IMPACT OF SEED DETERIORATION ON SEEDLING VIGOUR IN MANGO (*Mangifera indica* L.)

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

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DECLARATION

I hereby declare that this thesis entitled **"Impact of seed deterioration on seedling vigour in mango (*Mangifera indica* L.)"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

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Certified that this thesis entitled **"Impact of seed deterioration on seedling vigour in mango (*Mangifera indica* L.)"** is a record of research work done independently by **Miss. P. Anila** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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We, the undersigned members of the Advisory Committee of **Miss. P. Anila,** a candidate for the degree of **Master of Science in Agriculture,** with major in **Plant Breeding and Genetics,** agree that the thesis entitled **"Impact of seed deterioration on seedling vigour in mango (*Mangifera indica* L.)"** may be submitted by Miss. P. Anila, in partial fulfilment of the requirement for the degree.

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ANILA, P.

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ABBREVIATIONS

CSI	- Chlorophyll Stability Index
LAI	- Leaf Area Index
MAG	- Months after germination
V	- Variety
T	- Treatments

Dedicated to my
beloved parents

Introduction

INTRODUCTION

Mango, the king of fruits, is the choicest fruit of India. It is relished and taken by all sections of the people of this country. It is a native of Indo Burman region and is grown in 87 countries. In India, the area under mango cultivation is 1.002 million ha which is 70 per cent of the area devoted for fruit crops (Chadha, 1988).

In Kerala, mango occupies an area of 84537 ha (FIB, 2000). Commercial cultivation is mainly concentrated in the eastern tracts of Palakkad district. Since this fruit is of the tropical rain forest region, the seeds of this fruit have been identified as recalcitrant.

Commercial propagation of mango is mainly through vegetative means. The rootstock needed for vegetative propagation is generated from seeds. Unlike in other fruit trees, rootsock standardisation based on their vigour potential still remains as unfinished task in mango. The present practice is propagating commercial mango varieties through grafting with unselected seedling rootstock. The degenerative processes occurring in storage of seeds and their influence on seedling performance is being neglected in the selection of seeds and also in the selection of seedlings. This results in wide variation in the performance of grafts from the same clone.

The present investigation was undertaken in the Department of Plant Breeding and Genetics, College of Horticulture, Vellanikkara with the following objectives.

1) To delineate the physiological influence of seed deterioration from the genetic variability observed in mango seedlings.

2) To study the effect of seed deterioration on seed germination and growth characters of mango seedlings.

3) To develop a criteria for identifying physiologically vigorous seedlings in the nursery.

Review of Literature

2. REVIEW OF LITERATURE

Most of the agricultural crops are raised from seeds and hence the maintenance of seed viability in storage is of great importance. Certain seeds lose their viability very soon and hence cannot be stored for a long time. These are called as recalcitrant seeds (Roberts, 1973). Most of the plantation crops such as rubber, cocoa, coconut and fruit trees such as mango, jack, mangosteen etc. have recalcitrant seeds (Hanson, 1984). These seeds are shed wet and cannot be dehydrated or stored (Berjak *et al*, 1989).

2.1 Effect of seed size on germination and seedling vigour

Effect of seed size on germination and seedling vigour has been reported in several crops. Germination was not affected by seed size while shoot length was greatest for the large sized seeds in sponge gourd (Mangal *et al.*, 1979). A large amount of variation was noticed among the varieties of oats for germinability and seedling vigour determining characters. The overall germination percentage was high for large seeded varieties. The seed vigour was also higher with heavier seed group followed by moderate and lighter seed group (Mathur *et al.*, 1982). But in groundnut, seed size had no effect on vigour and storability (Usberti, 1982). The same was reported for mango (Costa and Carvalho, 1983).

Lopez and Grabe (1973) reported seed weight to be a better indicator of seedling vigour as it more closely reflected the metabolites utilized in germination. In *Acacia sps.* and *Azadirachta indica*, germination time did not vary with seed weight but seedling height was highest for the high weight seeds. Number of leaflets, biomass production and growth rate varied with seed weight (Oboho and Ali, 1985). In Pinus, a strong positive correlation was recorded between seed weight and early height measures (Toon *et al.*, 1991). In the case of coconut which is also a recalcitrant seed, large seeds showed better performance than medium and small seed nuts (Islam *et al.*, 1997). In mango varieties Espada and Uba, light seeds showed poor performance with respect to germination and seedling growth (Berger *et al.*, 1998).

Germination and seedling vigour were significantly influenced by seed size on pigeon pea. Small and medium seeded genotypes had better germination and mobilization efficiency than bold seeded genotypes, whereas bold seeded genotypes had higher vigour index (Khare and Satpute, 1999).

For polyembryonic cultivars of mango, the larger the embryo, the more rapid the germination and the more vigorous the young plants (Corbineau *et al.*, 1987).

2.2 Seed deterioration

Seed deterioration involves complex changes in many cellular constituents. The accumulation of these changes lead to decreased seed vigour and eventually to loss of seed viability (Farrant *et al.*, 1989).

Changes in quantifiable traits such as physiological and biochemical changes occur when seeds deteriorate. The main physiological changes occurring during seed deterioration is the reduction in germinability. During the deterioration of *Litchi chinensis, Dinocarpus longan* and *Mangifera indica*, the germinability was completely lost at room temperature (25-30°C) after 4-6 days of storage due to water loss (Chin and Fu, 1989).

In an experiment conducted by Anderson (1970) to evaluate the physiological and biochemical differences in barley, it was found that ageing decreased percentage germination considerably but only small difference were found in shoot length. As a result of seed deterioration, decreased germination and viability was reported in many economic crop species (Haferkamp *et al.*, 1953).

Another physiological manifestation of seed deterioration is the increased number of abnormal seedlings. Villiers (1974) reported that severe ageing damage can lead to abnormal seedlings and non-germinating seeds. Seedling abnormalities in roots and shoots and non-survival of some seedlings were reported in aged seeds of *Pisum sativum* (Murrata *et al.*, 1980; Toole and Toole, 1948).

Deteriorated seeds, if they germinate, often produce seedlings which grow slowly (Kearns and Toole, 1939; Parkinson, 1948; Toole and Toole, 1953). When the percentage germination of a seed lot declines, many of the seedlings obtained are abnormal (Navashin, 1933).

Changes occurring within the seed coat of *Cuscuta campestris* during desiccation were correlated with a decrease in germinability (Hutchinson and Ashton, 1979).

Percent germination, seedling length, fresh and dry weight decreases with increase in storage period (Saxena, 1979). This was confirmed by others also (Abdul-Baki and Anderson, 1972; Harrington, 1973; Pakeeraiah, 1985).

2.3 Effect of moisture content on germination and seedling vigour

Roberts (1979) suggested that the death of the recalcitrant seed occurred rapidly at or below some critical moisture content. This varied from species to species and was normally within the range of 12 to 31 per cent. According to Roberts and Ellis (1982) recalcitrant seeds cannot be dried to low moisture contents without loss of viability.

Twenty five per cent moisture content is the critical moisture level for the viability of Shorea seeds (Nautiyal and Purohit, 1985).

Ellis (1987) reported that there is an optimum moisture content below which there is no point in desiccating seeds further to maintain viability in storage.

The critical moisture content in *Mangifera indica* was found as 40 per cent (Fu *et al.*, 1990). Most of the tropical recalcitrant species cannot be cooled below 10-15°C, otherwise they show chilling injury (Roberts and Ellis, 1989). Critical moisture content in jack was assessed as 39 per cent (Krishnaswamy, 1990). The initial moisture level of the mango seed was reported to be around 70-75 per cent and the critical moisture level was at 45-50 per cent (Fu *et al.*, 1990). According to Doijode (1990), reduction of moisture content to less than 25 per cent in Alphonso and 32 per cent in Totapuri was injurious to seed viability and seedling vigour in *Mangifera indica.*

Liou and Kuo (1999) found that the moisture content increased and then decreased during maturation stages and fresh weight also showed the same trend in *Lithocarpus lipidocarpus* and based on these changes, these seeds are classified as recalcitrant.

2.4 Seedling performance

2.4.1 Seedling vigour

Seed vigour, a physiological property is conditioned by the genotype and modified by the environment (Perry, 1977). Speed of germination has been shown to be positively correlated with seed vigour in wheat and rice (Germ, 1960).

A practical measure of seedling growth is rate of germination or field emergence. This had been calculated in various ways such as emergence rate index (Allan *et al.*, 1962), germination rate (Magvire, 1962) and speed of germination (Lawrence, 1963). Speed and completeness may be combined into a single composite value such as the germination value (Czabator, 1962).

The degree of relationship between various indices of vigour and field performances will determine the usefulness of a vigour test.

Roberts (1986) reported that loss of viability in storage is preceded by a wide range of symptoms, collectively contributing to loss of vigour which can lead to decreased field emergence and poorer growth of plants resulting in poor final yield in crops.

Reduction in seed germination led to the decrease of seedling vigour index, shoot and rootlet mean length and weight for *Zea mays* and *Vicia faba* (Auramiuc *et al.*, 1998). In a study conducted on seeds of Neem and Jamun, it was seen that seedling vigour deteriorated much quicker in neem than in jamun. Hence seeds of those species should be sown in the nursery immediately after cultivation (Vanangamudi *et al.*, 2000).

2.4.2 Variability in seedling characters

Variation in a seedling population is attributed to seed characters which are mainly determined by genetic factors and also by environment. The seedlings raised from open pollinated progenies are highly variable in crops like mango. When seeds are to be used in such crops, steps are necessary to reduce the variability in progenies. The most potent means of ensuring uniformity in planting material, therefore appear to be in the direction of making a comprehensive selection of desirable types and building up of their clonal strains by vegetative propagation.

Uttaman and Koyamu (1957) noted considerable variation in cashew seedling progenies. Senanayake (1975) conducted variability studies in eight year old rubber trees. He found that in rubber, the girth of trees was much more uniform. Murthy *et al.* (1975) observed that wide variation existed in cashew germplasm in height, girth, number of primary and secondary branches, leaf length and nut yield. Height of the plant had been considered as an important morphological character related to the growth and development of the plant. The cultivars with vigorous seeds usually produce taller seedling (Yohe and Poehlman, 1975). Plant height was largely determined by the number of internodes or leaves. It was also observed that vigorous plants had more number of leaves than their parents (Ramanujam, 1978). Gopikumar (1978) reported that in cashew seedlings, least variation was noticed in girth. The maximum value for leaf number and dry weight of seedling components such as root, shoot, leaf can be used as s criteria for 'ecting nursery stock for field planting in semi arid conditions (Rawat and Singh,

2.5 Effect of seed deterioration on physiological characters

2.5.1 Seed leachate

The electrical conductivity of a solution in which plant tissues are immersed increases as the tissues die (Weber, 1836; Ranke, 1865). Various studies on naturally aged seeds indicated that more materials leached out of deteriorated seeds than from vigorous and sound seeds (Pollock and Toole, 1966; Mathews and Bradnock, 1968; Ching and Schoolcraft, 1968; Abdul Baki and Anderson, 1970; Mathews and Rogerson, 1976). Increased permeability of the cellular membranes would result in the leaching of organic and inorganic metabolites from the seeds into the imbibing medium (Ching, 1972).

Dehydration induced deterioration of the cell membrane was indicated by high increase in leakage of solutes (Chin and Roberts, 1980). Nagi and Nagi (1982) observed that the conductivity was inversely correlated with germination and fresh weight of shoot and root, while the percentage germination was positively correlated with shoot and root weight.

Measurement of leachate conductivity is most commonly used as a vigour test for grain legumes, species in which many deteriorative changes and even death of tissue can occur leading to increased leakage, indicative of reduced vigour without loss of viability (Powell, 1986). He also found that the level of leakage of solutes is influenced by the stage of seed maturation, the degree of seed ageing and the incidence of inhibition damage. The influence of these factors on leakage is discussed with particular emphasis on the role of deteriorated and damaged membranes in determining solute loss.

As seed deterioration advanced by ageing of wheat seeds, the electrical conductivity of seed leachate increased, speed of germination decreased and germination potential declined (Ram and Weisner, 1988). Leaching of water soluble sugars and leucine increased with seed deterioration. Agrawal (1990) explained this to be due to membrane deterioration during seed storage. These changes preceded the loss in germination.

Normah and Chin (1991) reported that there was an increase in leachate conductivity of rubber seeds as duration of storage increased. Loss of membrane integrity was suggested as one of the causes of seed deterioration during storage. Significant correlation between germination percentage and electric conductivity was observed when the change in electrolyte leakage from sunflower cv. Perodovik subjected to different storing temperature was studied (Paula *et al.*, 1994). Girija (1998) reported that in mango, increase in solute leakage indicate damage to plasma membrane.

2.5.2 Carbohydrate

Corbineau and Come (1985) observed that in mango, starch constituted the main storage reserve. The carbohydrate content in the mango seed was estimated by ICAR and found to be 79.2 per cent. Farrant *et al.* (1993) suggested that the type and quantity of nutrients had given the recalcitrant species an ecological advantage, ensuring rapid germination and subsequent growth. The gradation and the degree of recalcitrancy was found to be associated with the relative quantity and type of carbohydrates. Studies on the regulation of sucrose and starch metabolism in potato tubers by Geiginberger *et al.* (1997) had shown that under water stress, the synthesis of sucrose was accelerated and the conversion of sucrose to starch inhibited since the stress influenced the activities of enzymes involved in starch synthesis and also the concentration of 3 PGA which had declined subsequently.

2.5.3 Phenols

The seeds of many tropical plants contain high concentration of phenolic compounds and phenolic oxidase enzyme. These compounds are normally compartmentalized within cells. On desiccation the cell membranes are damaged and phenolic compounds are released. They are oxidized and protein/phenol complexes are formed with a consequent loss of enzyme activity (Loomis and Battaila, 1966). Total phenolic substances have been reported to be the cause of deterioration of viability in rough lemon (Bhekasut *et al.*, 1976).

It was reported by Kozlowska *et al.* (1983) that the presence of phenolic acid in the seed causes deterioration in the taste, odour and colour of the protein concentrates and prepared food products. The oxidized phenolic compounds could combine with the essential amino acids such as lysine or methionine forming complexes which become toxic later. Nautiyal and Purohit (1985) reported that concomittant with the ageing, there was an enhanced concentration of solutes in the seed leachates, rapid loss in moisture content, overall decline in the carbohydrates, proteins, a slight increase in phenolic contents and the loss of seed viability.

2.5.4 Chlorophyll

It has been reported that considerable chlorophyll loss occurs from desiccation intolerant species which presumably is a reflection of cellular degradation (Bewley and Krochko, 1982).

Chlorophyll stability index was highest (54.03%) in *Acacia auriculiformis* and lowest in *A. holocericea, A. manjium* and *A. aulacocarpa* under water stress conditions (Somen, 1998).

2.6 Anatomical studies

Majumdar *et al.* (1972) found that growth of stem was negatively correlated with bark percentage of root. Arora *et al.* (1978) studied vigour in mango based on bark percentage of root, stomatal count of leaves and number of xylem vessels per unit area of roots. Majumdar and Sharma (1990) reported that dwarfness is related to characters like high bark percentage, small area of xylem vessels and low stomatal density.

2.6.1 Stomatal density

Positive correlation was observed between frequency of stomatal distribution and vigour of plants (Chakladar, 1967). This character was suggested for selection and classification of mango rootstocks at the nursery stage (Majumdar *et al.*, 1972).

Stomatal density and tree vigour were reported to be related in different crops by different authors. Rajeevan and Rao (1975) reported that depending on the environmental condition, in which the leaves develop, the size and distribution of stomata per unit area may show marked variation. Agarwal (1986) reported that increase in stomata number may result in increase on photosynthate formation which eventually may lead to enhanced vigour of plant. Srivastava *et al.* (1980) classified mango rootstocks into dwarf, vigorous and very vigorous based on stomatal density.

2.7 Mitotic index and chromosomal aberrations

Chromosomal aberrations have been noticed during ageing of seeds. Amount of genetic damage is a function of time, moisture content and temperature (Navashin and Gerassimova, 1936; Cartledge *et al.*, 1936). It is well documented that an increase in the frequency of spontaneous chromosomal aberrations occurs in the embryos of aged seeds (Navashin, 1933; Nichols, 1941; D'Amato, 1954; Makinen, 1963; Sax, 1962). Ashton (1956) and Barton (1961) found that chromosomal aberrations are actually produced during ageing.

