°C
and 26.05°C respectively. The total rainfall for these
periods ranged between 722.7 mm and 729.8 mm, while the
relative humidity varied between 75.0 and 83.0 per cent
(Appendix I). During May and August, when growth was
low, the temperature was 28.75°C and 26.5°C respectively.
The rainfall ranged from 155.1 mm to 462.6 mm and the

FIG-1 SHOOT GROWTH IN RELATION TO TEMPERATURE RAINFALL AND RELATIVE HUMIDITY
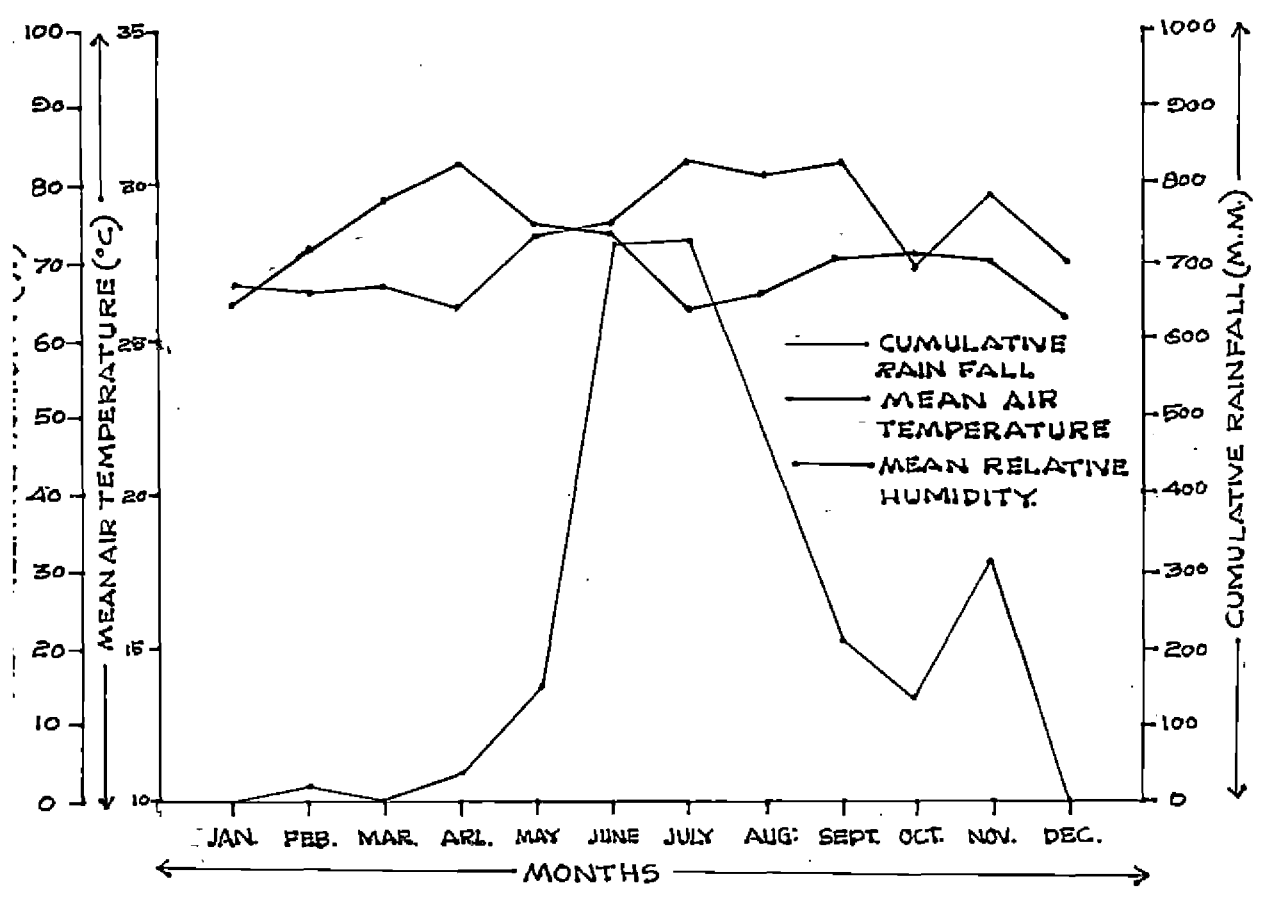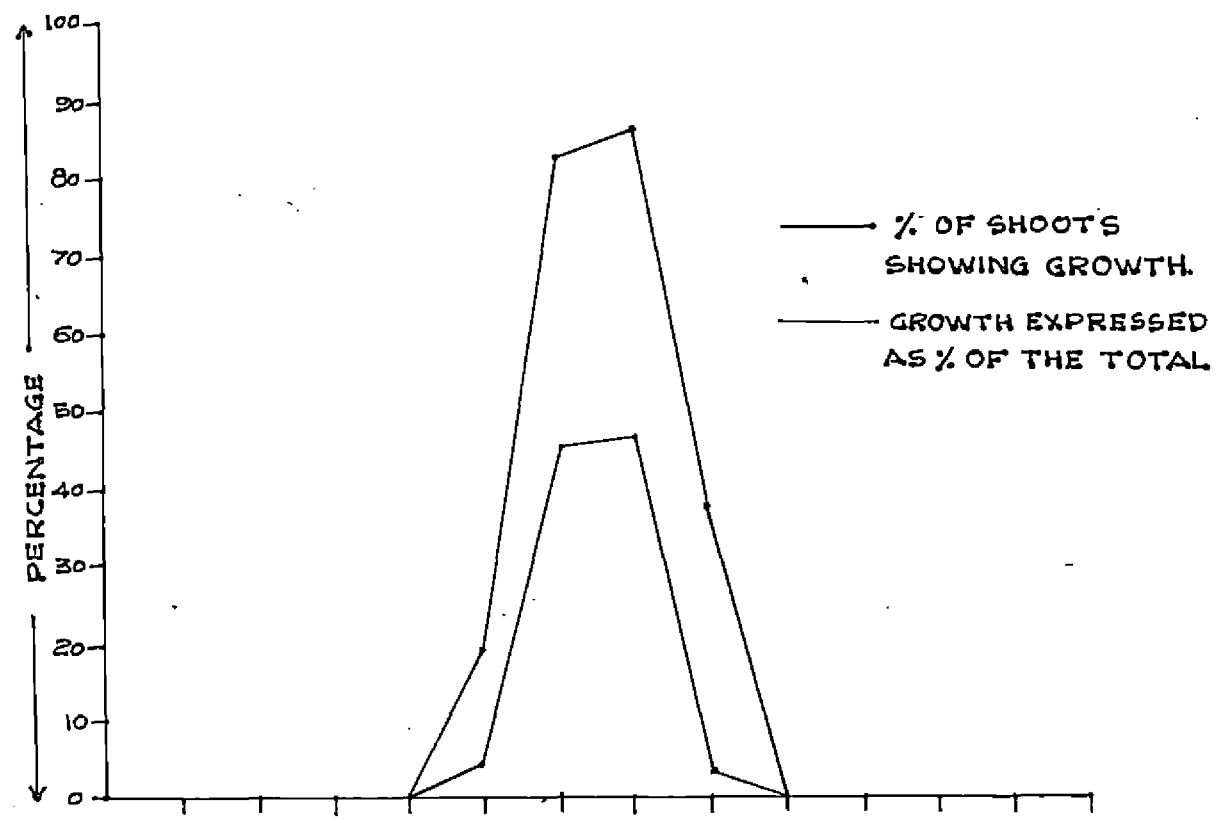
relative humidity from 74.5 per cent to 81.0 per cent. There was no growth from September to November, when rainfall varied between 127.3 mm and 317.4 mm. There was not much variation in temperature (27.7 to 27.55°C) and relative humidity (70.0 to 82.5%).

The mean growth of the individual standards is presented in Table 1b. Statistical analysis showed that the mean shoot extension and the mean percentage of shoots that showed growth in each standard varied significantly at one per cent level. The extension in shoot growth varied between 5.28 cm and 12.04 cm and the percentage of shoots in which growth was observed varied from 65 per cent to 100 per cent.

2. FLOWER CHARACTERS

The results of the studies on flower characters are presented as follows.