During ageing, the seeds accumulate chromosome damage, when the frequency of the aberrant cells exceeds some critical value, the embryo is unable to germinate and is classed as dead (Abdallah and Roberts, 1988). Roberts (1979) observed that under all methods of storage, loss of seed viability is associated with the accumulation of considerable genetic mutation. Results of ageing of isolated embryos and endosperms of durum wheat indicated that both aged embryos and endosperms produced mutagenic substances capable of inducing nuclear damage in the form of aberrant anaphases and chromatid and chromosome breaks in the radicle meristem and age induced damage in embryo was not a consequence of endosperm ageing (Floris and Anguillesi, 1974).

Orlova and Soldatova (1980) suggested that the mutability depends upon the rate of deterioration during ageing and that it is not necessarily expressed through typical Mendelian ratios in subsequent generation. Ageing induced loss of seed quality coinciding with an increase in chromosomal aberrations in the seedlings upon subsequent sowing has been reported (Roberts *et al.*, 1984).

Chauhan and Swaminathan (1984) reported that the progeny of aged seeds of soyabean and barley showed a marked decrease in mitotic index and chromosomal aberrations of various types increased at both mitosis and meiosis resulting in a significant loss of pollen viability as the ageing advanced.

In lettuce (*Lactuca sativa* L.) the rate of accumulation of genome damage as well as the rate of viability loss is dependent on the temperature and seed moisture content during storage (Rao *et al.*, 1987). Only a part of the genome damage that takes place during seed ageing may result in visible chromosome aberrations which may interfere with the relation between seed quality and chromosome damage. Guntharett *et al.*(1956) indicated that both chromosomal aberrations and genetic mutations have arisen in the seeds and that the frequencies of these cytogenetic changes increases with age.

Van *et al.* (1995) reported that ageing of tomato seeds cv. Lerica resulted in a significant decrease in seed quality as evidenced by decrease in total germination percentage of normal seedlings and the uniformity of germination. Cytological analysis showed that decrease in seed quality by ageing correlated with increase in percentage aberrant anaphases in the root tips of seedlings.

Materials and Methods

3. MATERIALS AND METHODS

The present study on the impact of seed deterioration on seedling vigour in mango (*Mangifera indica* L.) was conducted in the Department of Plant Breeding and Genetics and Central Nursery, Vellanikkara.

3.1 Materials

Three mango varieties viz., *Chandrakkaran*, *Moovandan* and *Puliyan* were collected for the study. Fruits of each variety were collected during two seasons, March to June 2000 and March to June 2001 for the study. The plants selected were of almost uniform age and all these plants were from the University campus.

3.2 Methods

Fruits were depulped and seeds were collected. Observations were made on the following characters.

3.2.1 Seed Morphology

3.2.1.1 Seed weight

The seeds were weighed in an electronic balance and expressed in grams.

3.2.1.2 Seed length

The length between the stylar end and stalk end of the stone was measured using a metre scale and expressed in cms.

3.2.1.3 Seed breadth

The width of the stone was measured using a metre scale and expressed in cms.

3.2.1.4 Seed thickness

The thickness of the stone was measured using a vernier calipers and expressed in cms.

3.2.2 Planting

Each seed was placed in plastic jar under open conditions and seeds were weighed on alternate days. Based on loss in seed weight, seeds were classified into six groups.

1) T_1 - Fresh seeds

2) T_2 - Seeds which had lost 10 per cent of the original weight

3) T_3 - Seeds which had lost 20 per cent of the original weight

4) T_4 - Seeds which had lost 30 per cent of the original weight

5) T_5 - Seeds which had lost 40 per cent of the original weight

6) T_6 - Seeds which had lost 50 per cent of the original weight

Based on the above treatments, seeds were sown in polythene bags filled with potting mixture (Plate 1).

3.2.3 Seedling characters

3.2.3.1 Germination percentage

The seeds germinated under each treatment was counted and expressed as percentage of seeds sown.

PLATE -1

General view of mango seedlings in the nursery

1. CHANDRAKKARAN

2. MOOVANDAN

3. PULIYAN

3.2.3.2 Seedling height

The height from the ground level to the tip of the germinated seedlings was measured at first, second, third, fourth and fifth month after germination using a metre scale and expressed in cms.

3.2.3.3 Seedling girth

The seedling girth at 1 cm above ground level of the seedlings was measured using vernier calipers of least count 0.1 mm at first, second, third, fourth and fifth month after germination and expressed in cms.

3.2.3.4 Internodal length

The internodal length was measured from the third node using metre scale at first, second, third, fourth and fifth month after germination and expressed in cms.

3.2.3.5 Number of leaves

The leaves per seedling were counted at monthly intervals.

3.2.3.6 Number of sprouts

The sprouts per seedling was counted at monthly intervals.

3.2.3.7 Vigour index

Vigour index was estimated as per the method of Abdul-Baiki and Anderson(1972).

Vigour index = Germination percentage x Height of the seedlings

Vigour index was also estimated in terms of height and girth of seedling. Using the formula

Vigour index = Height of the seedlings x Girth of the seedlings^2

3.2.3.8 Growth suppression factor

Estimated using the formulae

$$\frac{\text{Bark diameter in non stressed plants - Bark diameter in stressed plants}}{\text{Bark diameter in non stressed plants}} \times 100$$

3.2.4 Physiological characteristics

3.2.4.1 Moisture content

Moisture content in seed was worked out as the difference of dry weight from fresh weight expressed as percentage.

$$MC = \frac{FW - DW}{FW} \times 100$$

where MC = Moisture content

FW = Fresh weight (g)

DW = Dry weight (g)

3.2.4.2 Assessment of critical moisture content

For assessment of critical moisture content, the seeds were numbered serially. The initial weight of individual seed was recorded. They were then placed in a single layer on a plastic tray and exposed to sunlight during day time. The loss in weight was recorded and based on this, the moisture content was estimated.

A counter set with almost uniform weight was used for the germination study. The seeds were kept under identical condition and 5 seeds from this set was kept for germination based on their loss in weight. The moisture level upto which the seeds could germinate indicated the critical moisture content. To assess the seed moisture content at this stage seeds from the first lot which had almost uniform value were kept in a hot air oven at 105°C for 16 hours and the dry weight was estimated. The moisture content was estimated as per the procedure given above.

3.2.4.3 Leaf Area (cm^2)

Leaf area of the fourth leaf of seedling was measured using a leaf area meter (Model LI 3100-LI-COR) availing the facility at Kerala Forest Research Institute, Peechi.

3.2.4.3 Leaf Area Index

Leaf area index was estimated as the ratio of total leaf area of plant to ground area. LAI was worked out as suggested by Watson (1952). Here the ground area was taken as the area of the polythene gauge.

3.2.4.4 Seed leachate studies (Abdul-Ba ki and Anderson, 1972)

The seeds were immersed in 50 ml distilled water for 24 hours. The leachate was then collected and estimated for the following constituents.

3.2.4.5 Electrical conductivity

The electrical conductivity of the leachate was estimated using conductivity meter and the EC was expressed as dS m^{-1}.

3.2.4.6 Percentage solute leakage (Presley, 1958)

The EC was expressed in percentage using the formula.

$$\text{Percentage solute leakage} = \frac{\text{EC of leachate}}{\text{EC of leachate + EC of seed extract}} \times 100$$

3.2.5 Biochemical studies

3.2.5.1 Phenol content

Total phenol content was estimated using Folin-Ciocalteau method (Sadasivam and Manickam, 1966). 0.5 g of finely powdered plant sample was ground in a pestle and mortar with ten times volume of water and made upto 50 ml. 1 ml of made up solution was taken in a test tube and made upto 3 ml with water followed by the addition of 2 ml 20 per cent Na_2CO_3 and 0.5 ml Folin-Ciocalteau reagent and kept in a boiling water bath for one minute and cooled down to room temperature. The intensity of blue colour developed after cooling was read at 650 nm in a spectrophotometer. Total phenol content was calculated from a standard curve of catechol and was expressed as mg of phenol per g of the sample.

$$\text{Total phenol content} = \text{Factor} \times \frac{\text{Absorbance}}{\text{Volume made}} \times \frac{\text{Dilution (ml)}}{\text{Weight of sample (mg)}} \times \frac{1000}{1}$$

3.2.5.2 Total sugar content (Somogyi, 1962)

Total sugar content in seeds was estimated using anthrone reagent. 0.5 g of the sample was taken in a tube and hydrolysed by keeping it in a boiling water bath for three hours with 5 ml of 2.5 N HCl and cooled to room temperature. It was then neutralised with solid sodium carbonate until the effervescence ceased. The volume was then made upto 50 ml and centrifuged. From the supernatant solution, 0.5 ml aliquot was taken for analysis. The volume was made upto 1 ml in all the tubes by adding distilled water and 4 ml of anthrone reagent was added. It was then heated for eight minutes in a boiling water bath and then rapidly cooled and the intensity of green colour was read at 630 nm. Total sugar content was calculated from the standard curve of glucose and was expressed as mg of glucose per g of the sample.

$$\text{Total sugar content} = \text{Factor x } \frac{\text{Absorbance}}{\text{Volume}} \text{ x } \frac{\text{Dilution}}{\text{Weight}} \text{ x } 100$$

3.2.5.3 Chlorophyll content (Shoaf and Livm, 1976)

0.1 g of the fourth leaf sample was taken in a test tube and 10 ml of Dimethyl sulfoxide was added to it and kept overnight. The absorbance of the solution was read using Spectronic 20 - Spectrophotometer at 645, 652 and 663 nm against the solvent blank.

$$\text{mg chlorophyll a/g tissue} = 12.7\ (A_{663}) - 2.69\ (A_{645}) \text{ x } \frac{V}{1000 \text{ x } W}$$

$$\text{mg chlorophyll a/g tissue} = 22.9\ (A_{645}) - 4.68\ (A_{663}) \text{ x } \frac{V}{1000 \text{ x } W}$$

$$\text{mg total chlorophyll /g tissue} = 20.2\ (A_{645}) + 8.02\ (A_{663}) \text{ x } \frac{V}{1000 \text{ x } W}$$

$$\text{or} \quad = \frac{A(_{652}) \text{ x } 1000}{34.5} \text{ x } \frac{V}{1000 \text{ x } W}$$

where A_i = absorbance at wave length, i

V = Final volume of chlorophyll extract

W = Fresh weight of the tissue extract

3.2.5.4 Chlorophyll stability index (Murthy and Majumdar, 1972)

Representative leaf samples (0.1 g) were taken in two test tubes and 50 ml of distilled water was added. One tube was subjected to heat in water bath at 55°C ± 1°C for exactly 30 minutes. The other tube served as control. The leaf tissues were removed and blotted with filter paper gently. 10 ml of Dimethyl sulfoxide was then added to the leaf tissue and kept overnight. The absorbance was read at 652 nm in a Spectronic-20 colorimeter. The difference in two readings gave the chlorophyll stability index.

$$\text{Chlorophyll content} = \frac{A_{(652)} \times 1000}{34.5} \times \frac{V}{1000 \times W} \text{ mg/g}$$

$$\text{Chlorophyll stability index} = \frac{\text{Control - treated}}{\text{Control}} \times 100$$

3.3 Stomatal count

Stomatal count was recorded on leaves of one year old seedlings. Five leaves were collected, quick fix was smeared on the lower surface in the mid portion of the leaf during morning hours. After drying, the peel was removed and stomata were counted under microscope. Counts were taken from five fields in each sample and average of 25 fields was worked out. The procedure followed was as per Srivastava *et al.* (1980).

3.4 Anatomical studies

Stem cuttings were taken from tender portion of one year old seedlings and preserved in FAA. Free hand sections were taken from these cuttings, stained with saffranine and mounted in DPX after washing in alcohol series. The sections were observed under microscope.

3.5 Mitotic index

Roots were collected in the active growing stage during 10.30 am (Mukherjee, 1950) and fixed in Carnoy's fluid. The fixed roots were washed thoroughly and stained with Feulgen stain for 45 minutes after hydrolysis with 1 N HCl. The number of dividing cells in a microscopic view were counted and the mitotic index was calculated by the formula

$$\text{Mitotic index} = \frac{\text{Number of dividing cells}}{\text{Total number of cells}} \times 100$$

3.6 Statistical analysis

The data collected were subjected to statistical analysis using MSTAT C package. As unequal replications were present, non-orthogonal module was used to carry out the analysis of variance.

Results

4. RESULTS

The present investigation aims to study the effect of seed drying at the time of sowing on seedling performance and to ascertain the level of drying that contributes to a significant difference in seedling quality.

4.1 Seed biometrics

The biometric characters of seeds of three mango varieties viz., *Chandrakkaran* (V_1), *Moovandan* (V_2) and *Puliyan* (V_3) were studied and the range, mean and coefficient of variation are provided in Table 1.

Maximum seed length was obtained for the variety *Puliyan* (6.07 cm) followed by *Moovandan* (5.77 cm). *Chandrakkaran* had the lowest seed length (5.13 cm).

Seed breadth was also found to vary significantly among varieties. *Moovandan* seeds showed maximum breadth (4.30 cm) followed by the variety *Puliyan* (4.22 cm). Seed breadth of variety *Chandrakkaran* was 3.68 cm.

Thickness of seed was found to be higher for the variety *Puliyan* (2.35 cm) followed by the variety *Moovandan* (2.26 cm). *Chandrakkaran* seeds had a thickness of 1.70 cm.

When weight of seeds were observed, it was noticed that *Puliyan* seeds had a mean weight of 61.11 g. The variety *Moovandan* had an average seed weight of 56.05 g. *Chandrakkaran* seeds had a mean weight of 32.68 g. Seed volume was found to be higher for *Moovandan* (24.92 cm^3) followed by *Puliyan* (21.73 cm^3). The mean volume of *Chandrakkaran* seeds were 14.22 cm^3.

Table 1. Variation in biometric characters of mango seed

Sl. No.	Character	Range			Mean			Coefficient of variation		
		V_1	V_2	V_3	V_1	V_2	V_3	V_1	V_2	V_3
1	Seed length (cm)	4.3-6.2	4.6-7	5-7.2	5.13	5.77	6.07	13.05	12.02	11.8
2	Seed breadth (cm)	3-4.5	3.6-5.1	3.3-5.2	3.68	4.30	4.22	16.88	13.15	12.92
3	Seed thickness (cm)	1.4-2.1	1.88-2.52	2.01-3.1	1.70	2.26	2.35	24.75	19.06	18.15
4	Seed weight (g)	20.83-58.46	37.8-84.22	34.33-86	32.68	56.05	61.11	13.74	9.86	11.32
5	Seed volume (cm^3)	9.55-20.5	15.6-42.81	9.36.38.87	14.22	24.92	21.73	8.63	5.70	5.30
6	Seed density (g cm^{-3})	0.3-0.74	0.24-1.27	0.18-0.44	0.55	0.43	0.36	17.85	14.54	27.7
7	Seed size	5.4-15.96	12.23-27.04	11.44-27.72	11.88	18.83	20.43	15.04	9.91	9.25

Density of seeds were found to be higher for *Chandrakkaran* (0.55 g cm^{-3}) followed by *Moovandan* (0.43 g cm^{-3}). *Puliyan* seeds had a density of 0.36 g cm^{-3}.

When seed size was observed, it was found that *Moovandan* and *Puliyan* did not vary significantly in seed size while the size of *Chandrakkaran* (11.88) was significantly lower than the other two varieties.

4.2 Seed germination and critical moisture content

4.2.1 Seed germination

Loss of moisture from the seeds contributed to a progressive decline in the germination percentage of all the three mango varieties studied (Table 2). The response of varieties to moisture loss was found to be different.

Chandrakkaran

There was a progressive decline in germination percentages of seeds with loss in weight. Seeds sown immediately after removing the pulp had the maximum germination percentage of 73. Fifty per cent germination was observed for seeds which had lost 30 per cent of its original weight by drying (T_4). Lowest germination percentage was recorded for the treatment T_6 (47%). The decline in germination was lower compared to the other two varieties.

Moovandan

Germination percentage varied significantly with loss in seed weight. Fresh seeds showed a maximum germination percentage of 63. Fifty per cent of the seeds germinated when seeds lost 30 per cent of their original weight (T_4). Lowest germination percentage was shown by T_6 seeds (22%). The decline in germination percentage of *Moovandan* was faster when the seeds lost more than 30 per cent of their original weight.

Puliyan

In this variety, fresh seeds showed the maximum germination percentage of 64. Twenty per cent loss in weight did not affect the germination percentage significantly. Fifty per cent seed germination was obtained when the seeds lost 30 per cent of their original weight. T_6 seeds showed the lowest germination percentage (25%).

In short, when seeds were subjected to drying, 30 per cent loss in seed weight was the critical value when 50 per cent of the seeds germinated. Below this value there was significant decline in germination in all the three varieties studied.

Table 2. Effect of drying on germination percentage of mango seeds

Treatments	Varieties			
	V_1	V_2	V_3	Mean
T_1	73^{a}	63^{a}	64^{a}	67^{a}
T_2	59^{b}	52^{b}	59^{ab}	57^{b}
T_3	52^{bc}	53^{b}	57^{ab}	54^{bc}
T_4	51^{bc}	50^{b}	51^{b}	51^{bc}
T_5	46^{c}	26^{c}	40^{c}	37^{d}
T_6	47^{c}	22^{c}	25^{d}	21^{d}
SEm				2.486

4.2.2 Critical moisture content

Moisture loss from the seeds of mango leads to reduction in germinability. Assessment of critical moisture content of the variety *Chandrakkaran* indicated that when the moisture content reduced to 24 per cent, the seeds did not germinate at all. In *Moovandan*, the seeds did not germinate when the moisture content was reduced to 30 per cent. In the case of *Puliyan*, the seeds lost viability when the moisture content was reduced below 28 per cent. Hence 24 per cent is considered as the critical moisture content of *Chandrakkaran*. The critical moisture content of *Moovandan* is 30 per cent and that of *Puliyan* is 28 per cent. This is represented in Table 3.

At the time of depulping, the moisture content of the seeds of *Chandrakkaran* was 51 per cent. The maximum germination percentage recorded from these seeds was only 73 per cent. Seeds lost 10 per cent of seed weight when kept exposed under shade for 2 days and the germination percentage was only 59 per cent. By the 6th day, 50 per cent germination of seeds was obtained when the moisture content was 32 per cent. However the seeds did not germinate when the moisture content fell below 24 per cent.

In the case of *Moovandan* seeds, initially the seeds had a moisture content of 72 per cent. The maximum germination percentage was only 63 per cent. Seeds lost 10 per cent of seed weight when kept exposed under shade for 2 days. By the 6th day, 50 per cent seed germination was observed when the moisture content was 46 per cent. However, the seeds did not germinate below a moisture content of 30 per cent.

In the case of *Puliyan*, fresh seeds had a moisture content of 56 per cent and the maximum germination percentage was 64 per cent. 50 per cent germination of the seeds was obtained when the moisture content was 32 per cent. The moisture content reduced to this level by 6 days of seed exposure. The seeds did not germinate when the moisture content fell below 28 per cent.

Table 3. Effect of seed drying on germination and moisture content of mango seeds

Days	% loss in weight	V_1		V_2		V_3	
		Germination (%)	Moisture content (%)	Germination (%)	Moisture content (%)	Germination (%)	Moisture content (%)
0	0	73	51	63	72	64	56
2	10	59	46	61	66	59	42
4	20	52	38	60	50	54	35
6	30	51	32	52	46	50	32
8	40	30	28	15	38	10	30
10	50	0	24	0	30	0	28

4.3 Variability in seedling characters

4.3.1 Morphological studies

The seedlings were all half sibs and comparison was made between seedlings from fresh seeds and those from desiccated seeds. The data collected on four characters were subjected to analysis of variance for testing the differences between varieties. Variances and coefficient of variation were estimated for seedling characters in seedlings from fresh seeds and also seedlings from desiccated seeds (Table 4).

Individually all the varieties concerned showed similar effect in the variability in seedling characters. High variability was seen in seedling girth between seedlings from fresh seeds and seedlings from dried seeds. In all the three varieties concerned, high coefficient of variation was seen in the case of seedling girth. Variety *Chandrakkaran* showed a coefficient of variation of 56.8 and 96.9 per cent in girth for fresh seedlings and seeds from desiccated seeds respectively. The coefficient of variation for girth in *Moovandan* was 44.3 and 48.6 per cent for fresh seedlings and seedlings from dried seeds respectively. Variety *Puliyan* also showed a high coefficient of variation for girth (50.8 and 86.5%). Interaction between varieties and desiccation was found to be significant for girth of seedlings which shows that seedling girth is dependent on varieties and physiological characters.

Table 4. Variability among seedling characters in seedlings from fresh seeds and those from dried seeds

Seedling characters	Variance	Coefficient of variation	
		Fresh seedlings	Seedlings from dried seeds
Chandrakkaran			
Height	12.51	8.50	23.60
Girth	63.71	56.80	96.90
Internodal length	1.88	24.20	18.22
No, of leaves	13.94	17.29	29.08
Moovandan			
Height	5,73	4.30	6.45
Girth	24.57	44.30	48.60
Internodal length	2.22	8.80	11.60
No. of leaves	12.16	9.64	8.21
Puliyan			
Height	1.77	7.14	18.50
Girth	11.77	50.80	86.50
Internodal length	2.48	17.60	17.95
No. of leaves	3.07	12.88	13.80

Analysis of variance was done on the three mango varieties to bring out the influence of rate of seed drying on seedling characters.

4.3.1.1 Seedling height

Chandrakkaran

In the variety *Chandrakkaran*, the seedling height showed significant difference among treatments at various stages of growth (Table 5). At 1 MAG, there was significant difference between seedling from fresh seeds and seeds which lost 50 per cent of its weight. The maximum height was 16.43 cm for seedlings from T_1 and the lowest height was 12 cm for seedlings from T_6. But there was no significant difference among other treatments viz., T_2, T_3, T_4 and T_5. At 2 MAG, seedlings from the treatments T_1 (21.31 cm), T_2 (20.14 cm), T_3 (19.00 cm) and T_4 (18.98 cm) were on par and T_5 (14.67 cm) and T_6 (14.37 cm) showed significant variation from T_2 and T_3. At 3 MAG, T_1, T_2, T_3 and T_4 did not show significant variation while they varied significantly from T_5 and T_6 (16.33 cm). At 4 MAG, T_1, T_2 and T_3 showed the maximum height and did not show significant variation. But treatments T_5 (19.58 cm) and T_6 (19.00 cm) were significantly inferior to the others in plant height. At 5 MAG also, the same pattern was observed in all the treatments. At all stages of growth, seedlings from fresh seeds had the maximum height and seedlings grown from seeds which had lost 50 per cent weight had the lowest height.

Table 5. Effect of seed drying on seedling height (cm) of variety *Chandrakkaran*

Treatments	1 MAG	2 MAG	3 MAG	4 MAG	5 MAG
T_1	16.43 ^{a}	21.31 ^{a}	23.07 ^{a}	25.70 ^{a}	28.38 ^{a}
T_2	16.00 ^{ab}	20.14 ^{a}	22.85 ^{a}	24.73 ^{a}	28.07 ^{a}
T_3	16.00 ^{ab}	19.00 ^{a}	22.11 ^{a}	24.96 ^{a}	27.18 ^{a}
T_4	15.31 ^{ab}	18.98 ^{a}	21.31 ^{a}	22.50 ^{ab}	24.53 ^{ab}
T_5	12.88 ^{ab}	14.67 ^{b}	16.33 ^{b}	19.58 ^{b}	20.75 ^{b}
T_6	12.00 ^{b}	14.37 ^{b}	16.33 ^{b}	19.00 ^{b}	20.53 ^{b}
SEm	1.725	1.525	1.666	1.709	1.716

Moovandan

In this variety, there was considerable difference among treatments at all stages of growth and this is given in Table 6. At 1 MAG, T_1 showed the maximum height of 20.02 cm. T_2 (16.59 cm), T_3 (16.40 cm) and T_4 (14.81 cm) were homogeneous. T_5 (13.38 cm) and T_6 (12.20 cm) showed the lowest seedling height. T_1, T_2 and T_3 did not show significant variation at 2^{nd}, 3^{rd}, 4^{th} and 5^{th} month after germination. At 2^{nd} and 3^{rd} MAG, T_4 and T_5 did not show significant difference. At 4 MAG, T_1, T_2, T_3 and T_4 were on par. T_5 and T_6 were homogeneous. At 5 MAG, T_4, T_5 and T_6 did not vary significantly in their height.

At all stages of growth except 1 MAG, T_1, T_2 and T_3 did not show significant difference in height. T_2 which was significantly different from T_1 at 1 MAG become homogeneous with T_1 at later stages of growth.

Table 6. Effect of seed drying on seedling height (cm) of the variety *Moovandan*

Treatments	1 MAG	2 MAG	3 MAG	4 MAG	5 MAG
T_1	20.02^{a}	24.75^{a}	27.92^{a}	30.29^{a}	32.92^{a}
T_2	16.59^{b}	21.47^{ab}	24.97^{ab}	27.53^{ab}	30.17^{ab}
T_3	16.40^{bc}	20.87^{a}	24.73^{ab}	27.20^{ab}	29.21^{abc}
T_4	14.81^{bcd}	20.00^{b}	23.06^{bc}	26.31^{abc}	28.53^{bc}
T_5	13.38^{cd}	17.50^{bc}	22.00^{bc}	24.75^{bc}	27.50^{bc}
T_6	12.20^{d}	16.00^{bc}	20.00^{c}	22.60^{c}	25.20^{c}
SEm	1.035	1.341	1.427	1.332	1.385

Puliyan

The height of seedlings at different stages of growth are represented in Table 7. At 1 MAG and 2 MAG, T_1 and T_2 did not show significant variation and T_1 had a height of 17.22 and 21.39 cm respectively. T_5 and T_6 recorded the lowest height at both stages. But by the 3 MAG there was significant variation between the seedlings from the various treatments. T_1 had the maximum height of 26.67 cm and this was significantly superior to the seedlings from treatment T_2 (23.06 cm). The lowest height was recorded by T_6 at all stages of growth. The same trend was observed in the next two stages.

Table 7. Effect of seed drying on seedling height (cm) of the variety *Puliyan*

Treatments	1 MAG	2 MAG	3 MAG	4 MAG	5 MAG
T_1	17.22 ^{a}	21.39 ^{a}	26.67 ^{a}	33.61 ^{a}	39.39 ^{a}
T_2	14.94 ^{a}	19.00 ^{a}	23.06 ^{b}	27.25 ^{b}	31.19 ^{b}
T_3	12.06 ^{b}	16.12 ^{b}	20.24 ^{c}	24.29 ^{c}	28.35 ^{c}
T_4	8.90 ^{c}	11.90 ^{c}	14.80 ^{d}	18.30 ^{d}	22.20 ^{d}
T_5	6.00 ^{d}	8.25 ^{d}	10.50 ^{e}	13.50 ^{e}	16.25 ^{e}
T_6	4.67 ^{d}	6.67 ^{d}	8.67 ^{f}	10.67 ^{f}	14.00 ^{f}
SEm	0.970	0.9891	0.9750	0.834	0.7854

A pooled analysis of the parameter revealed that height varied significantly among the treatments at all stages of growth (Table 8). At 1 MAG, height of seedlings varied from 9.93 cm (T_6 seeds) to 17.81 cm (T_1 seeds). At 2 MAG, seedlings from fresh seeds had a height of 21.77 cm and T_6 (seedlings from seeds which had lost 50% of its weight) had a height of 12.74 cm. At 3 MAG, seedlings from fresh seeds recorded the maximum height (25.85 cm) and seedling from T_6 showed the lowest height (15.59 cm). Seedlings from fresh seeds recorded the maximum height at 4 MAG and 5 MAG (29.62 cm and 33.07 cm) and the lowest height was recorded by seedling from T_6 (18.05 cm and 20.54 cm).

Table 8. Effect of seed drying on seedling height in mango

Treatments	1 MAG	2 MAG	3 MAG	4 MAG	5 MAG
T_1	17.81 ^{a}	21.77 ^{a}	25.85 ^{a}	29.62 ^{a}	33.07 ^{a}
T_2	16.00 ^{ab}	20.70 ^{ab}	23.75 ^{ab}	26.55 ^{ab}	29.47 ^{ab}
T_3	15.06 ^{ab}	19.19 ^{abc}	22.49 ^{abc}	25.49 ^{ab}	28.49 ^{ab}
T_4	13.43 ^{ab}	17.51 ^{abc}	20.31 ^{abc}	22.96 ^{ab}	25.61 ^{ab}
T_5	11.59 ^{b}	14.29 ^{bc}	17.22 ^{bc}	20.07 ^{ab}	22.77 ^{ab}
T_6	9.93 ^{b}	12.74 ^{c}	15.59 ^{c}	18.05 ^{b}	20.54 ^{b}
SEm	1.777	2.113	2.317	3.052	3.558

In general, there was a progressive decline in seedling height with moisture loss from seeds. Seedlings from fresh seeds yielded maximum seedling height at all stages and the lowest height was recorded by seedlings from seeds which lost 50 per cent of their weight. Moreover, seedling from T_5 which showed less height in the early stages became on par with other seeds.

4.3.1.2 Seedling girth

Chandrakkaran

Table 9 shows the girth of seedling of the variety *Chandrakkaran* at various stages of growth with moisture loss from seeds. At 1 MAG, T_1, T_2, T_3 and T_4 seedlings showed no significant variation but they differed significantly from T_5 (0.12 cm) and T_6 (0.11 cm) seedlings which had the lowest seedling girth. At 2 MAG, T_1, T_2, T_3, T_4 and T_5 did not show significant variation. At 3rd MAG and 4th MAG, maximum seedling girth was observed in T_1 seedlings (0.54 cm and 0.62 cm). T_2, T_3 and T_4 were on par with T_1 seedlings. At 5 MAG, T_1 seedlings showed the maximum girth (0.66 cm), T_2 and T_3 seedlings were on par with seedlings from T_1. T_5 (0.44 cm) and T_6 (0.41 cm) did not show any significant difference in seedling girth.

Table 9. Effect of seed drying on seedling girth (cm) of variety *Chandrakkaran*

Treatments	1 MAG	2 MAG	3 MAG	4 MAG	5 MAG
T_1	0.21 ^{a}	0.42 ^{a}	0.54 ^{a}	0.62 ^{a}	0.66 ^{a}
T_2	0.18 ^{a}	0.38 ^{a}	0.48 ^{ab}	0.52 ^{ab}	0.62 ^{ab}
T_3	0.19 ^{a}	0.39 ^{a}	0.49 ^{ab}	0.53 ^{ab}	0.59 ^{ab}
T_4	0.17 ^{a}	0.33 ^{ab}	0.43 ^{abc}	0.50 ^{abc}	0.52 ^{bc}
T_5	0.12 ^{b}	0.31 ^{ab}	0.36 ^{bc}	0.40 ^{bc}	0.44 ^{c}
T_6	0.11 ^{b}	0.25 ^{a}	0.33 ^{c}	0.38 ^{c}	0.41 ^{c}
SEm	0.01509	0.03616	0.04385	0.04385	0.04297

Moovandan

Seedling girth showed significant variation at all stages of growth with loss in seed weight. This is represented in Table 10. The maximum seedling girth was recorded for T_1 seeds (0.45 cm) at 1 MAG. T_2, T_3, T_4 and T_5 did not vary significantly. T_5 and T_6 seedlings were on par. At 2 MAG, T_1, T_2, T_3 and T_4 did not differ significantly in seedling girth. T_1 seedlings varied significantly from T_5 and T_6. At 3 MAG, T_1 seedlings showed the maximum seedling girth T_2, T_3 and T_4 did not vary significantly from T_1 seedlings. T_5 seedlings were on par with T_4 seedlings. T_5 and T_6 seedlings did not differ significantly. At 4 MAG, the seedling girth pattern was same as that of 3 MAG. At 5 MAG, T_1 seedlings did not vary significantly from T_2 and T_3 seedlings. T_5 and T_6 seedlings varied significantly from T_1 seedlings.