2.1 Flowering pattern

The observations on flowering of pepper vines during the different months are presented in Table 2a. The data indicated that in pepper, flowering was confined to four months of the year, 1979, that is, May, June,

Table 1b. Mean extension growth of pepper shoots
in different standards (c.v. Panniyur-1)

Vines	Mean extension in cm	Percentage of shoots showing growth	
S_1	5.28	70.00	(56.79)
S_2	8.79	90.00	(71.56)
S_3	12.04	100.00	(90.00)
S_4	12.00	90.00	(71.56)
S_5	7.80	75.00	(60.00)
S_6	11.73	85.00	(67.21)
S_7	7.09	70.00	(56.79)
S_8	6.58	65.00	(53.73)
P value	13.75**	20.27**	
CD (0.05)	0.20	7.70	

** Significant at one per cent level

* Values in parenthesis indicate angular transformed ones

Table 2. Pattern of monthly flowering in pepper
(c.v. Panniyur-1)

Months	No. of shoots studied	Percentage of shoots flowered		No. of spikes per shoot	
				Mean	% of the total
May	120	35.00	(36.06)*	0.53	11.80
June	120	60.00	(50.83)	1.33	29.62
July	120	79.17	(63.13)	2.26	50.33
August	120	25.00	(30.39)	0.38	8.46

F value 31.93**   95.49**

CD (0.05)0.47   4.56

** Significant at one per cent level

* Values in parenthesis indicate angular transformed ones.

July and August. Maximum percentage of shoots flowered in July (79.17%) followed by June (60.00%), May (35.00%) and August (25.00%). No off season flowering was observed. Statistical analysis showed significant variation between months with respect to the percentage of shoots flowered. The mean number of spikes per shoot also followed the same pattern with the maximum in July (50.33%) and minimum in August (8.46%). There was significant difference in the mean number of spikes per shoot among the months from May to August.

The data on flowering of individual standards are presented in Table 2b. Statistical analysis showed that significant variation existed between standards with respect to the percentage of flowering. S_4 (95%) recorded significantly higher flowering followed by S_5 (85%), S_6 (85%), S_1 (85%), S_2 (85%) and S_3 (80%). No significant difference was noted for the mean number of spikes per shoot between standards. The percentage of aborted spikes varied from 40.1 to 26.31 per cent in different standards.

2.2 Spike development

The extension growth of spikes from emergence is

Table 2b. Pattern of flowering in different pepper
standards (c. v. Panniyur-I)

Details of standard	No. of shoots studied	Percentage of shoots flowered	Mean number of spikes per shoot	Percentage of aborted spikes per shoot
S_1	120	85	3.65	13.69
S_2	120	85	5.15	4.85
S_3	120	80	2.85	26.31
S_4	120	95	4.75	4.21
S_5	120	85	4.55	7.69
S_6	120	85	6.00	0.00
F value		5.72**	2.21[NS]	
CD (0.05)		5.58		

** Significant at one per cent level

NS   Not significant

presented in Table 3a, Fig.2 and Plates I and II.

The spikes of both cultivars showed a linear growth pattern. The length of spike at emergence was 1.34 cm in Panniyur-I, which showed regular increase till the twenty-second day. At this stage the length was 10.2 cm, after which the growth decreased. The spike attained the maximum length of 12.5 cm in 31.67 days.

The spike of Karimunda had a length of 0.9 cm at the time of emergence, which increased steadily till the twenty-fifth day. Thereafter the growth decreased, reaching the maximum length of 6.20 cm in 29.25 days.

The period of spike development, anthesis and anther dehiscence of Panniyur-I and Karimunda are given in Table 3b.

In Panniyur-I, the spike attained maximum length in 31.67 days after its emergence. Anthesis started from the base of the spike and progressed towards the tip. The anthesis of the first few flowers (3 to 12) commenced 17.33 days after emergence. The anthesis of all the flowers in a spike was completed in 25.44 days after emergence. The interval between anthesis of the

Table 3a. Extension growth of spikes from emergence in pepper
(o.vs. Panniyur-I and Karimunda) (Mean of 100 spikes)

	Panniyur-I			Karimunda		
	Extension (cm)	Increase in growth(cm)	Growth expressed as percentage of total	Extension (cm)	Increase in growth (cm)	Growth expressed as percentage of total
1	1.34	1.34	10.72	0.90	0.90	14.52
4	2.70	1.36	10.88	1.40	0.50	80.6
7	3.60	0.90	7.20	1.80	0.40	6.45
10	4.80	1.20	9.60	2.40	0.60	9.68
13	6.30	1.50	12.00	3.00	0.60	9.68
16	7.60	1.30	10.40	3.70	0.70	11.90
19	8.90	1.30	10.40	4.30	0.60	9.68
22	10.20	1.30	10.40	4.90	0.60	9.68
25	11.00	0.80	6.40	5.50	0.60	9.68
28	11.60	0.60	4.80	5.90	0.40	6.45
31	12.20	0.60	4.80	6.20	0.30	4.84
34	12.50	0.30	2.40	0	0	0

FIG-2 EXTENSION GROWTH OF SPIKES (CVS. PANNIYUR-I AND KARIMUNDA)
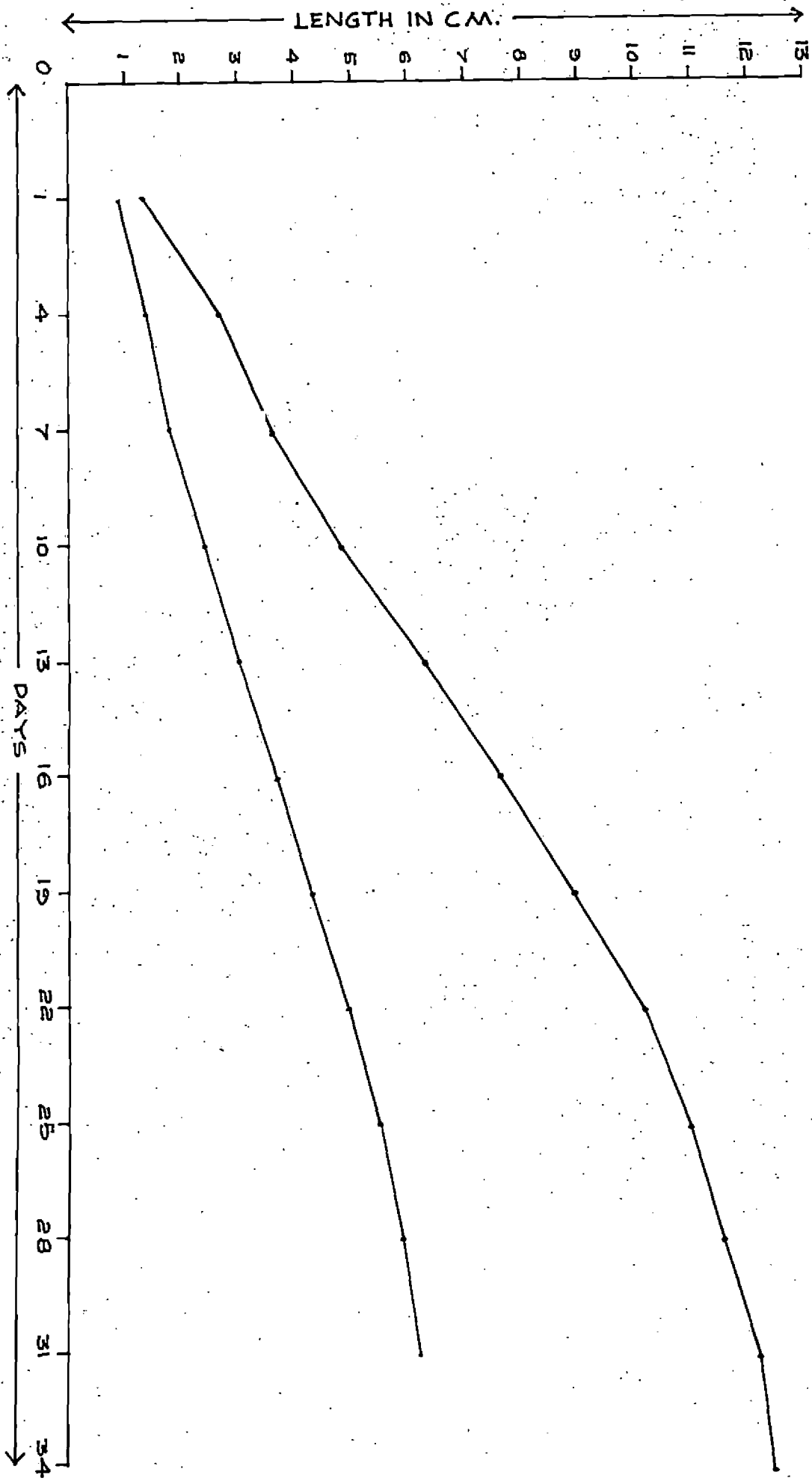
Plate I   Stages of spike development in cv. Panniyur-I

Plate II   Stages of spike development in cv. Karimunda

Table 3b. Pattern of spike development, anthesis and anther dehiscence in pepper
(o. vs. Panniyur-I and Karimunda)

Cultivar	Mean number of days taken from emergence to						
	Attain max. length	First flower opening	Last flower opening	First anther dehiscence	Last anther dehiscence	Interval between first and last flower opening	Interval between first and last anther dehiscence
Panniyur-1	31.67	17.33	25.44	23.85	31.57	8.12 (range 6 - 10)	7.72 (range 4 - 9)
Karimunda	29.26	19.01	28.22	24.23	29.28	9.21 (range 4 - 11)	5.0 (range 3 - 8)

first and the last flower was 8.12 days. The immature
spike was green in colour, the colour being retained
for the first 4 to 5 days of anthesis. Thereafter a
greenish yellow colour developed from the base and
continued towards the tip. The colour deepened as the
days advanced and the whole spike attained a yellow
colour by the time all flowers were open. The stigma
had a white, shiny appearance during the receptive
period. The flowers were protogynous and the protogynic
stage existed for 6.52 days. The anther dehiscence
usually commenced from the base of the spike, progressing
towards the tip. But a non-chronological dehiscence was
observed occassionally. The first anthers (1 to 6)
dehisced 23.85 days after spike emergence. The dehiscence
was longitudinal, which within anther pairs was not
simultaneous. The anthers which were white in colour
initially, turned brownish white before dehiscence.
The dehiscence of all the anthers in a spike was comple-
ted in 31.57 days and the period of dehiscence was 7.72
days.