Table 10. Effect of seed drying on seedling girth (cm) of variety *Moovandan*

Treatments	1 MAG	2 MAG	3 MAG	4 MAG	5 MAG
T_1	0.45^{a}	0.52^{a}	0.57^{a}	0.68^{a}	0.71^{a}
T_2	0.32^{b}	0.48^{ab}	0.52^{a}	0.57^{ab}	0.62^{ab}
T_3	0.34^{b}	0.45^{ab}	0.52^{a}	0.57^{ab}	0.62^{ab}
T_4	0.32^{b}	0.44^{ab}	0.50^{ab}	0.59^{ab}	0.62^{ab}
T_5	0.27^{bc}	0.38^{bc}	0.47^{ab}	0.51^{b}	0.54^{b}
T_6	0.19^{c}	0.33^{c}	0.42^{b}	0.48^{b}	0.52^{b}
SEm	0.0333	0.0333	0.0333	0.0365	0.0365

For the variety *Moovandan*, it can be seen that T_2 seedlings which was inferior to T_1 seedlings at 1 MAG became on par with T_1 seedlings at later stages. T_6 seedlings showed the lowest seedling girth at all stages.

Puliyan

Seedlings of the variety *Puliyan* showed significant difference in seedling girth (Table 11). At 1 MAG, T_1 and T_2 showed no significant difference but differed significantly from T_3, T_4, T_5 and T_6 seedlings. Girth of seedlings varied from 0.07 cm to 0.45 cm. The lowest seedling girth was observed in seedlings from treatments T_5 (0.11 cm) and T_6 (0.07 cm). At 2 MAG, seedling girth varied significantly. The maximum girth was shown by seedlings from treatment T_1 (0.54 cm). T_5 (0.15 cm) and T_6 (0.11 cm) showed the lowest seedling girth. The similar pattern was maintained at 3, 4 and 5 MAG.

Table 11. Effect of seed drying on seedling girth (cm) of variety *Puliyan*

Treatments	1 MAG	2 MAG	3 MAG	4 MAG	5 MAG
T_1	0.45 ^{a}	0.54 ^{a}	0.63 ^{a}	0.70 ^{a}	0.82 ^{a}
T_2	0.40 ^{a}	0.45 ^{b}	0.51 ^{a}	0.56 ^{b}	0.61 ^{b}
T_3	0.31 ^{b}	0.36 ^{c}	0.41 ^{c}	0.45 ^{c}	0.50 ^{c}
T_4	0.21 ^{c}	0.26 ^{d}	0.30 ^{d}	0.34 ^{d}	0.39 ^{d}
T_5	0.11 ^{d}	0.15 ^{e}	0.19 ^{e}	0.23 ^{e}	0.29 ^{e}
T_6	0.07 ^{d}	0.11 ^{e}	0.15 ^{e}	0.20 ^{e}	0.26 ^{e}
SEm	0.02582	0.03028	0.02582	0.02415	0.02552

A pooled analysis of data (Table 12) indicated that seedling girth varied significantly between seedlings from fresh seeds and those from seeds with 50 per cent loss in weight at all stages of growth. Seedling girth at 1 MAG varied from 0.12 cm (T_6) to 0.37 cm (T_1). At 2 MAG, T_1 and T_2 did not show any significant variation. At 3 MAG, T_1 seedlings showed the maximum girth (0.58 cm). T_2, T_3, T_4 and T_5 seedlings showed no significant difference. At 4 and 5 MAG only the seedlings from treatment T_5 and T_6 showed significant difference in seedling girth compared to other treatments.

Table 12. Effect of seed drying on seedling girth (cm) of mango

Treatments	1 MAG	2 MAG	3 MAG	4 MAG	5 MAG
T_1	0.37 [a]	0.49 [a]	0.58 [a]	0.67 [a]	0.72 [a]
T_2	0.30 [ab]	0.44 [a]	0.51 [ab]	0.55 [ab]	0.61 [ab]
T_3	0.28 [ab]	0.40 [ab]	0.47 [ab]	0.52 [ab]	0.57 [ab]
T_4	0.24 [ab]	0.35 [ab]	0.43 [ab]	0.50 [ab]	0.53 [ab]
T_5	0.19 [ab]	0.32 [ab]	0.37 [ab]	0.41 [b]	0.45 [b]
T_6	0.12 [b]	0.24 [b]	0.32 [b]	0.37 [b]	0.41 [b]
SEm	0.0533	0.0542	0.03721	0.06504	0.03823

In general, seedlings from fresh seeds showed the maximum girth at all stages and seedlings from seeds with 50 per cent weight loss showed the minimum girth at all stages. There was no significant difference among the other treatments.

4.3.1.3 Internodal length

Chandrakkaran

Internodal length of seedlings differed significantly with loss in seed weight (Table 13). At 1 MAG, T_1, T_2 and T_3 did not differ significantly. Similarly T_4, T_5 and T_6 did not differ significantly. But T_1 (2.09 cm) differed significantly from T_6 seeds (1.33 cm). At 2 MAG T_1 (2.66 cm) and T_2 (2.65 cm) did not differ significantly but differed significantly from T_6 which showed the lowest internodal length (1.83 cm). At 3 MAG, T_1 (3.16 cm) had the maximum internodal length. T_2 and T_3 did not vary from T_1. T_6 (1.97 cm) differed significantly from T_1. At 4 MAG, T_1 and T_2 did not differ significantly. T_3, T_4 and T_5 formed a homogeneous group and T_1 varied significantly from T_6. The internodal length ranged from 2.50 cm to 3.48 cm. At 5 MAG, T_1 (4.02 cm) showed the maximum internodal length. T_2, T_3, T_4 and T_5 did not significantly differ in internodal length. T_6 showed the lowest internodal length (2.67 cm).

Table 13. Effect of seed drying on internodal length (cm) of variety *Chandrakkaran*

Treatments	1 MAG	2 MAG	3 MAG	4 MAG	5 MAG
T_1	2.09 [a]	2.66 [a]	3.16 [a]	3.48 [a]	4.02 [a]
T_2	1.92 [a]	2.65 [a]	3.04 [a]	3.42 [a]	3.85 [ab]
T_3	1.89 [a]	2.36 [ab]	2.71 [ab]	3.00 [ab]	3.31 [b]
T_4	1.84 [ab]	2.28 [ab]	2.50 [bc]	2.91 [ab]	3.22 [bc]
T_5	1.65 [ab]	2.33 [ab]	2.46 [bc]	2.68 [ab]	3.29 [bc]
T_6	1.33 [b]	1.83 [b]	1.97 [c]	2.50 [b]	2.67 [c]
SEm	0.1765	0.1844	0.1932	0.1996	0.2129

Moovandan

Table 14 shows the variation in internodal length of seedlings with moisture loss. At 1 MAG, the maximum internodal length was observed in T_1 seedlings and it varied significantly from all other treatments. T_2 (3.56 cm) and T_3 (3.50 cm) did not show significant difference in internodal length. T_4 and T_5 seedlings were on par with seedlings from T_6. At 2 MAG, the internodal length ranged from 2.90 cm (T_6) to 5.17 cm (T_1). T_1 differed significantly from other treatments T_2, T_3 and T_4 were on par. T_6 showed the lowest internodal length (2.90 cm). At 3 MAG, T_1 seedlings (6.10 cm) differed significantly in internodal length from other treatments. T_2, T_3 and T_4 did not show significant difference. T_4, T_5 and T_6 showed no significant variation. At 4 MAG, T_1 seedlings showed the maximum internodal length (6.5 cm). T_2, T_3 and T_4 did not show significant variation. T_6 did not vary significantly from T_4 and T_5. At 5 MAG, T_1 (6.83 cm) seedlings varied significantly from other treatments but seedlings from other treatments did not show significant variation. Seedlings from T_5 and T_6 were on par and they varied significantly from T_1 seedlings.

Table 14. Effect of seed drying on internodal length (cm) of variety *Moovandan*

Treatments	1 MAG	2 MAG	3 MAG	4 MAG	5 MAG
T_1	4.42 ^{a}	5.17 ^{a}	6.10 ^{a}	6.50 ^{a}	6.83 ^{a}
T_2	3.56 ^{b}	4.00 ^{b}	4.35 ^{b}	4.82 ^{b}	5.18 ^{b}
T_3	3.50 ^{b}	4.00 ^{b}	4.07 ^{bc}	4.60 ^{bc}	4.93 ^{b}
T_4	3.03 ^{bc}	3.75 ^{bc}	3.88 ^{bc}	4.31 ^{bcd}	4.84 ^{bc}
T_5	2.50 ^{c}	3.00 ^{cd}	3.44 ^{c}	3.81 ^{cd}	4.13 ^{c}
T_6	2.30 ^{c}	2.90 ^{d}	3.30 ^{c}	3.70 ^{d}	4.10 ^{c}
SEm	0.2583	0.2757	0.2867	0.2741	0.2714

Puliyan

There was significant variation in internodal length of seedlings (Table 15). At 1 MAG, the maximum internodal length was observed in seedlings from T_1 (4.78 cm). These were significantly superior to all other treatments. At 2 and 3 MAG, the same pattern was obtained. At 4 MAG, T_1 seedlings differed significantly from other treatments and showed the maximum internodal length of 6.53 cm. T_2 (5.66 cm) varied significantly from T_3, T_4 and T_5. T_6 showed the lowest internodal length (3.67 cm). AT 5 MAG, the maximum internodal length was obtained for T_1 (7.14 cm) and the lowest for seedlings from T_6 (4.17 cm). All treatments differed significantly from each other in internodal length.

Table 15. Effect of seed drying on internodal length (cm) of variety *Puliyan*

Treatments	1 MAG	2 MAG	3 MAG	4 MAG	5 MAG
T_1	4.78 ^{a}	5.17 ^{a}	5.94 ^{a}	6.53 ^{a}	7.14 ^{a}
T_2	3.81 ^{b}	4.41 ^{b}	5.06 ^{b}	5.66 ^{b}	6.19 ^{b}
T_3	3.50 ^{b}	4.09 ^{b}	4.62 ^{b}	5.09 ^{c}	5.68 ^{c}
T_4	2.60 ^{c}	3.10 ^{c}	3.60 ^{c}	4.10 ^{d}	4.60 ^{d}
T_5	2.63 ^{c}	3.13 ^{c}	3.63 ^{c}	4.13 ^{d}	4.63 ^{d}
T_6	2.17 ^{c}	2.63 ^{c}	3.13 ^{c}	3.67 ^{e}	4.17 ^{e}
SEm	0.1579	0.1555	0.1656	0.1567	0.1492

In general, internodal length showed significant reduction with loss in seed weight in all varieties. This is shown in Table 16. At 1 MAG, maximum internodal length was recorded by T_1 (3.72 cm) and the lowest by seedlings from T_6 (1.89 cm). At 2 MAG, there was no significant difference between T_2, T_3, T_4 and T_5 seedlings and the internodal length ranged from 2.43 cm (T_6) to 4.04 cm (T_1). At 3 MAG, seedlings from treatments T_3, T_4 and T_5 were statistically on par in internodal length. At 4 MAG, the maximum internodal length was recorded by seedling from T_1 (5.47 cm). T_2, T_3, T_4, T_5 and T_6 did not differ significantly at 4 and 5 MAG.

Hence in all stages of growth, the maximum internodal length was recorded by seedlings from T_1 seeds and the lowest by seedlings from T_6 seeds. Seedlings upto 30 per cent loss in seed weight were statistically on par with the fresh seedling and there was no significant difference between the seedlings from treatments T_4, T_5 and T_6 which were found to be similar in performance.

Table 16. Effect of seed drying on internodal length (cm) in mango

Treatments	1 MAG	2 MAG	3 MAG	4 MAG	5 MAG
T_1	3.72^{a}	4.04^{a}	5.05^{a}	5.47^{a}	5.96^{a}
T_2	3.08^{ab}	3.66^{ab}	4.11^{b}	4.59^{ab}	5.02^{ab}
T_3	2.98^{ab}	3.47^{ab}	3.78^{b}	4.20^{ab}	4.62^{ab}
T_4	2.54^{ab}	3.10^{ab}	3.36^{b}	3.81^{ab}	4.26^{b}
T_5	2.36^{ab}	2.94^{ab}	3.28^{b}	3.72^{b}	4.13^{b}
T_6	1.89^{b}	2.43^{b}	2.78^{b}	3.24^{b}	3.61^{b}
SEm	0.4058	0.4280	0.4786	0.4974	0.2376

4.3.1.4 Number of leaves

Chandrakkaran

There was significant variation in the number of leaves produced by the seedlings depending on the seed quality. This is shown in Table 17. At 1 MAG, seedlings from T_2, T_3 and T_4 were found to be on par with T_1. T_4 and T_5 seedlings were on par with seedlings from treatment T_6 in number of leaves. The number of leaves per seedling ranged from 2.93 (T_6) to 4 (T_1). At 2 MAG, T_1, T_2, T_3, T_4 and T_5 did not show significant variation in leaf number. At 3 MAG, T_1 and T_2 did not vary significantly, but T_1 varied significantly from T_4, T_5 and T_6. At 4 MAG, the same pattern was obtained. At 5 MAG, T_1 (9.36) and T_2 (8.38) seedlings did not significantly differ in the number of leaves per seedling. But it varied significantly from T_6 (6.23)..

Table 17. Effect of seed drying on number of leaves produced in the variety *Chandrakkaran*

Treatments	1 MAG	2 MAG	3 MAG	4 MAG	5 MAG
T_1	4.00 ^{a}	6.84 ^{a}	6.41 ^{a}	8.41 ^{a}	9.36 ^{a}
T_2	3.86 ^{ab}	4.62 ^{ab}	5.31 ^{ab}	7.00 ^{ab}	8.38 ^{ab}
T_3	3.19 ^{abc}	3.71 ^{b}	4.93 ^{b}	5.64 ^{b}	6.57 ^{bc}
T_4	3.00 ^{c}	3.53 ^{b}	4.63 ^{b}	5.44 ^{b}	6.50 ^{bc}
T_5	3.00 ^{c}	4.00 ^{ab}	4.53 ^{b}	5.42 ^{b}	6.45 ^{bc}
T_6	2.93 ^{c}	3.33 ^{b}	4.00 ^{b}	5.67 ^{b}	6.23 ^{c}
SEm	0.2846	0.4222	0.4908	0.5840	0.6705

Moovandan

There was significant difference in the number of leaves produced among the treatments (Table 18). At 1 MAG, seedlings from T_1 (9.79) differed significantly from T_6 (3.60) in the number of leaves produced. AT 2 MAG, T_1, T_2 and T_3 did not differ significantly in number of leaves produced. T_3, T_4 and T_5 did not differ significantly. The range is 6.60 (T_6) to 9.42 (T_1). At 3 MAG, T_1 varied significantly from all other treatments. Maximum number of leaves was produced by seedlings from T_1 (11.04). At 4 MAG, T_1 seedlings did not differ significantly from T_2, T_3, T_4 and T_5 seedlings but varied significantly from T_6 seedlings. Range was from 9.40 (T_6) to 12.75 (T_1). At 5 MAG, the same pattern was observed. The number of leaves produced ranged from 10.60 (T_6) to 13.58 (T_1).

Table 18. Effect of seed drying on number of leaves produced in the variety *Moovandan*

Treatments	1 MAG	2 MAG	3 MAG	4 MAG	5 MAG
T_1	9.79 ^{a}	9.42 ^{a}	11.04 ^{a}	12.75 ^{a}	13.58 ^{a}
T_2	6.35 ^{ab}	8.35 ^{ab}	10.00 ^{b}	11.18 ^{ab}	12.41 ^{ab}
T_3	6.06 ^{ab}	7.80 ^{abc}	10.00 ^{b}	11.07 ^{ab}	12.33 ^{ab}
T_4	5.50 ^{ab}	7.44 ^{bc}	9.00 ^{b}	10.75 ^{ab}	12.31 ^{ab}
T_5	5.00 ^{ab}	7.13 ^{bc}	8.75 ^{b}	10.50 ^{ab}	11.88 ^{ab}
T_6	3.60 ^{b}	6.60 ^{c}	8.00 ^{c}	9.40 ^{b}	10.60 ^{b}
SEm	1.789	0.5487	0.5443	1.980	0.6142

Puliyan

Number of leaves produced per seedling varied significantly among treatments and the details are presented in Table 19. At 1 MAG, seedlings from T_1 seeds produced the maximum number of leaves (5.67) and varied significantly from all other treatments. T_2, T_3, T_4 and T_5 were on par and T_5 and T_6 did not vary significantly. At 2 MAG, maximum number of leaves were observed in the seedlings from T_1 seeds (7.78). The performance of T_2 and T_3 were similar to T_1. T_4, T_5 and T_6 showed no significant difference in the number of leaves produced. But they were significantly lower than T_1 and T_2. At 3 MAG, T_1 varied significantly from all other treatments. T_2 and T_3 did not differ significantly. T_5 and

T_6 also showed no significant variation and the number of leaves produced ranged from 5.00 (T_6) to 10.17 (T_1). At 4 MAG, the same pattern was noticed in the production of leaves and it ranged from 8.33 (T_6) to 12.89 (T_1). At 5 MAG, T_1 seedling had the maximum number of leaves (15.33). Number of leaves produced by the seedlings in T_4, T_5 and T_6 treatments were significantly lower than T_1 (15.33) and T_2 (13.31).

Table 19. Effect of seed drying on number of leaves produced in the variety *Puliyan*

Treatments	1 MAG	2 MAG	3 MAG	4 MAG	5 MAG
T_1	5.67 ^{a}	7.78 ^{a}	10.17 ^{a}	12.89 ^{a}	15.33 ^{a}
T_2	4.00 ^{b}	6.19 ^{b}	8.44 ^{b}	10.94 ^{b}	13.31 ^{b}
T_3	3.71 ^{b}	6.12 ^{b}	7.88 ^{bc}	10.12 ^{bc}	12.06 ^{bc}
T_4	3.60 ^{b}	4.80 ^{c}	7.30 ^{c}	9.20 ^{cd}	11.40 ^{c}
T_5	3.25 ^{bc}	4.50 ^{c}	5.50 ^{d}	8.50 ^{d}	11.25 ^{c}
T_6	2.67 ^{c}	4.33 ^{c}	5.00 ^{d}	8.33 ^{d}	11.00 ^{c}
SEm	0.2918	0.3527	0.3798	0.4334	0.4712

Significant difference in the number of leaves produced was observed between seedlings from fresh seeds (T_1) and seedlings from seeds with 50 per cent loss in weight (T_6 seedlings) in all the three varieties. The data are given in Table 20. At 1 MAG, maximum number of leaves were produced by seedlings from T_1 (6.57). There was no significant variation among T_2, T_3, T_4, T_5 and T_6. At 2 MAG, seedlings from T_1 and T_2 did not show significant variation and seedlings from T_5 and T_6 also did not show significant variation. At 3 MAG, seedling from T_1 produced the maximum number of leaves (9.19). There was no difference among T_2, T_3, T_4 and T_5. At 4 MAG, T_1 and T_2 did not show significant difference and the number of leaves produced ranged from 7.67 (T_6) to 11.21 (T_1). At 5 MAG, T_1 seedlings (12.63) differed significantly from T_3, T_4, T_5 and T_6 seeds.

In short, at all stages of growth, seedlings from fresh seeds had the maximum number of leaves and seedling from seeds with 50 per cent loss in weight had the least number of leaves.

Table 20. Effect of seed drying on number of leaves produced in the mango seedlings

Treatments	1 MAG	2 MAG	3 MAG	4 MAG	5 MAG
T_1	6.57 [a]	7.29 [a]	9.19 [a]	11.21 [a]	12.63 [a]
T_2	4.81 [ab]	6.41 [ab]	8.69 [ab]	9.65 [ab]	11.26 [ab]
T_3	4.49 [b]	5.93 [bc]	7.40 [b]	8.96 [c]	10.25 [b]
T_4	4.37 [b]	5.40 [cd]	7.02 [bc]	9.94 [ab]	10.09 [b]
T_5	4.08 [b]	5.50 [d]	6.63 [bc]	8.33 [c]	9.79 [b]
T_6	3.55 [b]	4.77 [d]	5.76 [c]	7.67 [c]	9.21 [b]
SEm	0.6586	0.2847	0.2788	0.8929	0.6366

4.3.2 Number of sprouts

Number of sprouts produced from seeds did not show significant difference with variety (Table 21). All the three varieties studied were found to be polyembryonic. Loss in moisture content did not affect the polyembryonic nature of the varieties. All the varieties behaved similarly with moisture loss.

Table 21. Number of sprouts produced in different varieties of mango

Variety	No. of sprouts
V_1	2.08 [a]
V_2	2.49 [a]
V_3	2.44 [a]
SEm	0.1251

4.3.3 Leaf Area Index

Leaf area index varied significantly in each variety with loss in seed weight. This is represented in Table 22.

Chandrakkaran

In this variety, maximum leaf area index was shown by seedlings from fresh seeds. Seedlings from each treatment varied significantly. Seedlings from T_6 showed the lowest leaf area index of 0.39.

Moovandan

In this variety, there was significant difference in leaf area index produced by seedlings from different treatments. Seedlings from fresh seeds showed the maximum leaf area index of 1.23. Seedlings from T_4 and T_5 seeds did not show much variation in leaf area index. Seedlings from T_6 (0.68) seeds showed the lowest leaf area index.

Puliyan

There was considerable variation in leaf area index. Seedlings from fresh seeds showed the maximum leaf area index of 1.26 and the lowest by seedlings from T_6 (0.41) seeds.

In short, in all varieties, seedlings from fresh seeds showed the maximum leaf area index (1.19) and seedlings from T_6 seeds showed the lowest leaf area index (0.49).

Table 22. Effect of seed drying on leaf area index of mango seedlings

Treatments	Varieties			
	V_1	V_2	V_3	Mean
T_1	1.08	1.23	1.26	1.19
T_2	0.86	1.03	0.94	0.94
T_3	0.77	0.85	0.71	0.77
T_4	0.69	0.74	0.62	0.69
T_5	0.49	0.73	0.53	0.58
T_6	0.39	0.68	0.41	0.49
SEm				0.0288

4.3.4 Vigour index

Vigour index of seedlings after 5 months of germination is presented in Table 23. Determination of vigour index brought out the effect due to seed weight loss on the performance of seedlings. The data clearly indicated that in all varieties seedlings from fresh seeds gave the maximum vigour index. Seedlings obtained from T_6 seeds showed the lowest vigour which was significantly inferior to the seedlings obtained by sowing the seeds immediately after depulping.

Table 23. Effect of seed drying on vigour index

Treatments	Varieties			
	V_1	V_2	V_3	Mean
T_1	20.71	20.73	25.21	22.15 [a]
T_2	16.56	15.18	18.52	16.70 [b]
T_3	14.13	15.99	16.15	15.37 [bc]
T_4	12.51	14.27	11.32	13.06 [c]
T_5	9.55	7.15	6.50	8.49 [d]
T_6	3.49	5.54	3.50	4.38 [e]
SEm				4.375

Vigour index was also estimated as a factor which depends upon height of seedlings and girth of seedlings. In this case also, seedling from seeds sown immediately after depulping showed the best performance. Seedlings from T_6 seeds had very low vigour. The data are presented in Table 24 along with the percentage decrease in seedling vigour.

In variety *Chandrakkaran*, fresh seeds showed maximum vigour index (13.33). Seedlings from T_5 and T_6 showed low performance. In the variety *Moovandan* also, seedlings from fresh seeds showed the best performance (17.55). The same pattern of performance was shown by seedlings of *Puliyan* also.

When height alone was considered, such a drastic decline in vigour was not brought out by the computation. The results indicated marked difference between varieties when both height and girth of seedlings were considered. For the variety *Chandrakkaran*, the percentage decline in vigour between treatments T_1 and T_3 was only 24 per cent and there was not much significant variation between these treatments. In the case of *Moovandan*, the percentage decline in vigour between T_1 and T_3 was around 31.85 per cent. T3 showed significant difference from the seedlings obtained from fresh seeds (T_1). For the variety *Puliyan*, the decrease in vigour was pronounced even with 20 per cent loss in weight, the percentage decline in vigour was around 73 per cent. In this case, even a 10 per cent decrease in seed weight due to moisture loss lead to 50 per cent decline in vigour.

Table 24. Effect of seed drying in vigour index in mango seedlings

Treat-ments	V_1		V_2		V_3		Mean	% decline in V.I
	V.I	% decline in V.I	V.I	% decline in V.I	V.I	% decline in V.I		
T_1	13.33 ^{a}		17.55 ^{a}		27.56 ^{a}		18.92 ^{a}	
T_2	11.91 ^{ab}	10.60	12.63 ^{b}	28.00	11.63 ^{b}	57.80	12.08 ^{b}	36.00
T_3	10.09 ^{ab}	24.30	11.96 ^{b}	31.80	7.30 ^{c}	73.50	9.67 ^{c}	48.80
T_4	8.10 ^{bc}	39.23	12.06 ^{b}	31.3	3.45 ^{d}	87.50	8.50 ^{c}	55.00
T_5	4.79 ^{c}	64.00	9.98 ^{bc}	43.13	1.32 ^{d}	95.20	5.94 ^{d}	68.00
T_6	4.73 ^{c}	64.50	6.98 ^{c}	47.60	0.95 ^{d}	96.00	4.70 ^{e}	75.00
SEm	1.355		1.306		1.281		0.3998	

4.3.5 Growth suppression

The growth suppression value was computed based on seedling girth of the fresh seedlings. Growth suppression was found to vary significantly with treatments (Table 25). In all varieties, growth suppression was found to be less for

T_2 and T_3 as compared to T_5 and T_6. In short, growth suppression increases with moisture loss from the seeds.

Table 25. Effect of seed drying on growth suppression of mango seedlings

Treatments	V_1	V_2	V_3	Mean
T_1	0	0	0	0
T_2	6.06	12.6	25.6	14.75 ^{c}
T_3	10.6	12.6	39.02	20.74 ^{bc}
T_4	21.2	12.6	52.4	28.73 ^{b}
T_5	33.3	23.9	64.6	40.60 ^{a}
T_6	37.8	26.76	68.3	44.29 ^{a}
SEm				2.9836

4.4 Variability in physiological characters of seedlings

4.4.1 Electrolytic conductivity in the seed leachate

Electrolytic conductivity shown by the seed leachates varied significantly among all the seeds. Among the three varieties, in the variety *Chandrakkaran*, fresh seeds (T_1 seeds) had the lowest conductivity (0.5 dS m^{-1}) and seeds with 50 per cent loss in weight had the maximum conductivity in seed leachate (1.52 dS m^{-1}). In the variety *Moovandan*, the lowest conductivity was shown by fresh seeds (0.15 dS m^{-1}) and the maximum conductivity by the seeds with 50 per cent loss in weight (1.1 dS m^{-1}). Fresh seeds of variety *Puliyan* also showed the lowest conductivity (0.23 dS m^{-1}) and seeds with 50 per cent loss in weight showed the maximum conductivity of 1.24 dS m^{-1} (Table 26).

Thus in general, fresh seeds (T_1 seeds) had the lowest conductivity (0.29 dS m^{-1}) and seeds with 50 per cent loss in weight had the maximum conductivity in the seed leachate (1.33 dS m^{-1}).

4.4.2 Per cent solute leakage

There was significant difference in the per cent solute leaked out of seeds as a result of loss in seed weight. In the variety *Chandrakkaran* fresh seeds gave the lowest per cent solute leakage of 22.66 per cent and the seeds with 50 per cent loss in weight gave the highest per cent solute leakage (76.33%). Fresh seeds of *Moovandan* also gave the lowest per cent solute leakage of 8.45 per cent and seeds with 50 per cent loss in weight showed the highest per cent solute leakage (63.33%). Similar pattern was obtained in the variety *Puliyan* also.

Table 26. EC (dS m^{-1}) and per cent solute leakage in the three mango varieties.

Treatments	V_1		V_2		V_3	
	EC	Per cent solute leakage	EC	Per cent solute leakage	EC	Per cent solute leakage
T_1	0.50 ^{f}	22.66 ^{a}	0.15 ^{f}	8.45 ^{a}	0.23 ^{f}	10.05 ^{a}
T_2	0.65 ^{e}	30.02 ^{ab}	0.24 ^{e}	19.91 ^{ab}	0.42 ^{e}	16.33 ^{ab}
T_3	0.72 ^{d}	40.50 ^{bc}	0.43 ^{d}	23.78 ^{ab}	0.55 ^{d}	31.24 ^{ab}
T_4	0.92 ^{c}	55.60 ^{bc}	0.72 ^{c}	32.14 ^{ab}	0.76 ^{e}	42.90 ^{bc}
T_5	1.32 ^{b}	63.33 ^{c}	0.98 ^{b}	46.33 ^{bc}	0.93 ^{b}	56.33 ^{bc}
T_6	1.52 ^{a}	76.33 ^{cd}	1.10 ^{a}	63.33 ^{c}	1.24 ^{a}	73.55 ^{cd}
SEm	2.932	2.932	0.321	2.732	0.362	2.823

Lowest per cent solute leakage was shown by fresh seeds (13.67%) and the highest by seeds with 50 per cent loss in weight (63.78%). T_2 and T_3 did not show significant difference. The data on electrolytic conductivity and per cent solute leakage are given in Table 27.

Table 27. EC leakage (dS m^{-1}) and per cent solute leakage on mango seeds with seed drying

Treatments	EC leakage	% solute leakage
T_1	0.29 ^{f}	13.68 ^{a}
T_2	0.48 ^{e}	21.54 ^{ab}
T_3	0.62 ^{d}	31.51 ^{ab}
T_4	0.88 ^{c}	43.39 ^{bc}
T_5	1.04 ^{b}	54.34 ^{bc}
T_6	1.33 ^{a}	63.78 ^{c}
SEm	0.3801	2.817

4.4.3 Chlorophyll content

Chlorophyll content varied significantly among the seeds with loss in weight in the 3 varieties.

Chandrakkaran

The maximum chlorophyll a content, chlorophyll b content and total chlorophyll content were recorded in seedlings from T_1 seeds (2.288, 0.721 and 2.884 mg g^{-1} respectively). T_3, T_4 and T_5 did not vary significantly. Seedlings from T_6 seeds showed the lowest chlorophyll a (0.764 mg g^{-1}), chlorophyll b (0.256 mg g^{-1}) and total chlorophyll content (1.021 mg g^{-1}) (Table 28).

Table 28. Effect of seed drying on chlorophyll content (mg g^{-1}) in *Chandrakkaran*

Treatments	Chlorophyll a	Chlorophyll b	Total chlorophyll
T_1	2.288	0.721	2.884
T_2	2.026	0.442	2.123
T_3	1.394	0.429	1.993
T_4	1.361	0.416	1.717
T_5	1.309	0.306	1.485
T_6	0.764	0.256	1.021

Moovandan

In variety *Moovandan* also, the maximum chlorophyll a, chlorophyll b and total chlorophyll content were recorded by seedlings from T_1 seeds (1.413, 0.486 and 1.909 mg g^{-1}). Lowest chlorophyll a, chlorophyll b and total chlorophyll content were observed on seedlings from T_6 seeds (0.56, 0.215 and 0.775 mg g^{-1} respectively) (Table 29).

Table 29. Effect of seed drying on chlorophyll content (mg g^{-1}) in *Moovandan*

Treatment	Chlorophyll a	Chlorophyll b	Total chlorophyll
T_1	1.413	0.486	1.909
T_2	1.004	0.294	1.267
T_3	0.904	0.270	1.209
T_4	0.620	0.235	0.853
T_5	0.606	0.226	0.815
T_6	0.56	0.215	0.775

Puliyan

In variety *Puliyan*, seedlings from T1 seeds showed the highest chlorophyll a, chlorophyll b and total chlorophyll content (1.214; 0.567; 1.92 mg g^{-1} respectively). Seedlings from seeds with 50 per cent loss in weight showed the lowest chlorophyll contents (Table 30).