The spike development pattern in Karimunda was
similar to that in Panniyur-I, differing in the mean
number of days taken for attaining the various stages.
The spike attained maximum length in 29.26 days. Anthesis

started 19.01 days after emergence and was completed
in 28.22 days after emergence, the period being 9.21
days. Anther dehiscence commenced 24.28 days after
emergence and lasted for a period of 5.00 days. The
protogynic condition existed for 5.27 days.

2.3 Floral biology

The different aspects of floral biology of
pepper are described below.

2.3.1 Sex ratio.

The sex ratio pattern of Panniyur-I and Kari-
munda are given in Table 4. In Panniyur-I, two types
of flowers that is, hermaphrodite and pistillate, were
observed. The total number of flowers per spike ranged
between 99 and 116.85 with a mean of 107.74. Herma-
phrodite flowers varied from 96.0 to 112.6 with a mean
of 104.7 and accounted to 97.18 per cent of the total
flowers per spike. The rest which were pistillate
flowers ranged between 1 to 4 with a mean of 3.13
(2.82%).

In Karimunda, the total number of flowers
observed per spike varied from 42.50 to 48.61 with a
mean reaching 46.23, which were all hermaphrodite.

Table 4. Pattern of sex-ratio in pepper (c.vs. Panniyur-I and Karimunda)

Variety	Mean number of flowers/ spike	Mean number of hermaphro- dite flowers	Percen- tage	Mean number of pistil- late flowers	Percen- tage	Mean number of stami- nate flowers	Percen- tage
Panniyur-1	107.74	104.7	97.18	3.13	2.82	0	0
Karimunda	46.23	46.23	100.00	0	0	0	0

2.3.2 Hermaphrodite flower.

The flowers occured closely, more or less sunk in the fleshy axis of pendant spikes (Plate III & IV). Individual flowers were small, measuring about 2 mm, bracteate and without perianth. The bracts appeared, ovate, fleshy and sheild like. The stamens, which were persistant varied from 1 to 2, each consisting of two anthers, borne on a very short filament. The anthers were spherical, white before and brownish black after dehiscence. The stigma was sessile, star shaped and deciduous with 3 to 4 lobes. The stigma was shiny white when receptive, turning black after fertilization. The ovary was globose, ünilocular and superior, with a single orthotropous ovule.

2.3.3. Pistillate flower.

Pistillate flowers resembled hermaphrodite flower except for the absence of stamens.

2.3.4 Anthesis.

The data in Table 5 give the anthesis time of pepper flowers. The anthesis started between 18.00 and 18.30 hours and continued up to 02.30 hours of the next day. Maximum flowers opened between 18.30 and

PLATE-III STRUCTURE OF SPIKE (CV. PANNIYUR-I)

A SPIKE (PART) ENLARGED ×5

T. S. OF THE SPIKE AT THE REGION OF A FLOWER ☿

| PLATE-IV | STRUCTURE OF HERMAPHRODITE FLOWER (CV. PANNIYUR)

A BISEXUAL FLOWER

OVARY. T.S. X 5

STAMEN X 5

SHIELD LIKE BRACT
(SEPARATED)
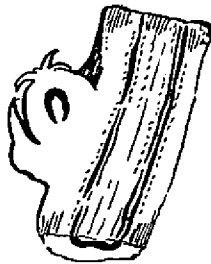
L.S. OF A FLOWER X 5
(STAMENS CAN NOT BE SHOWN
IN THE L.S. BECAUSE THEY ARE
ON EITHER SIDES HENCE THE T.S.)

$\oint \oplus B_r P_o A_2 G_{\underline{1}}$
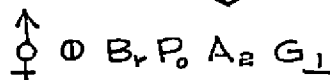
Table 5. Period of anthesis in pepper
(c.v. Panniyur-I)

Time (hours)	Number of flowers observed	Number opened	Percentage of the total
18.00	84	0	
18.30		12	14.28
20.30		36	42.87
22.30		18	21.42
24.30		11	13.10
02.30		7	8.33
04.30		0	0.00
Total		84	100.00

2@.30 hours. The study showed that anthesis in pepper
was for a period of 8.30 hours between 18.00 and 02.30
hours.

2.3.5 <u>Anther dehiscence</u>.

Observations on anther dehiscence at hourly
intervals starting from 13.30 hours are presented in
Table 6. The data indicated that dehiscence started
by 14.30 hours and continued up to 16.30 hours.
Maximum dehiscence (56%) occured between 14.30 and
15.30 hours, followed by 24 per cent between 15.30 and
16.30 hours.

2.3.6 <u>Stigmatic receptivity</u>.

The white, shiny stigmatic surface was found to
be retained up to 5 to 8 days after anthesis. Pollination
studies presented in Table 7 showed that fruit set occured
when pollinated from the day of anthesis up to seven days
after anthesis. Maximum fruit set was recorded during
the first three days, where the set ranged from 77.25
to 85.00 per cent. The percentage of set on the fourth
day was 72.19. Thereafter the set decreased progressively
till the eight day, when it was nil.

Table 6. Period of anther dehiscence in pepper
(c. v. Panniyur-I)

Time (hours)	Number of anther observed	Number dehis-ced	Percentage of the total
13.30	25	0	
14.30		5	20.00
15.30		14	56.00
16.30		6	24.00
17.30		0	0.00
Total		25	100.00

Table 7. Percentage of fruit set on hand pollination at
different intervals in pepper (c.v. Panniyur-I)
(Time 9 AM - 10.30 AM)

Pollinated	Number of spikes	Mean number of flowers pollinated	Mean number set	Percentage set
One day before anthesis	25	20	0	0
First day of anthesis	25	20	15.45	77.25
Second day of anthesis	25	20.47	16.60	81.09
Third day of anthesis	25	20.00	17.00	85.00
Fourth day of anthesis	25	20.10	14.50	72.14
Fifth day of anthesis	25	20.05	13.65	68.07
Sixth day of anthesis	25	20.10	8.00	39.80
Seventh day of anthesis	25	22.00	2.51	11.40
Eighth day of anthesis	25	20.00	0	0
No pollination	25	20.00	0	0

3. MODE OF POLLINATION

The result of the study on the mode of pollination in pepper is presented in Table 8.

The data revealed that spikes protected from rain registered a lower fruit set compared to spikes that were left open. Under bagged conditions, the set ranged from 61.42 per cent to 72.57 per cent with a mean of 67.35 per cent in the different standards. Under open conditions, the set recorded varied from 81.05 per cent to 86.50 per cent with a mean reaching 83.42 per cent. Statistical analysis showed significant difference between treatments at one per cent level.

The effects of different pollination treatments (no pollination, open pollination and hand pollination) are presented in Table 8b. No set was recorded in the absence of pollination. Under open pollination, a set of 83.44 per cent was noticed. When hand pollinated, the set observed was only 80.00 per cent. This indicated that under open pollination, a higher percentage of set was possible than under hand pollination.

4. POLLEN STUDIES

The results of the different aspects of pollen studies are described below.

Table 8a. Fruit set in pepper (c.v. Panniyur-I) under bagged and open conditions

Treatments	No. of spikes observed	Mean number of flowers/ spike	Number set	Percentage set
Spikes bagged	150	100.07	67.13	67.35
Spikes open	150	106.70	89.02	83.42
			t =	2.228**

** Significant at one per cent level

Table 8b. Fruit set in Pepper (c. v. Panniyur-I)
under different pollination treatments

Treatments	Number of flowers observed	Number set	Percentage set
No pollination	250	0	0
Open pollination	640	534	83.44
Hand pollination	150	120	80.00

4.1   Morphology and fertility

Pollen grains of pepper were not visible to the naked eye. Microscopic examination showed that the pollen grains were light brown spherical structures with a well demarcated exine and a single nucleus. A single pollen grain measured 9.52 to 10.20 μ in diameter with a mean reaching 9.86 μ . The fertility recorded by the stain test was 98.47 per cent in acetocarmine and 97.61 per cent in iodine with a mean of 98.04 per cent (Table 9).