Table 30. Effect of seed drying on chlorophyll content (mg g^{-1}) in *Puliyan*

Treatment	Chlorophyll a	Chlorophyll b	Total chlorophyll
T_1	1.214	0.567	1.920
T_2	1.011	0.521	1.370
T_3	0.920	0.460	1.120
T_4	0.689	0.193	0.940
T_5	0.660	0.151	0.805
T_6	0.600	0.101	0.650

Chlorophyll content varied significantly among the seedlings with loss in weight. These data are given in Table 31. Seedlings from fresh seeds (T_1) showed maximum chlorophyll a, chlorophyll b and total chlorophyll content. While the lowest content was observed in seedlings from seeds with 50 per cent loss in weight (T_6). Chlorophyll a content ranges from 0.569 mg g^{-1} (T_6 seedlings) to 1.720 mg g^{-1} (T_1 seedlings). Chlorophyll b content was maximum for seedlings from fresh seeds (0.577 mg g^{-1}) and the lowest for T_6 seeds (0.181 mg g^{-1}). Seedlings from fresh seeds also showed maximum total chlorophyll content (2.242 mg g^{-1}) and those from seeds with 50 per cent loss in weight showed the lowest total chlorophyll content (0.591 mg g^{-1}).

Table 31. Effect of seed drying on chlorophyll content (mg g^{-1}) of mango seedlings

Treatment	Chlorophyll a	Chlorophyll b	Total chlorophyll
T_1	1.720 ^{a}	0.577 ^{a}	2.242 ^{a}
T_2	1.219 ^{b}	0.368 ^{b}	1.576 ^{b}
T_3	1.009 ^{c}	0.351 ^{b}	1.277 ^{c}
T_4	0.900 ^{cd}	0.264 ^{c}	0.974 ^{d}
T_5	0.818 ^{d}	0.224 ^{cd}	0.773 ^{de}
T_6	0.569 ^{c}	0.181 ^{d}	0.591 ^{e}
SEm	0.08323	0.02108	0.08165

4.4.4 Chlorophyll stability index

Chlorophyll stability index showed significant difference among the treatments. In the variety *Chandrakkaran*, fresh seeds showed the lowest chlorophyll stability index of 15.49 and seeds with 50 per cent loss in weight showed a chlorophyll stability index of 41.5. The chlorophyll stability index of fresh seeds of *Moovandan* variety was 19.5 and that of *Puliyan* variety was 22.00.

Seeds with 50 per cent loss in weight showed a chlorophyll stability index of 47.5 in variety *Moovandan* and 44 in variety *Puliyan* (Table 32).

Table 32. Chlorophyll stability index (CSI) in the three varieties of mango

Treatments	CSI		
	V_1	V_2	V_3
T_1	15.49 [d]	19.50 [cd]	22.00 [cd]
T_2	21.30 [c]	23.20 [cd]	26.49 [bc]
T_3	25.00 [bc]	27.10 [bc]	28.80 [bc]
T_4	33.00 [b]	37.4 [ab]	38.46 [ab]
T_5	37.00 [ab]	42.3 [ab]	40.10 [ab]
T_6	41.50 [a]	47.50 [a]	44.00 [a]
SEm	2.314	2.682	2.560

Seedlings from fresh seeds showed the lowest chlorophyll stability index of 17.67. Seedlings from seeds with 10 per cent, 20 per cent, 30 per cent and 40 per cent loss in weight showed a chlorophyll stability index of 24, 26.33, 35 and 39 respectively. Seedlings from seeds with 50 per cent loss in weight showed a chlorophyll stability index of 43.33. The data are presented in Table 33.

Table 33. Chlorophyll stability index of mango seedlings

Treatments	C.S.I.
T_1	17.67 [d]
T_2	24.00 [cd]
T_3	26.33 [bc]
T_4	35.00 [b]
T_5	39.00 [ab]
T_6	43.33 [a]
SEm	2.480

4.4.5 Phenol content of leaves and seeds

The data on phenol content in leaves and seeds are presented in Table 34. Phenol content in leaves showed significant difference among treatments.

Highest phenol content was seen in leaves of fresh seeds (31.67 mg g^{-1}) and leaves from seeds with 50 per cent loss in weight produced the lowest phenol content (15.67 mg g^{-1}).

Phenol content in seeds also showed significant variation based on their loss in weight. Seeds with 30 per cent and 40 per cent loss in weight (T_4 and T_5 seeds) did not show significant difference. Phenol content in seeds ranged from 0.177 mg g^{-1} (T_6 seeds) to 0.590 mg g^{-1} (T_1 seeds).

4.4.6 Sugar content of the seed

Sugar content of the seed showed significant variation among seeds based on their loss in weight. Fresh seeds showed the maximum sugar content (33.467 mg g^{-1}) and seeds with 50 per cent loss in weight showed the lowest sugar content (14.583 mg g^{-1}) on fresh weight basis (Table 34).

Table 34. Effect of seed drying on the phenol content (mg g^{-1}) in leaves and seed; sugar content (mg g^{-1}) of mango seeds

Treatments	Phenol content (leaves)	Phenol content (seeds)	Sugar content (seeds)
T_1	31.667 ^{a}	0.590 ^{a}	33.467 ^{a}
T_2	25.667 ^{b}	0.450 ^{ab}	29.087 ^{b}
T_3	25.333 ^{b}	0.380 ^{abc}	25.733 ^{c}
T_4	22.000 ^{c}	0.283 ^{bc}	20.693 ^{d}
T_5	18.667 ^{d}	0.227 ^{bc}	17.863 ^{e}
T_6	15.667 ^{e}	0.177 ^{c}	14.583 ^{f}
SEm	0.8563	0.07638	0.4773

4.5 Anatomical studies

Seedlng girth decreased with respect to seed ageing. The anatomy of the stem of the seedlings showed that as a result of seed ageing, the sections of stressed seedlings showed a decrease in the number of bundle sheaths with an increase in starch grains and sclerenchymatous cells.

4.5.1 Stomatal density

Maximum stomatal density was seen in the case of seedlings from fresh seeds. The stomatal count decreased with loss in moisture content from seeds which resulted in less vigorous seedlings. Seedlings from T_6 seeds had the lowest stomatal content in the 3 varieties (Table 35).

Table 35. Effect of seed drying on stomatal count in mango varieties

Treatments	V_1	V_2	V_3
T1	12	14	18
T2	10	11	14
T3	9	10	11
T4	8	8	10
T5	6	8	8
T6	4	4	7

4.6 Mitotic index and chromosomal aberrations

Mitotic divisions were observed during 9.30 am to 10.30 am. But the number of dividing cells was very low that it was not sufficient to work out the mitotic index.

With ageing of seeds with respect to loss in moisture content upto 30 per cent, no chromosomal aberration was noticed in the cells.

4.7 Correlation

Seedling vigour is positively correlated with chlorophyll content, phenol content in leaves and seeds and sugar content. It was negatively correlated with electrolytic conductivity (Table 36).

Table 36. Correlation coefficients between seedling vigour and physiological characters

	Electrolytic conductivity	Total chlorophyll	Phenol (leaves)	Phenol (seeds)	Sugar (leaves)
Seedling vigour	-0.91	0.99	0.975	0.375	0.96

A high positive correlation was observed between total chlorophyll content, phenol content and sugar content in the leaves of vigorous seedlings obtained from fresh seeds of all the three mango varieties studied. This indicated the higher metabolic efficiency of the seedlings from fresh seeds as compared to seedlings from desiccated seeds.

A high negative correlation was observed between electrolytic conductivity of the seeds and seedling vigour. This indicated that higher solute leakage from the desiccated seeds resulted in the reduced vigour of the seedlings.

Seedling vigour is positively correlated with internodal length and number of leaves (Table 37).

Table 37. Correlation coefficients between seedling vigour and seedling characters

	Internodal length	No. of leaves
Seedling vigour	0.62	0.68

The positive correlation between the internodal length and number of leaves of vigorous seedlings can be used as a criteria for the selection of vigorous seedlings in the nursery.

Discussion

5. DISCUSSION

Mango is basically a seed propagated crop. In a highly cross-pollinated crop like mango, vegetative propagation like grafting is usually resorted for the maintenance and multiplication. To develop good quality rootstock we have to depend on mango seeds. The recalcitrant nature of the mango seeds results in a rapid decline in the viability of the mango seeds. From the results obtained in the present investigation, an attempt is made to discuss the effect of genetic and physiological factors that contribute to variation in the seedling progenies obtained from a single mother plant (half sibs) and to develop a criteria by which such seedlings can be identified in the nurseries before being used as rootstock material. The growth parameters of seedlings upto 5 months after germination was evaluated periodically in the field.

5.1 Variability studies

5.1.1 Seed characters

Three varieties of mango viz., *Chandrakkaran*, *Moovandan* and *Puliyan* were selected for the experiment. Among the seed characters studied, maximum variation was noticed in seed thickness in all the three varieties, while the least variation was noticed in seed volume. The range of variation in seed characters exhibited among the progenies of each variety varied considerably.

Variation in seed characters of mango has been observed by Rao and Hassan (1956) and Mukherjee (1950). But in those studies, the progenies used were not from a single mother tree. In the present study where fresh seeds were collected from a single mother plant, there was not much variation in seed length in the three varieties. Coefficient of variation in seed breadth ranged from 12.92 to 16.88. Range of variation in seed thickness was maximum for *Chandrakkaran*. The coefficient of variation for seed volume ranged from 5.30 percent in *Puliyan* to 8.63 per cent in *Chandrakkaran*. In all the seed characters studied, the maximum variation was noticed for the variety *Chandrakkaran*.

5.1.2 Seedling characters

The degree of variation in seedling characters such as height, girth, internodal length and number of leaves were studied. Among these characters, maximum variability was seen in seedling girth. This is in accordance with the findings of Jyothi (2000) who reported high variation in the growth of seedlings in terms of height and girth of seedling.

On analysis, it was found that seedlings from fresh seeds showed the least variability in seedling girth. When individual varieties were considered, high variability was seen in seedling girth between seedlings from fresh seeds and those from desiccated seeds. Maximum coefficient of variation in seedling girth was seen in the case of variety *Chandrakkaran*. Interaction between varieties and seed desiccation was found to be significant for seedling girth proving that seedling girth is dependent on varieties and physiological characters. High variation in girth as a result of desiccation can be supported from the anatomical studies where there is a change in the number of bundle sheath.

5.2 Germination studies

5.2.1 Germination percentage

A gradual decline in germination with moisture loss was obtained in all the three varieties studied. Moreover, there was variation in germination percentage of the three varieties. This is in accordance with the findings of Doijode (1990) who reported variation in the loss of seed viability at different moisture contents in different mango varieties. Moisture content of seeds reduced rapidly on storage and this decline in moisture content on storage in turn resulted in reduced germination (Mallareddy and Sharma, 1983).

In the present study, the fresh seeds of the variety *Chandrakkaran* had a maximum germination percentage of 73 per cent and seeds which lost 50 per cent of its weight gave 47 per cent germination. The maximum germination percentage of 63 was obtained from fresh seeds of *Moovandan* and 64 per cent from the fresh seeds of *Puliyan*. Seeds which lost 50 per cent of the original weight showed the lowest germination percentage of 22 per cent for *Moovandan* and 25 per cent for *Puliyan*. In general, fresh seeds gave maximum germination percentage of 67 per cent and seeds which lost 50 per cent of the weight showed a germination percentage of 31 per cent. Hence it can be persumed that the loss in seed weight accounted for loss in germination percentage.

5.2.2 Critical moisture content of mango

The critical moisture content varies from species to species. Critical moisture content of jack is 39 per cent (Krishnaswamy, 1990). Several studies have been conducted to estimate the critical moisture content of different mango varieties. The initial moisture content of mango seeds was reported to be around 70-75 per cent and the critical moisture level was at 45-50 per cent (Fu *et al.*, 1990). In the present study conducted to estimate the critical moisture content of the three mango varieties, it was found that in the variety *Chandrakkaran*, 50 per cent germination of seeds was obtained when the moisture content was 32 per cent and complete loss of seed viability was observed when the moisture content fell below 24 per cent. In the variety *Moovandan* 50 per cent germination was obtained when the moisture content was 46 per cent and the seeds did not germinate below a moisture content of 30 per cent in variety *Moovandan*. The seeds of *Puliyan* showed 50 per cent germination when the moisture content was 32 per cent and lost their viability completely below a moisture content of 28 per cent. This is in accordance with the findings of Doijode (1990) who reported the critical moisture content of Alphonso variety to be 25 per cent and Totapuri to be 32 per cent. Critical moisture content of Goa and Neelum was found to be 29 per cent and 34 per cent respectively (Girija *et al.*, 1998).

5.3 Effect of seed desiccation on seedling characters

5.3.1 Height of seedling

There was significant decrease in height of mango seedlings when they were dried and sown. This is in accordance with the findings of Girija (1998) who reported progressive decline in seedling height with storage of seeds. Assessment of the effect of seed drying on seedling height of the three mango varieties revealed that for the variety *Chandrakkaran*, seed drying upto T_5 did not significantly affect the seedling height and seedling performance during 1 MAG. Performance of the seedling from T_1 to T_4 was on par with the fresh seedlings at all stages of growth. But for the variety *Moovandan*, a significant decrease in seedling height was observed on the first month itself even with 10 per cent reduction in seed weight. But by 2nd month, these seedlings could improve their performance and seedlings with 10 per cent and 20 per cent loss in weight were on par with fresh seedlings. But when the weight was reduced below 30 per cent, their performance was significantly affected and this could not improve even after 5 MAG. For the variety *Puliyan*, even 10 per cent weight loss from the seed significantly affected the seedling performance. They were on par with fresh seedlings during 1 MAG. But by 3 MAG, their quality declined (Fig. 1).

The pooled analysis revealed that irrespective of the variety, drying the seeds below 30 per cent loss in weight would significantly affect the seedling height. Seeds sown after 40 per cent and 50 per cent loss in weight were significantly inferior to seeds sown fresh. Hence seedlings from fresh seeds can be regarded as vigorous seedling as suggested by Yohe and Poehlmann (1975) (Plate 2).

5.3.2 Girth of seedlings

The seedling girth is an important attribute in deciding the vigour of seedlings (Auckland, 1961). The seedling girth of the variety *Chandrakkaran* varied significantly only when the weight of seeds was reduced below 40 per cent

PLATE - 2

Effect of seed desiccation on height (H) of mango seedlings

1. CHANDRAKKARAN

2. MOOVANDAN

3. PULIYAN

during 1 MAG. Number of leaves is considered to be an important aspect for deciding the vigour of seedlings (Ramanujam, 1978). The number of leaves of seedlings in T_4 treatment was found to be significantly reduced. This in turn might have contributed to the decrease in the girth of seedlings after 4 month of growth as compared to the 1 month old seedlings. The 1 month old seedlings utilizes the stored nutrients in the seed for its initial growth.

In the variety *Moovandan*, there was marked reduction in girth even with 10 per cent weight loss from the seed. The girth of seedlings were found to improve with subsequent growth. Seedlings from seeds with 40 per cent loss in weight also could improve the seedling girth by the 5^{th} month and these were as good as fresh seedling in performance. Such a behaviour could also be explained based on number of leaves. The number of leaves retained by fresh seedlings and those from seeds which lost 30 per cent of its weight were on par.

In the variety *Puliyan*, seedling girth was highly influenced by drying of seeds. Even a 10 per cent decrease in weight contributed to significant reduction in girth of seedlings (Fig.2).

Based on seedling girth, the growth suppression factors were worked out for all the three varieties and the results indicated a significant difference in girth. The suppression in growth of seedlings from those seeds which lost 10 per cent and 20 per cent of its weight was marginal for the variety *Chandrakkaran*. The growth suppression was significant when they were grown from seedlings which had lost more than 30 per cent of its original weight for the variety

Fig. 1. Effect of seed drying on seedling height

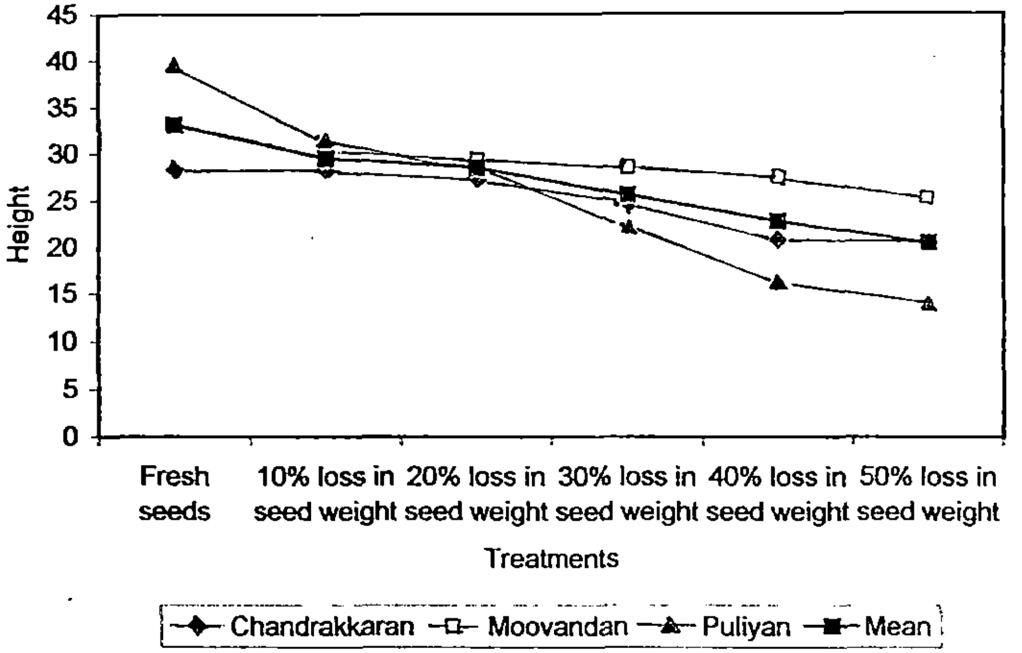
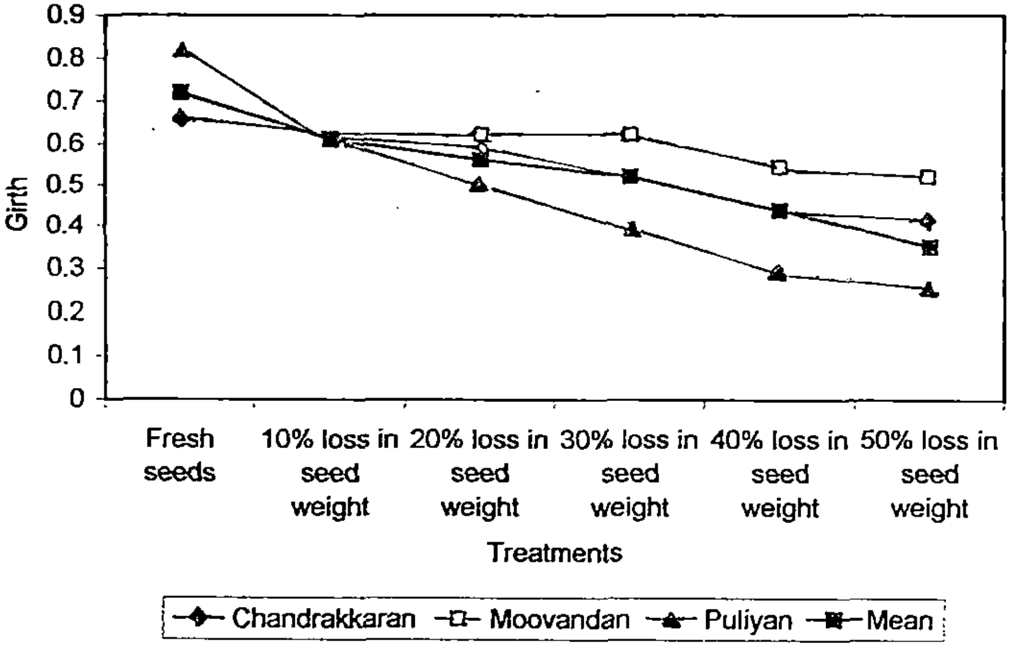


Fig. 2. Effect of seed drying on seedling girth



Moovandan, a stable value was obtained upto T_3 and the suppression increased when the seeds were subjected to 40 per cent of reduction in seed weight. *Puliyan* was found to be the most sensitive variety wherein a 30 per cent reduction in weight contributed to 52.4 per cent growth suppression. A comparison of girth of seedlings from fresh and desiccated seeds of the three varieties indicated a marked reduction in the number of bundle sheaths and secondary thickening.

The analysis revealed that generally for mango, seed drying induces reduction in seedling girth. Significant reduction in seedling vigour is observed when seeds lose 40 per cent of its weight. Among the three varieties, Chadrakkaran and *Moovandan* followed a similar trend while in *Puliyan* variety, the seedling girth decreased even with 10 per cent loss in moisture.

5.3.3 Internodal length of seedlings

Desiccation of seeds contributed to wide variation in internodal length. Seedlings of the variety *Chandrakkaran* showed significant reduction only when 40 per cent of the seed weight was reduced by drying whereas in the *Moovandan* variety, even a 10 per cent reduction in seed weight contributed to significant reduction in internodal length. The same pattern was observed in the variety *Puliyan* also (Fig. 3).

In all stages of growth, the maximum internodal length was recorded by seedlings from fresh seeds and the lowest by seedlings from seeds with 50 per cent loss in weight. Zagaja and Faust (1983) reported that vigorous seedlings of mango had maximum internodal length.

Fig. 3. Effect of seed drying on internodal length

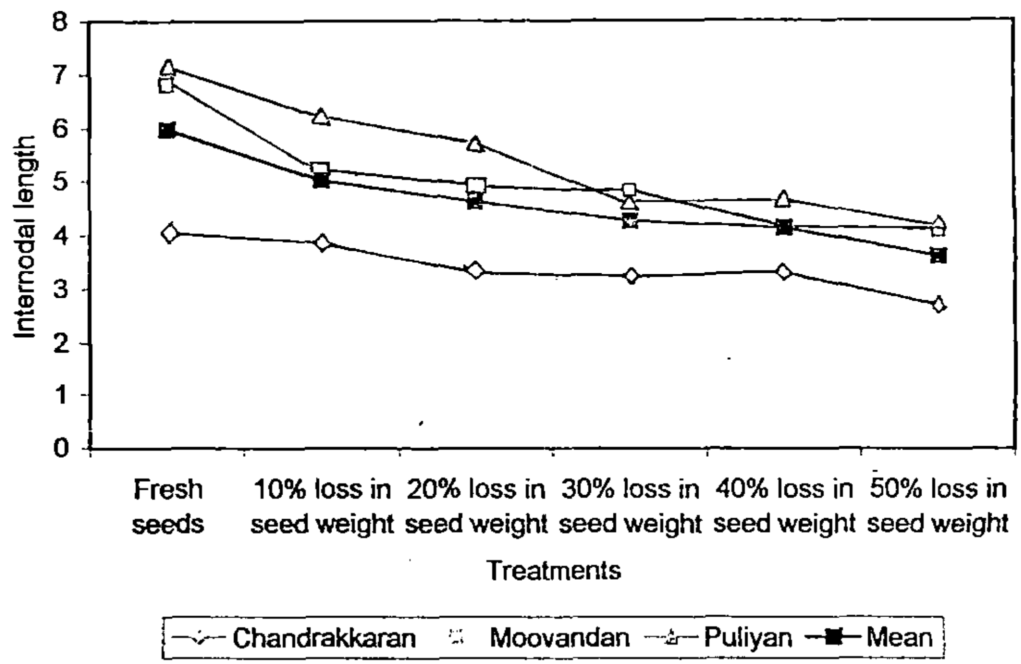
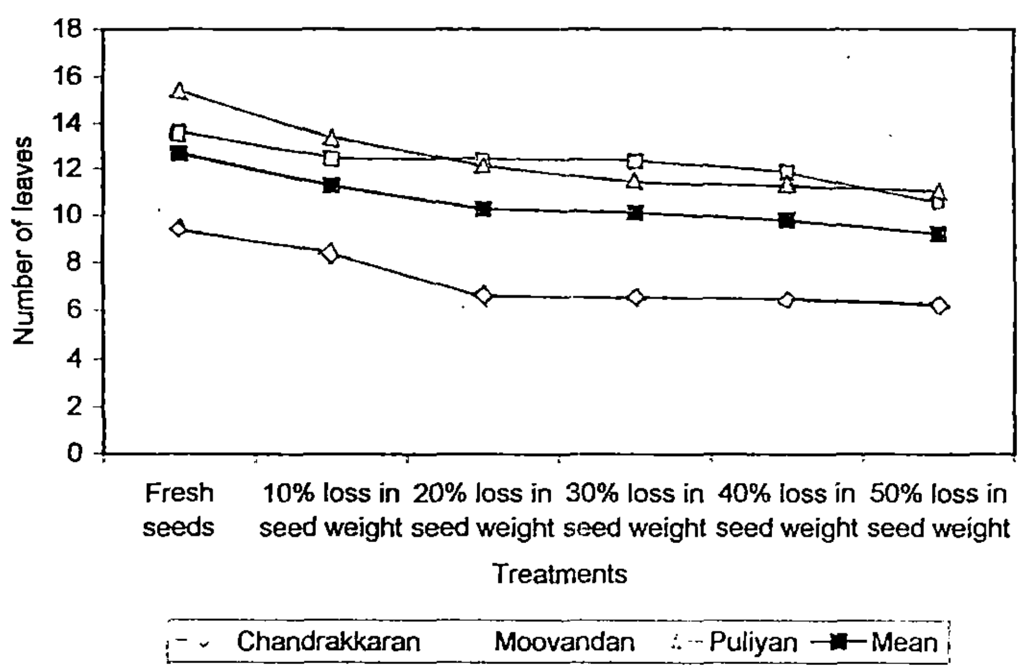


Fig. 4. Effect of seed drying on number of leaves



5.3.4 Number of leaves

Leaves produced in a plant represent the photosynthetic activity of the plant. As a result of moisture loss from seeds, the number of leaves produced in seedling.declined. It was observed that vigorous plants had more number of leaves than their parents (Ramanujam, 1978). Rawat and Singh (2000) reported that the maximum value for leaf number and dry weight of seedling components such as root, shoot and leaf can be used as criteria for selecting nursery stock for field planting.

The rate of leaf production was different for the three varieties tested. In variety *Chandrakkaran*, number of leaves of seedlings from seeds with 30 per cent loss in weight was significantly low. In variety *Moovandan*, the number of leaves retained by fresh seedlings and seedlings from seeds with 30 per cent loss in weight did not differ significantly. A similar trend in number of leaves was followed in the variety *Puliyan* also (Fig. 4).

Leaf area index also varied significantly among seedlings. Maximum leaf area was observed for seedlings from fresh seeds. This is in accordance with the reports of Shinde (1982) that vigorous rootstocks had greater leaf area than that of dwarfing ones in citrus.

5.4. Polyembryony

The formation of more than one embryo in an embryo sac was reported for the first time in 1825 by Reinwardt (Wester, 1912). This phenomenon, technically known as polyembryony is now known to occur in a number of varieties (Juliano, 1934; Sen and Mallik, 1940; Maheswari *et al.*, 1955). Polyembryonic nature was seen in all the three varieties considered for the study. It was observed that seed drying did not have any influence on the polyembryonic character of the variety. Desiccation did not effect the multiple embryos present in the seed. It did not affect the activator which was responsible for the development of multiple shoots.

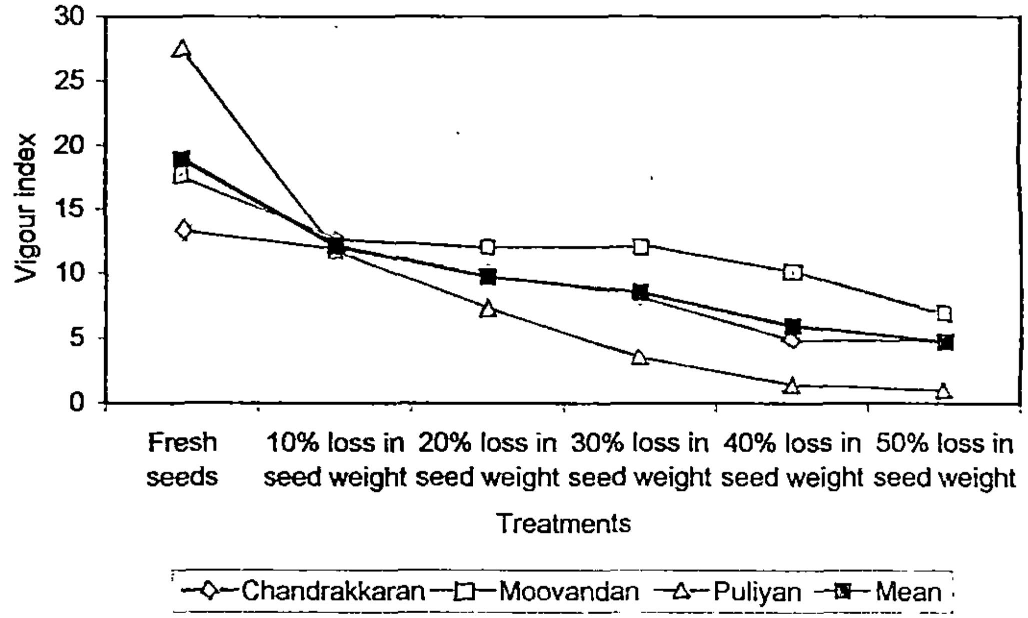
5.5 Seedling vigour

Loss of viability in storage is preceded by a wide range of symptoms, collectively contributing to loss of vigour which can lead to decreased field emergence and poorer growth of plants resulting in poor final yield in crops.

In the present study, vigour index was estimated on five month old mango seedlings. It was observed that seedling vigour was reduced with seed desiccation. Vigour index was also estimated as a factor which depends upon height and girth of seedlings. Among the varieties studied, maximum vigour index was observed in seedlings from fresh seeds of variety *Puliyan*, followed by the varieties *Moovandan* and *Chandrakkaran.* This is in accordance with the findings of Murthy and Bavappa (1960) who have reported variation in vigour of different varieties of mango trees. Jyothi (2000) recorded variation in the vigour of mango seedlings after 3 months, 6 months and 1 year of sowing.

The maximum vigour decline was observed in the seedlings grown from seeds which had lost 50 per cent of its weight (Fig. 5).

Fig. 5. Effect of seed drying in vigour index of mango seedlings



5.6 Seed leachate

As a result of ageing of seeds, certain biochemical changes occur in the cell structure hastening the leaching of metabolites from seeds leading to the reduction of seed viability (Doijode, 1990). More materials leach out of deteriorated seeds than from vigorous seeds. In the present study, it has been found that solute leakage was highest from deteriorated seeds i.e., seeds with 50 per cent loss in weight. Leachate from fresh seeds was very low. Increased leachate from deteriorated seeds is indicative of reduced vigour with loss of viability (Mathews and Bradnock, 1968). The electrical conductivity of leachate increased with seed deterioration. Ram and Weisner (1988) reported that as a result of increase in the electrical conductivity of the seed leachate, speed of germination decreased and germination potential declined. The increase in leachate is due to the membrane deterioration during seed storage which is followed by loss in germination. In the present study it was found that percent solute leakage increased with decrease in seed weight due to desiccation.

5.7 Physiological characters associated with moisture loss from seeds

It has been found that seed viability is eventually lost during storage in mango due to some degenerative processes occurring in the seed. In the present study, measures were taken to estimate the degenerative changes occurring in the seed as a result of desiccation. It was found that chlorophyll content, phenol content and sugar content of seeds decreased with ageing of seeds. Loomis and Battaila (1966) had reported that loss of compartmentalization of cells on desiccation result in the formation of protein phenol complexes leading to loss of enzyme activity. In *Mangifera indica,* Chin and Fu (1989) had reported an increase in polyphenol oxidase activity on seed deterioration. In the present study a decrease in phenol content in leaves of mango seedlings has been observed.

Chlorophyll content was found to be higher for seedlings from fresh seeds. But chlorophyll stability index was higher for the seedlings from seeds which lost 50 per cent of its weight.

5.8 Anatomical studies

Arora *et al.* (1978) studied vigour in mango based on bark percentage of root, stomatal count and number of xylem vessels per unit area. In the present study, it was found that in all the three varieties of mango considered, the sections of stem cuttings of stressed seedlings showed a decrease in the number of bundle sheaths and an increase in starch grains and sclerenchymatous cells as compared to those of the fresh seedlings (Plate 3).