4.2   Pollen production

The recorded number of pollen per flower ranged from 7000 to 13000 (Table 10), with a mean of 9542. Statistical analysis showed significant variation between standards at 1 per cent level in the number of pollen grains per flower.

4.3   Role of sucrose in pollen germination

Results of pollen germination in different sucrose concentrations are given in Table 11. Maximum germination was observed in four per cent sucrose followed by six, two, eight, ten and zero. There was no germination in twelve per cent sucrose media. Statistical analysis showed significant difference between treatments at one

Table 9. Pollen morphology and fertility in pepper
(c.v. Panniyur-1)

Stain used	Number of pollen observed	Number of viable pollen	Number of non-viable pollen	Percentage of fertility	Average size of pollen (μ)
Acetocarmine	655	645	10	98.47	10.20
Iodine (0.1%)	630	615	15	97.61	9.52
Total	1285	1260	25	196.08	19.72
Mean		630	12.50	98.04	9.86

Table 10. Pollen production in different standards in
pepper (c'v. Panniyur-T)

Standards	Number of flowers observed	Number of pollen/flower	
		Mean	Range
S_1	250	9090	7000 - 12000
S_2	250	9389	7300 - 11000
S_3	250	10148	7200 - 13000
Total	750	28627	
Mean	250	9542.33	
F value		5.93**	
CD		1709.34	

** Significant at one per cent level

Table 11. Pollen germination in pepper (c.v. Panniyur-I) in sucrose agar media

Sucrose concentration (%)	Interval between incubation and observation hrs.	Percentage germination	Mean tube length (μ)
0	18	3.20	18.70
2	18	69.55	80.86
4	18	87.29	99.82
6	18	73.10	90.50
8	18	45.13	59.67
10	18	20.28	40.21
12	18	0	0

F value   2007.40**

CD   1.53

** Significant at one per cent level

per cent level. The data in Table 12 showed that the
percentage germination in four per cent sucrose-agar
media reached the maximum of 87.29 per cent in four
hours at room temperature in humid chamber. There was
no increase in tube growth after four hours.

4.4   Effect of boric acid and calcium nitrate in
       pollen germination

The effects of boric acid and calcium nitrate
at different sucrose concentrations with 0.5 per cent
agar are presented in Table 13 and Table 14 respectively.

Table 13 revealed that boric acid at 10, 20 and
30 ppm increased pollen germination at all levels of
sucrose. The maximum germination percentage (94.68%)
was recorded in four per cent sucrose with 20 ppm
boric acid.

Data in Table 14 showed that at all levels of
sucrose, calcium nitrate at 10 and 20 ppm increased
germination percentage. But the percentage germination
was reduced in the presence of 30 and 40 ppm calcium
nitrate. Maximum germination (89.97%) was noted at four
per cent sucrose with 20 ppm calcium nitrate.

However, the maximum percentage of pollen

Table 12. Duration of optimum incubation for maximum germination in four per cent sucrose agar media

Sl. No.	Hours after pollen planting	Percentage germination	Tube length
1	1	25.62	28.11
2	2	59.83	44.00
3	3	75.35	69.00
4	4	87.29	99.82
5	5	87.25	99.00
6	6	87.26	99.32
7	7	87.11	99.51
8	8	87.25	99.50

Table 13. Effect of boric acid on pollen germination percentage at different sucrose concentrations in pepper (c.v. Panniyur-I)

Sucrose (%)	Concentrations of boric acid (ppm)				
	0	10	20	30	40
0	3.20	3.44	4.31	0	0
2	69.55	77.37	83.52	77.64	58.58
4	87.29	90.38	94.68	89.20	71.52
6	73.10	76.47	80.22	76.69	62.00
8	45.13	52.15	58.79	54.67	38.10
10	20.28	26.21	33.49	27.67	14.60

F value	643.01**	3394.42**
CD	0.74	0.70

** Significant at one per cent level

Table 14. Effect of calcium nitrate on pollen
germination percentage at different
sucrose concentrations in pepper
(c.v. Panniyur-I)

Sucrose (%)	Concentrations of calcium nitrate (ppm)				
	0	10	20	30	40
0	3.20	1.37	0	0	0
2	69.55	71.80	73.72	69.00	49.36
4	67.29	89.15	89.97	84.57	61.15
6	73.10	75.29	77.66	64.83	44.18
8	45.13	47.13	49.43	41.78	25.31
10	20.28	22.12	23.85	14.29	4.53

F value 1173.58** 5278.17**

CD 0.92 0.82

** Significant at one per cent level

germination (95.77%) was observed for 20 ppm boric
acid and 10 ppm calcium nitrate in four per cent
sucrose and 0.5 per cent agar media (Table 15).

Statistical analysis of the data for pollen
germination showed that the treatments varied signi-
ficantly. The individual effects and the combined
effects of all treatments were found to be significant
at one per cent level. Normal pollen grains and tube
growth in sucrose agar media are illustrated in Plates
V and VI respectively.

4.5   Pollen storage

The percentage viability of pollen grains in
acetocarmine under different treatments, recorded at
daily intervals are presented in Table 16. The data
indicated that pollen grains of pepper could be stored
for 1 to 4 days in water at room temperature and at 4°C.

Pollen suspension in distilled water stored at
4°C remained viable for four days. The viability ranged
from 86.88 per cent on the first day to 12.10 per cent
on the fourth day after collection, with a maximum of
86.88 per cent on the first day. At room temperature
and kept in a desiccator, pollen in distilled water lost

Plate   V   Normal pollen grains of pepper, cv. Panniyur-I
                     (X 120)

Plate   VI   Pollen germinated in sucrose agar media
                     (X 120)
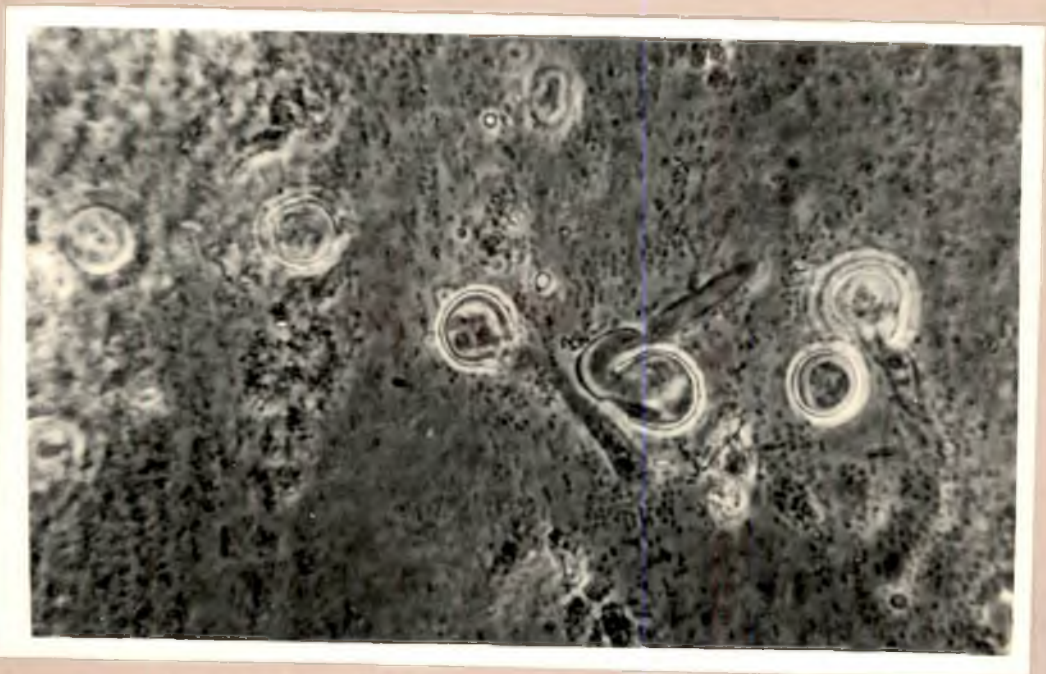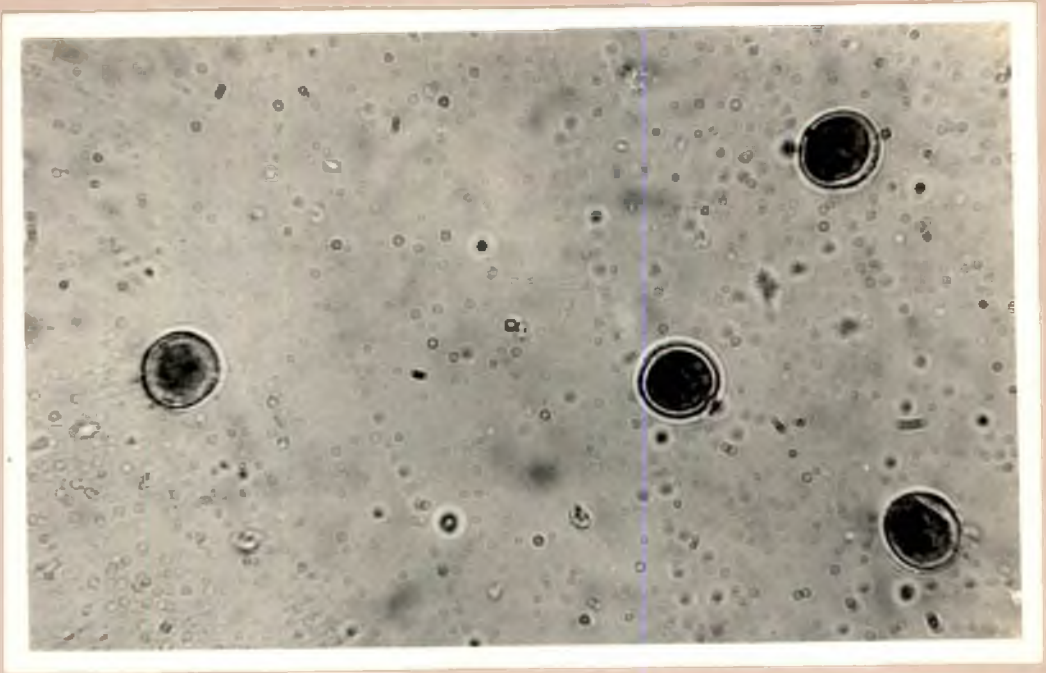
Table 15. Effect of boric acid and calcium nitrate on pollen germination percentage at 4 per cent sucrose in pepper (c.v. Panniyur-1)