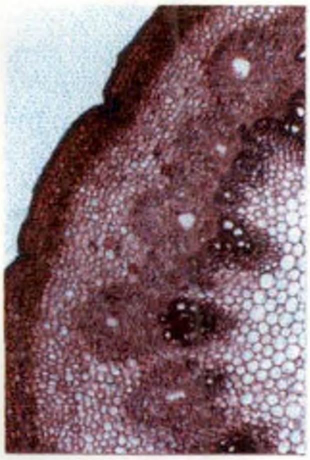
5.8.1 Stomatal count

Stomatal count has been reported to be related to vigour of the tree. Positive correlation was observed between frequency of stomatal distribution and vigour of plants (Chaklader, 1967). This character was suggested for selection and classification of mango rootstocks at nursery stage by Majumdar *et al.* (1972). In the present study seedlings from fresh seeds of all the three varieties of mango studied had higher stomatal indices than those from dried seeds indicating that seedlings from fresh seeds were more vigorous than seedlings from dried seeds.

PLATE - 3

Cross section of stems of mango seedlings from fresh (F) & desiccated (D) seeds

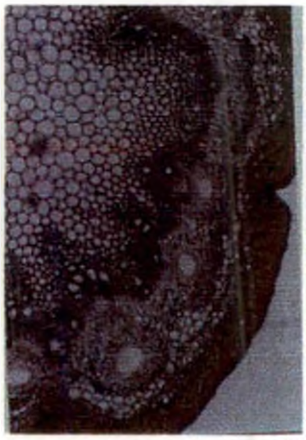
1. CHANDRAKKARAN



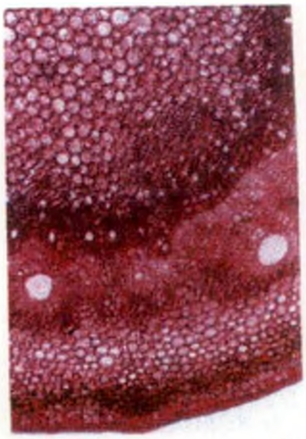
F

D

2. MOOVANDAN



F



D

3. PULIYAN

F

D

5.9 Cytological observations as influenced by ageing

Chauhan and Swaminathan (1984) reported a marked decline in mitotic index and increase in chromosomal aberrations with ageing of seed. In the present study, all the mitotic divisions could be observed but the number of mitotic divisions was not sufficient enough to work out the mitotic indices. Moreover, any type of chromosomal aberration was not detected with loss of moisture content of the seeds (Plate 4).

5.10 Correlation between seedling vigour and seedling characters

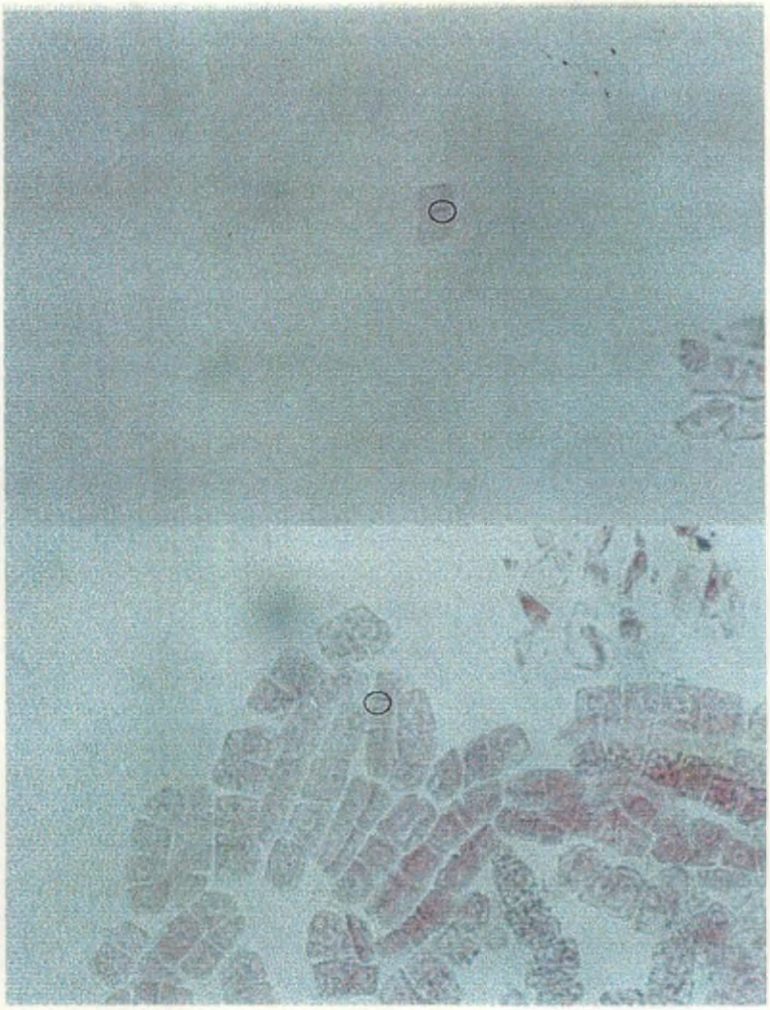
High positive correlation was observed between seedling vigour and seedling characters like internodal length and number of leaves. Ramanujam (1978) had reported that plant height was largely determined by the number of internodes and leaves. Vigorous plants had more number of leaves. In the present study, the correlation coefficient between seedling vigour and internodal length was found to be 0.62 and that between seedling vigour and number of leaves was 0.68.

5.11 Correlation between seedling vigour and physiological characters

Physiological parameters like chlorophyll content of leaves, phenol content of leaves and seeds and sugar content of leaves were found to have positive correlation with seedling vigour. Seedling vigour was negatively correlated with electrolytic conductivity of the seed leachate. Various studies on naturally aged seeds indicated that more materials leached out of deteriorated seeds than from vigorous and sound seeds (Pollock and Toole, 1966). In the present study, it has

PLATE - 4

Stages of cell division in the root tip of mango seedlings



Metaphase

Early Anaphase

been found that less vigorous seedlings were obtained from deteriorated seeds from which more materials had been leached out indicated by the high electrolytic conductivity of the seed leachate.

Presence of high phenol compounds have been reported in the seeds of tropical plants (Loomis and Battaila, 1966). They are normally compartmentalized within cells. On desiccation of mango seeds, they are released and cause damage to the surrounding cells (Girija, 1998). High phenol content is positively correlated with vigour of the seedlings (Marie, 2001). Production of high secondary metabolites in the plant is an indication of higher metabolic activity of the plant system.

In the present study, seedlings from fresh seeds were found to have higher phenolic content which progressively declined with seed desiccation indicating that the metabolic efficiency of the seedling from fresh seeds leading to higher accumulation of secondary metabolities. Desiccation of seeds affects the metabolic efficiency of the seedling contributing to lower production of phenols in the leaves.

Higher content of total sugars in the leaves of vigorous plants indicate the metabolic efficiency of the seedling compared to the less vigorous seedlings produced from desiccated seeds.

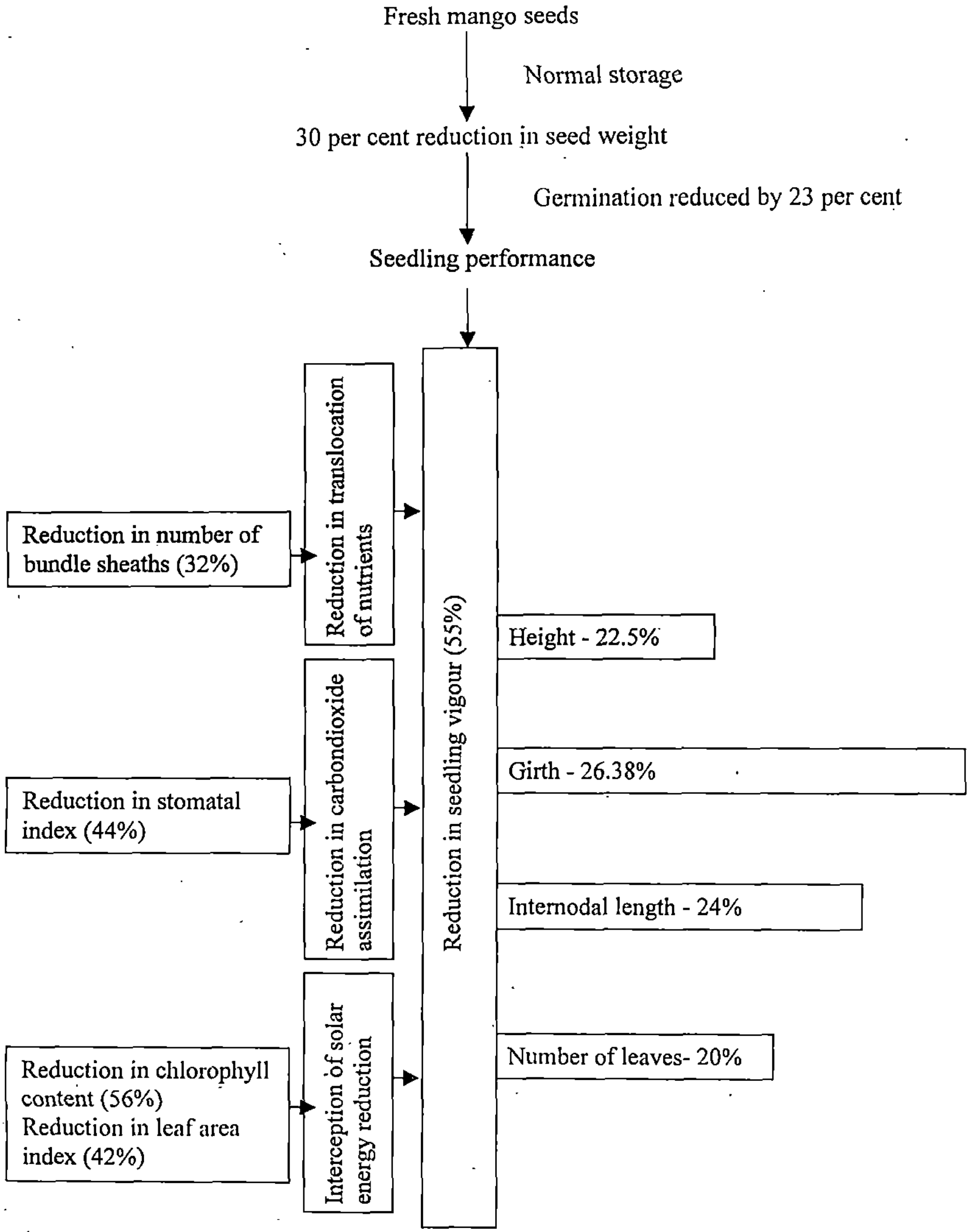
In fruit trees and plantation crops, the criteria for seedling selection in the nursery is based on seedling vigour. In a recalcitrant crop like mango, reduction in moisture content of the seed leads to decline in seedling vigour and ultimately the death of the seedlings. The influence of moisture content on the physiological and morphological attributes of mango seedling is evident from this study. The study also shows that the varieties vary in their response to moisture loss. Variety *Chandrakkaran* seems to have a wider adaptability with respect to moisture loss from seeds,while the variety *Puliyan* was found to be the most sensitive. The study also revealed that the reduction of moisture content below a critical level can contribute to a decline in physiological attributes like leaf area index where by light interception is reduced. A reduction in chlorophyll content of the seedling can contribute to reduced photosynthetic efficiency of seedling. The reduced stomatal index will lead to reduced carbondioxide assimilation.

All these factors in turn will affect the amount of carbondioxide fixed by the seedling and thereby the total dry matter content. This in turn will contribute to a reduction in morphological attributes of the seedling like height, internodal length and girth of the seedling. The reduction in the number of bundle sheaths will adversely affect the translocation of nutrients leading to reduced growth and development which in turn lead to decline in seedling vigour (Fig. 6).

The future line of work can be undertaken to evaluate the performance of grafted seedlings in the field which will help to standardise the quality of the rootstock material.

Cryopreservation technique can be tried for preservation of mango seeds taking into account the desiccation tolerance of the variety.

Fig. 6. Percentage inhibition in morphological attributes of mango seedlings due to seed desiccation



Summary

6. SUMMARY

Three varieties of mango viz., *Chandrakkaran*, *Moovandan* and *Puliyan* were selected for the study. The experiment was aimed to assess the variability in the seedling characters obtained from a single mother plant and to study the effect of seed deterioration in the seedling characters.

Assessment of variability in seedling characters revealed that the most variable seedling character is the seedling girth. Variation in seedling girth is dependent on varieties. Desiccation of seed also resulted in variation in seedling girth leading to the inference that seedling girth is controlled by physiological processes also. High amount of variability in seedling girth was noticed in the variety *Chandrakkaran*.

Gradual decline in germination percentage occurred with loss in seed weight due to moisture loss from the seeds.

Critical moisture content was estimated to be 24 per cent for *Chandrakkaran*, 30 per cent for *Moovandan* and 28 per cent for *Puliyan*.

Seedling height gradually declined with desiccation of seeds. Effect of seed desiccation varied in varieties with respect to height of seedlings. *Chandrakkaran* was the least sensitive to desiccation with respect to height.

There was considerable decrease in seedling girth with moisture loss from the seeds in all the three varieties studied. Growth suppression in seedlings increased with loss of seed weight. *Puliyan* was found to be the most sensitive variety and *Chandrakkaran* to be the least sensitive.

Internodal length of seedlings decreased with loss of moisture from seeds. The variation in internodal length with desiccation was least for the variety *Chandrakkaran*.

Irrespective of the variety the rate of leaf production decreased with desiccation of seed. Leaf area index was also significantly reduced by moisture loss from seeds.

Polyembryonic nature of the varieties was not affected by desiccation of seeds.

Seedling vigour was positively correlated with internodal length and number of leaves in all the three varieties studied.

Chandrakkaran was found to be the most adaptive variety and exhibited more tolerance to seed desiccation indicating that it has a broad genetic base.

In less vigorous seedlings obtained from desiccated seeds of all the three varieties had lower phenol content, sugar content and chlorophyll content.

Chlorophyll stability index was found to be higher for the variety *Moovandan*.

The percent solute leakage was found to be higher from the desiccated seeds than fresh seeds.

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* Originals not seen

Appendices

APPENDIX-1

Mean squares of seedling characters in mango

	df	Height	Girth	Internodal length	No. of leaves
Treatments	5	639.581	0.435	25.107	60.887
Variety	2	325.434	0.095	107.119	680.757
Treatment x Variety	10	164.552	0.085	2.797	4.737
Error	215	27.992	0.019	0.734	5.269

APPENDIX-2

Mean squares of physiological characters of mango seedlings

	df	LAI	Chlorophyll a	Chlorophyll b	Total chlorophyll
Treatments	5	0.881	1.394	0.179	3.236
Variety	2	0.157	2.306	0.170	5.378
Treatment x Variety	10	0.020	0.051	0.008	0.120
Error	215	0.011	0.022	0.005	0.068

IMPACT OF SEED DETERIORATION ON SEEDLING VIGOUR IN MANGO
(*Mangifera indica* L.)

By

ANILA, P.

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

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ABSTRACT

The present study on 'Impact of seed deterioration on seedling vigour in mango' was undertaken at the Department of Plant Breeding and Genetics, College of Horticulture, Vellanikkara during 1999-2001 with the objectives of assessing the variability of seedling characters obtained from a single plant, the effect of seed deterioration on seedling characters and to ascertain the critical moisture content of the varieties.

Three varieties of mango were selected for the study. Assessment of variability of seedling characters of these varieties revealed that seedling girth is the most variable character, variability within varieties and between varieties was high for this character. Moreover, the response of girth to variation in seed weight due to loss in moisture content of the seed was also high indicating that this character may be influenced by both genetic factor as well as the physiological condition of the seed.

The critical moisture content was estimated to be 24% for *Chandrakkaran*, 30% for *Moovandan* and 28% for *Puliyan*.

Seedling characters like height, girth, internodal length, number of leaves etc. were studied. These characters were found to be highly depended upon the moisture content of seed. There was considerable reduction in these characters with loss of moisture from seed. Polyembryonic nature of these varieties were not affected by seed desiccation.

Biochemical characters like chlorophyll content, phenol content and sugar content were found to decrease with seed desiccation. Electrolyte leakage was found to be high with seed desiccation leading to reduction in viability. Seedling vigour was found to be positively correlated with biochemical characters.