Concentration of calcium nitrate (ppm)	Concentration of boric acid (ppm)				
	0	10	20	30	40
0	87.29	90.38	94.68	89.20	71.52
10	89.15	93.19	95.77	93.48	71.94
20	89.97	89.95	90.27	88.39	68.42
30	84.57	86.30	88.35	79.63	60.70
40	61.15	62.33	60.33	50.44	45.53

F value	301.36**	609.68**
CD	1.85	1.53

** Significant at one per cent level

Table 16. Percentage pollen fertility in acetocarmine
under different storage treatments in pepper
(c.v. Panniyur-I)

Treatments	Days after collection				
	1	2	3	4	5
1. Pollen suspension in distilled water					
a. Kept in decdchator at room temperature	65.50	27.17	0	0	0
b. Kept at 4°C	86.88	69.23	33.00	12.10	0
2. Pollen suspension in ordinary (tap) water					
a. Kept in decichator at room temperature	21.96	0	0	0	0
b. Kept at 4°C	79.26	48.67	17.38	0	0

viability on the third day. Here the percentage
viability was 65.50 and 27.17 per cent on the first
and second day after collection respectively.

In tap water, pollen lost viability on the
fourth day when kept at 4°C and on the second day at
room temperature. At 4°C, the viability ranged from
79.26 per cent to 17.38 per cent on the first and third
day after collection respectively. At room temperature,
the viability was only 21.96 per cent after storing for
one day.

5. SPIKE SHEDDING

The observations on spike shedding during the
different months are presented in Table 17 and in Fig.3.
Shedding was observed in almost all the months starting
from flowering till harvest. Maximum shed was noticed
in June (51.31%) followed by July (23.00%), November
(13.94%), December (4.81%), August (2.69%) and October
(2.63%). Shedding was minimum in May (1.69%), while
in September it was nil. Statistical analysis showed
that months differed significantly for the percentage
of spikes shed.

The extent of shedding shown by the different

Table 17. Spike shedding during different months in pepper (c.v. Panniyur-I)

Months 1979	Mean number of spikes shed	Percentage of the total shed	
May	1.69	1.69	(7.49)*
June	51.31	51.31	(45.75)
July	23.00	23.00	(28.66)
August	2.69	2.69	(9.46)
September	0.00	0.00	(0.00)
October	2.63	2.63	(9.28)
November	13.94	13.94	(21.89)
December	4.81	4.81	(12.66)
F value	45.17**		
CD	6.53		

** Significant at one per cent level

* Values in parenthesis indicate angular transformed ones

FIG-3 MONTHLY SHEDDING OF SPIKES IN PEPPER (CV. PANNIYUR-I)
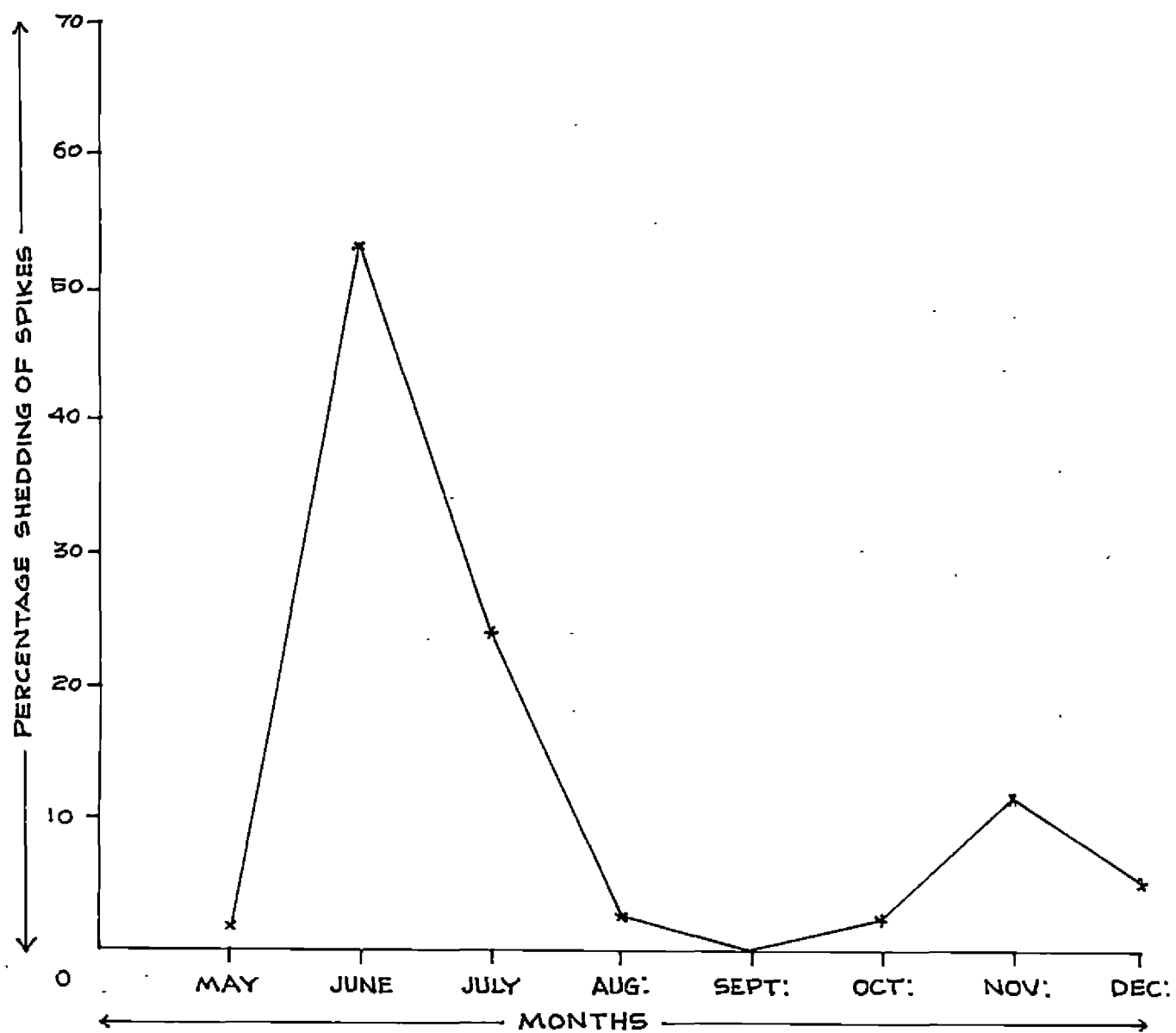
standards is presented in Table 18. The number of
spikes shed by a standard varied from 66 to 168 with
a mean of 100.06 spikes per standard. This accounted
to a mean shed of 23.82 per cent of the total spikes
produced per standard. There was no significant
difference between standards at 1 per cent level.

The data on the percentage of spikes dropped
during the various stages of development is given in
Table 19. The data indicated that spikes were shed at
all stages of development starting from emergence till
harvest. It was possible to recognise eight stages of
shedding. Maximum percentage of shedding (33.15%) was
noticed during the first month of fruit set. This
was followed by shedding before anthesis (24.86%) and
that during anthesis (16.57). The shed showed a decline
during the second (5.52%), third (2.76%) and fourth
(1.66%) months of fruit set which increased to 5.52 per
cent and 9.94 per cent during the fifth and sixth month
of fruit set.

Table 18. Extent of shedding in different standards in pepper (c.v. Panniyur-1)

No.	Number of spikes produced	Number of spikes shed	Shed expressed as percentage of total spikes
S_1	278	158	56.83
S_2	508	168	33.07
S_3	231	144	62.34
S_4	350	120	34.29
S_5	614	81	13.19
S_6	462	102	22.08
S_7	388	101	26.03
S_8	371	66	17.79
S_9	624	113	18.11
S_{10}	347	42	12.10
S_{11}	556	45	8.09
S_{12}	463	49	10.58
S_{13}	797	91	11.42
S_{14}	883	76	8.61
S_{15}	362	92	25.41
S_{16}	825	153	21.10
Total	8059	1601	381.04
Mean	503.69	100.06	23.82
F value		0.26 NS	

NS   Not Significant

Table 19. Shedding of spikes at different stages
of development in pepper (c.v. Panniyur-I)

Sl. No.	Stages	Percentage shed
1	Before anthesis	24.86
2	During anthesis	16.57
3	First month of fruit set	33.15
4	Second month of fruit set	5.52
5	Third month of fruit set	2.76
6	Fourth month of fruit set	1.66
7	Fifth month of fruit set	5.52
8	Sixth month of fruit set	9.94

DISCUSSION

DISCUSSION

The results of the various studies conducted
with respect to growth, flowering, floral biology
and spike shedding are discussed below.

1. SHOOT GROWTH

The maximum extension growth of shoots (82.43%)
and the percentage of shoots that showed growth (71.25%
to 86.25%) in the cultivar Panniyur-1 corresponded to
the months of June and July. Growth ceased by the
middle of August and no further extension was observed.
The extension growth in the different standards varied
between 5.28 cm and 12.04 cm, while the percentage of
shoots showing growth varied between 65 per cent and
100 per cent.

The maximum growth observed during the months
of June and July is natural in pepper considering the
high soil moisture level consequent to rain in June
(722.7 mm) and July (729.8 mm). The maximum and
minimum temperature during that period was 35.7°C and
22°C respectively with a mean of 28.5°C. The relative
humidity during the above two months ranged between
53 per cent and 98 per cent with a mean of 83 per cent.

The optimum temperature and rain may be responsible
for the higher growth during these months and the
lower rainfall during May (155.1 mm) and August
(462.6 mm) for the poor growth during that period.

In addition to the main growth, an offseason
growth is also noticed in pepper during certain years
when a dry spell is followed by high rainfall. But
this was not observed in Panniyur-I during the year
of study. The absence of growth during September
and October may be attributed to the continuous rains
experienced during August (462.6 mm) and September
(208.7 mm). This indicates that continuous rain is
not conducive for a second flush, but more detailed
studies are required to confirm the above indications.

2. FLOWER CHARACTERS

   2.1 Flowering pattern

   The maximum flowering with respect to
the percentage of shoots spiked and the mean number
of spikes per shoots was observed during the months
of June and July. The standards differed significantly
for the number of shoots spiked and the mean number of

spikes per shoot. The data clearly follows the pattern of shoot growth which is quite natural because of the fact that spikes are produced on the current season's growth opposite to a leaf.

The percentage of aborted spikes varied from 0 to 26.31 per cent. The reason for the occurance of spike abortion are not clear. It can be partly explained as due to, physiological and genetic causes. More detailed studies are required in this line.

2.2 Spike developement

The growth of spikes in both the cultivars followed a linear pattern. In Panniyur-I, the spike attained the maximum length of 12.5 cm in 31.67 days after emergence. In Karimunda it took 29.26 days for attaining the maximum length (6.2 cm). The period of anthesis ranged between 6 to 10 days (Mean 8.12) and 4 to 11 days (Mean 9.21) in Panniyur-I and Karimunda respectively. The period of anther dehiscence was 4 to 9 days (Mean 7.72) in Panniyur-I and 3 to 8 days (Mean 5.00) in Karimunda. These observations are in agreement with the findings of Nambiar et al. (1978) except in the number of days taken for attaining maximum length, which according to them was 20 to 25 days.

The flowers were protogynous and the proto-
gynic condition existed for 5 to 8 days (Mean 6.52)
in Panniyur-1 and 3 to 7 days (Mean 5.27) in
Karimunda. Anandan (1924) and Cobley and Steele
(1976) observed that protogyny existed for 7 to 8
days under Indian conditions. Martin and Gregory
(1962) observed protogyny for 3 to 8 days in Puerto
Rico. Nambiar et al. (1978) found the protogynic
stage to last for 2 to 10 days in different cultivars
studied. Therefore the results of the present studies
are in confirmity with the findings of the above
authors.

Protandry and the simultaneous occurence of
anthesis and dehiscence were not observed during
this study as was reported by Nambiar et al. (1978).

The dehiscence of anthers was longitudinal,
which usually commenced from the base of the spike,
though occassionally a non-chronological dehiscence
was noticed. Similar observations were made by
De Waard (1967).

2.3 Floral biology

In Panniyur-1, the mean number of flowers

in a spike was 107.74, of which 104.7 were herma-
phrodite (97.18%) and 3.13 were pistillate (2.82%).
In Karimunda, a spike had a mean of 46.23 flowers,
which were all hermaphrodite. The preponderance of
hermaphrodite flowers in these cultivars is respon-
sible for the high percentage of berry set.

The flowers were bracteate without perianth
as recorded by Benson (1970) and Rendle (1971). The
bract appeared fleshly and shield like as described
by Purseglove (1977). In hermaphrodite flowers, the
stamens were found on either side of the ovary and
the number varied from 1 to 2. Rendle (1971) found
the stamen number as 2, while Cobley and Steele (1976)
and Purseglove (1977) observed the number as ranging
from 2 to 4. The number of stigmatic lobes were
observed to vary from 3 to 4. Benson (1970) recorded
the number of stigmatic lobes as 2 to 5, while De Waard
(1967) and Purseglove (1977) reported the number as
varying from 3 to 5. The slight variation in the
number of stamens and stigmatic lobes in Panniyur-I
is a varietal attribute. The climate and physiological
condition of the vine are also likely to contribute to
such variation. The stigma was sessile and star shaped
as observed by Cobley and Steele (1976). The ovary

appeared ovate, unilocular and superior with a single orthotropous ovule. Similar observations were made by Benson (1970), Purseglove (1977) and Shukla and Misra (1979).

2.3.1 Anthesis

In pepper flowers, anthesis was observed for a period of 8.30 hours between 18.00 hours and 02.30 hours on the next day, with a maximum between 18.30 hours and 24.30 hours. These observations are in confirmity with the findings of Nambiar et al. (1978) who found the anthesis to commence from 19.30 hours under Panniyur conditions.

2.3.2 Anther dehiscence

Anther dehiscence started by 14.30 hours and continued upto 16.30 hours with the maximum between 14.30 and 15.30 hours. The mean temperature during the period of study was 31.1°C and relative humidity ranged between 68.0 and 98.0 per cent.

De Waard (1967) reported that anther dehiscence took place between 12.00 and 14.00 hours at Sarawak, when 60 per cent RH and 32°C temperature prevailed and under conditions of bright sunshine. Hasan Iljas (1960)

and Martin and Gregory (1962) have also reported
the influence of relative humidity and temperature
on anther dehiscence. Slight variation in the time
of dehiscence observed during the present studies
may be attributed to variation in temperature,
humidity and sunshine.

2.3.3 Stigmatic receptivity

Stigmatic receptivity commenced from
the day of anthesis and lasted upto seven days after
anthesis. Receptivity was not observed during the
preanthesis stage. The results are in agreement with
those obtained by Nambiar et al. (1978), who observed
that flowers at the base of the spike had a receptive
period of 7 to 9 days. De Waard (1967) found the
peak period of receptivity to be three to five days
after anthesis, while in the present studies the peak
receptive period was observed to be on the first three
days. The difference observed may be due to climatic
variations.

2.3.4 Pollen studies

Pollen grains of pepper were microscopic.
Pollen grains were spherical, measuring within a range
of 9.52 to 10.2 μ in diameter with a mean of 9.86 μ .

Stain tests recorded 98.04 per cent fertility. Pollen number per flower (in four anthers) ranged from 7000 to 13000 with a mean of 9542.

Hasan Iljas (1960) and Martin and Gregory (1962) found the mean diameter of pollen grains as 10 irrespective of cultivars which is almost in agreement with the present observations.

The pollen yield per spike has been estimated to be 5 to 7 lakhs by Marinet (1955) and 1 to 3 lakhs by Martin and Gregory (1962) in Indian cultivars. According to the present findings, the mean number of flowers per spike is 107 in Panniyur-1 with 97.18 per cent hermaphrodite flowers. Therefore in the case of this cultivar under Kerala conditions 7 to 13 lakhs pollen grains are estimated per spike which is higher than the estimation of the above authors. Even among their findings there is wide difference. Therefore the higher pollen production may be a varietal character which in turn is affected by climatic variations.

Pollen germination studies showed that sucrose, boric acid and calcium nitrate influenced germination of pepper pollen. Germination was observed in zero to ten per cent sucrose with 0.5 per cent agar with a

maximum (87.29%) in four per cent sucrose agar.
Optimum time for incubation was found to be four
hours. In the presence of sucrose and boric acid,
maximum germination (94.68%) was recorded in four
per cent sucrose with 20 ppm boric acid. With calcium
nitrate, maximum (89.97%) was recorded for 20 ppm
calcium nitrate in four per cent sucrose agar media.
With regard to the combined effects of the three,
maximum was observed for 20 ppm boric acid and 10 ppm
calcium nitrate in four per cent sucrose and 0.5 per
cent agar (95.77%).

Pollen germination in sucrose agar media has
been reported in several crops, with varied concentra-
tions such as 25 per cent sucrose and 0.5 per cent
agar for mango (Singh, 1961), 16 per cent sucrose and
0.7 per cent agar for sapota (Rao and Khader, 1962)
and 15 per cent sucrose for cocoa (Ravindran, 1977).
The effect of sucrose in pollen germination may either
be nutritive or due to the osmotic or turgor phenomena
of sugar as postulated by O'Kelly (1955).

The stimulative influence of boric acid on
pollen germination has been reported by various workers
which include 25 to 40 ppm in various fruit crops

(Thompson and Batjer, 1950), 10 to 100 ppm in citrus (Resnik, 1956), 20 ppm in mango (Singh, 1961), 200 ppm in sapota (Jose and Magoon, 1972) and 100 ppm in cocoa (Ravindran, 1977). The results of the present studies are in agreement with the above workers, except in the concentration. The beneficial effect of boron is due to the fact that it is found to occur in the stigmatic fluids and the pistillate tissues as suggested by Schumucker (1935).

Calcium nitrate has been reported to inhibit (Lidforss, 1896; Brink, 1924) as well as promote (Kwack and Brewhaker 1963; Jose and Magoon, 1972; Ravindran, 1977) pollen germination. The promotive action of calcium nitrate in the present studies may be attributed to the non-metabolic incorporation of calcium with pectic substances of the pollen wall and the increased resistance of the pollen tubes against bursting in the presence of calcium as explained by Jose and Magoon (1972).

Pollen storage studies revealed the possibility of storing pollen grains of pepper as a suspension in water. Distilled water proved to be a better storage medium than tap water. In distilled water at 4°C,

the pollen had a storage life upto 4 days, while
in tap water it was 3 days. The shorter storage
life in tap water can be due to the possible
impurities present in it. The fact that pollen
retains its viability in water also suggests the
role of rain water for proper pollination in pepper.

3. MODE OF POLLINATION

Pollination studies showed that under protected
conditions in polythene bags, spikes registered a
lower fruit set (67.35%) than under open conditions.
Hand pollination of spikes showed a lower fruit set
(80.00%) than open pollination (83.44%).

Nambiar et al. (1978) observed a very low fruit
set in vines protected from rains. They considered
rain water as the chief pollinating agent. During the
present studies, though the spikes were protected with
polythene bags it was not possible to exclude water
droplets completely. Water droplets resulting from
high humid conditions within the bag and also due to
transpiration of the spike were retained inspite of the
holes provided at the bottom. These droplets may have

assisted the movement of pollen grains down the
spike, thus effecting pollination. In the pendu-
lous nature of the spike and the dehiscence of anther
from the base of the spike would have helped the
transport of pollen by gravity. The result of the
present study confirmed the view of De Waard (1967)
who found geitonogamy under the influence of gravity
and dew drops to be effective in hermaphrodite
cultivars.

Sreekumary Amma and Vijayagopal (1977)
reported that rain water did not have any role in
pollination of pepper, as they did not find any
difference in fruit-set between protected and un-
protected spikes. But they did not consider the
possible effect of water drops within the bags on
pollination. The significantly lower fruit set
observed in bagged spikes during the present study
indicates the role of rain water in the natural
pollination of pepper.

For the present it is reasonable to assume
that rain water in combination with other factors
such as gravity does have a role in the natural
pollination of pepper.

The lower fruit set under hand pollination
may have been due to the injury caused to the ovary
during emasculation. De Waard (1967) obtained a
set of 50 to 75 per cent with hand pollination which
is lower than that recorded during the present study.
The variation in the results may be due to differences
in the method adopted.

4. SPIKE SHEDDING

Spike shedding was observed in almost all the
months starting from flowering till harvest. The
maximum shed was noticed in June (51.31%) and minimum
in May (1.69%). In September the shedding was nil.
Spike shedding was observed to the tune of 23.82 per
cent of the spikes produced per standard. Spike
shedding occured during the various stages of develop-
ment in varying intensities. The shed which occured
during the period between spike emergence and first
month of fruit set accounted to 74.58 per cent. Shed
during the second, third and fourth months worked out
to 9.94 per cent. During the fifth and sixth month of
fruit set a shed of 15.46 per cent was noticed.

Two waves of spike shedding were observed in
the cultivar Panniyur-I. The first wave started from

the spike emergence to the first month of fruit set,
which corresponded to the period from May to August.
The second wave, which can be considered as pre-
harvest drop corresponded to the months of November
and December. Pillai et al. (1977) could identify
two peaks of spike shedding, that is, in the post
fertilization period and in the advanced stages of
spike development. Dropping of fruits in waves have
been reported in different crops such as apple
(Mc Cown, 1938; Randhawa, 1971) and mango (Singh,
1960; Singh, 1963).

The shed noticed during the period between
emergence and anthesis may be due to an abscission
mechanism as reported by Addicott and Lynch (1955),
Chadha and Singh (1963) and Randhawa (1971) in
different crops. The drop during anthesis can be
attributed to lack of pollination. Poor berry setting
can be considered as a factor responsible for the
shedding noticed during the first month of fruit set.
Pillai et al. (1977) found very low percentage of
setting (0 to 25%) in the spikes dropped during the
post fertilization period. The drop at this stage
may also be related to the relative production of

hormones by the developing embryo as explained by
Lewis (1946).

The drop observed from the second month of
fruit set till harvest can be explained as due to
nutritional or hormonal imbalance. Bardwaj (1975)
have suggested that the interaction of the various
plant growth regulators determines the ultimate
abscission. Pillai et al. (1977) attributed moisture
stress as one of the factors for spike shedding in
the advanced stages of fruit development. But during
the year of study, moisture cannot be taken as a
limiting factor during the pre-harvest shedding,
because there was rain during October (127.3 mm) and
November (317.4 mm). The fact that fungus attack
(Colletotrichum sp) was noticed during the second wave
of shedding indicates the possible association of
pathogens.

During the year of study, shedding observed in
Panniyur-1 was 23.82 per cent Pillai et al. (1977)
observed a shedding of 26.24 per cent in this cultivar.
The variation observed clearly indicates that environ-
mental conditions nutritional factors, and physiological
condition of the vine also play a role in spike shedding.

SUMMARY

SUMMARY

The present studies were carried out at the
Pepper Research Scheme attached to the College of
Horticulture during a period of 16 months from May,
1979 to August, 1980, with the following objectives.

To study (i) the pattern of growth and flowering
(ii) the floral biology and (iii) the pattern of spike
shedding.

The following conclusions were made based on
the present studies.

1. Shoot growth in pepper (c.v. Panniyur-I)
was observed for a period of four months from May to
August.

2. The maximum growth occurred during July
(46.70%) followed by that in June (35.73%), May
(4.36%) and August (3.47%). The percentage of shoot
that showed growth also followed the same trend.
Significant variation was observed for the mean
extension growth and the percentage of shoots showing
growth in the different months.

3. The extension of shoots varied between 5.28
and 12.04 cm with a mean of 10.27 cm. Significant

difference was noted for the mean growth in the different standards. No off season growth was noticed during the year of study.

4. Flowering followed a pattern similar to growth with maximum in July (50.33%) followed by that in June (29.62%), May (11.80%) and August (8.46%). Significant variation existed between standards with respect to the percentage of flowering. The percentage of aborted spikes varied from 0.1 to 26.31 per cent in the different standards.

5. The spike development followed a linear pattern. In Panniyur-I the maximum length (12.5 cm) was attained in 31.67 days, while in Karimunda (6.20 cm) it took 29.26 days.

6. The period of anthesis in a spike varied from 6 to 10 days (Mean 8.12) in Panniyur-I and 4 to 11 days (Mean 9.21) in Karimunda. The anthesis of the first few flowers commenced 17.33 days after emergence of spike in Panniyur-1. The anthesis of all the flowers in a spike was completed in 25.44 days. In Karimunda, anthesis started 19.01 days after emergence and was completed in 28.22 days.

7. The flowers were protogynous. The proto-
gynic stages existed for 5 to 8 days (Mean 6.52) in
Panniyur-1 and 3 to 7 (Mean 5.27) in Karimunda.

8. Anther dehiscence which commenced 23.85 days
after spike emergence, extended for a period of 4 to
9 days (Mean 7.72) in Panniyur-I. In Karimunda it
started 19.01 days after emergence and lasted for a
period of 3 to 8 days (Mean 5.00). The dehiscence
which was longitudinal, usually commenced from the base
of the spike and progressed towards the tip. A non-
chronological dehiscence was observed occasionally.

9. The mean number of flowers per spike in
Panniyur-1 was 107.74, with 97.18 per cent hermaphrodite
and 2.82 per cent pistillate flowers. In Karimunda,
the spike had a mean of 46.23 flowers, which were all
hermaphrodite.

10. Anthesis started between 18.00 and 18.30
hours and continued upto 02.30 hours of the next day.
The peak was recorded between 18.30 and 24.30 hours.

11. Anther dehiscence which started from 14.30
hours continued upto 16.30 hours, with the maximum
between 14.30 and 15.30 hours.

12. The flowers were found to be receptive from the day of anthesis upto seven days after anthesis with the maximum set (77.25 to 85.00%) for the first three days. Receptivity decreased thereafter to 11.40 per cent on the 7th day. The flowers were not receptive during the pre-anthesis period.

13. Pollen was spherical with a mean diameter of 9.86 μ . Stain test recorded 98.04 per cent fertility. Pollen production per flower (7000 to 13000) showed significant variation among the standards.

14. Sucrose, boric acid and calcium nitrate were found to influence pollen germination at specific concentrations. Without boric acid and calcium nitrate, four per cent sucrose gave maximum germination (87.29%). A germination of 94.68 per cent was recorded in four per cent sucrose with 20 ppm boric acid. With calcium nitrate, maximum germination (89.97%) was obtained at 20 ppm in four per cent sucrose. However, a combination of the three was found to be the best, wherein maximum germination of 95.77 per cent was recorded in the media containing four per cent sucrose, 20 ppm boric acid and 10 ppm calcium nitrate.

15. The pollen was found to be viable for 1 to 4

days in water. Maximum viability in acetocarmine
(86.88%) was recorded on the first day after collection
when stored in distilled water at 4°C. The viability
decreased to 12.10 per cent on the fourth day.

16. Significantly higher percentage of set
(83.42%) was obtained under open conditions than in
bagged conditions (67.35%). The result favoured the
view that rain water played a major role in the natural
pollination of pepper.

17. Under open pollination, a higher set (83.44%)
was possible than under hand pollination (80.00%). No
set was recorded in the absence of pollination.

18. Spike shedding was observed in almost all
the months starting from spike emergence till harvest.
Maximum (51.31%) was noticed in June and minimum in
May (1.69%). Shedding was nil in September. There was
significant difference in the percentage of shedding
between months.

19. Shedding in the different standards accoun-
ted for a mean of 23.82 per cent of the spikes produced
per standard. There was significant variation between
standards for the percentage of spikes shed.

20. Spikes were shed at various stages of
development, starting from emergence to harvest.
It was possible to recognize eight stages. Maximum
shedding (33.15%) was noticed during the first month
of berry set, followed by that which occurred before
anthesis (24.86%) and that during anthesis (16.57%).
Minimum shed (1.66%) was observed in the fourth
month of set.

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APPENDICES

APPENDIX - I

Weather data (monthly average) for the period from January 1979 to January 1980.

Month	Tempe-rature	Rela-tive humidity %	Total rain-fall mm	No. of rainy days
January	26.35	67.0	Nil	Nil
February	28.20	66.5	22.0	4
March	29.50	67.0	3.2	1
April	30.70	64.0	46.5	4
May	28.75	74.5	155.1	10
June	28.55	75.0	722.7	22
July	26.05	83.0	729.8	28
August	26.50	81.0	462.6	19
September	27.70	82.5	208.7	18
October	27.70	70.0	127.3	16
November	27.55	78.5	317.4	18
December	25.80	70.0	Nil	Nil
1980				
January	25.70	61.5	Nil	Nil

Source: 'B' class Observatory, Mannuthy.

APPENDIX - II

Analysis of variance for weekly growth of different standards

Source	df	Mean squares	
		Mean growth	Percentage of shoots showing growth
Total	103		
Weeks	12	1.29	3406.95
Standards	7	0.55	1972.42
Error	84	0.04	97.33

APPENDIX - III

Analysis of variance for spiking of pepper standards

Source	df	Mean squares Percentage of shoots spiked	Number of spikes per shoot
Total	23		
Months	3	1311.98	4.47
Standards	5	78.57	0.31
Error	15	13.74	0.14

APPENDIX - IV

Analysis of variance for pollen number per flower

Source	df	Mean squares
Total	29	
Standards	2	10278500.00
Error	27	1734750.00

APPENDIX - V

Analysis of variance for pollen germination in
sucrose agar medium

Source	df	Mean squares
Total	17	
Sucrose	5	1465.18
Error	12	0.73

APPENDIX - VI

Analysis of variance for pollen germination in agar medium with varied concentrations of sucrose and boric acid

Source	df	Mean squares
Total	89	
Sucrose (S)	4	643.01
Boric acid (B)	5	8894.42
S x B	20	33.93
Error	60	1.08

APPENDIX - VII

Analysis of variance for pollen germination in agar medium with varied concentrations of sucrose and calcium nitrate

Source	df	Mean squares
Total	89	
Sucrose (S)	4	1830.79
Calcium nitrate (C)	5	8233.94
S x C	20	91.69
Error	60	1.56

APPENDIX - VIII

Analysis of variance for pollen germination in four per cent sucrose - agar medium with varied concentrations of boric acid and calcium nitrate

Source	df	Mean squares
Total	74	
Boric acid (B)	4	635.87
Calcium nitrate (C)	4	1286.43
B x C	16	18.94
Error	50	2.11

GROWTH, FLOWERING, FLORAL BIOLOGY AND SPIKE SHEDDING IN PEPPER *(Piper nigrum L.)*

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APPENDIX - IX

Analysis of variance for monthly shedding of spikes

Source	df	Mean squares
Total	111	
Months	6	3958.17
Standards	15	22.23
Error	90	86.72

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ABSTRACT

The present studies were carried out in the
College of Horticulture, Kerala Agricultural University,
during the year 1979-80. The object was to study the
pattern of growth and flowering, floral biology and spike
shedding in pepper (Piper nigrum L.). The studies were
conducted on four year old pepper vines (c.v. Panniyur-1
and Karimunda) receiving uniform cultural and manurial
practices as per the package of practices of the Kerala
Agricultural University.

Shoot growth in pepper was observed during four
months of the year, from May to August, with maximum in
July and minimum in August. The mean growth and the
percentage of shoots that showed growth varied significantly
from month to month and standard to standard. The flower-
ing followed a pattern similar to growth. The percentage
of aborted spikes ranged from 4.01 to 26.31 per cent.

The spike development followed a linear pattern.
The spike attained maximum length in 31.67 and 29.26
days in Panniyur-1 and Karimunda, respectively. The
period of anthesis (from the first to the last flower
in a spike) was for 6 to 10 days (Mean 8.12) in Panniyur-1
and 4 to 11 days (Mean 9.21) in Karimunda. Anther dehis-
cence extended for a period of 4 to 9 (Mean 7.72) and

3 to 8 days (Mean 5.00). The protogynic stage existed
for 5 to 8 and 3 to 7 days (Mean 6.52 and 5.27) in the
two cultivars.

In Panniyur-1, the spike had hermaphrodite
(97.18%) and pistillate flowers (2.82%), while in
Karimunda all the flowers were hermaphrodite (100%).

Anthesis started between 18.00 and 18.30 hours
and attained a peak between 18.30 and 24.30 hours.
Anther dehiscence which commenced from 14.30 hours
was maximum between 14.30 and 15.30 hours. Stigmatic
receptivity lasted for seven days after anthesis, with
the maximum for the first three days. Rainwater was
found to be a major factor in pollination.

Pollen grains had a mean diameter of 9.86   .
Pollen production per flower (7000 to 13000) varied
from standard to standard. Sucrose at concentrations
of 2, 4, 6, 8 and 10 per cent, boric acid and calcium
nitrate at concentrations of 10, 20, 30 and 40 ppm each
promoted pollen germination. A combination of the three
(4% sucrose, 20 ppm boric acid and 10 ppm calcium nitrate)
gave maximum germination (95.77%). Pollen remained viable
for 1 to 3 days in water under the different treatments.

Spike shedding which occurred during almost all the months from spike emergence to harvest, was maximum in June and minimum in May. No shedding was observed in September. Eight stages of shedding could be observed, with the maximum shed during the first month of set. The percentage of shedding varied significantly between months and between standards.