HARVEST AND POSTHARVEST LOSSES IN MANGO (*Mangifera indica* L.) AND ITS MANAGEMENT

BY

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THESIS

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DECLARATION

I hereby declare that this thesis entitled **Harvest and Postharvest Losses in Mango (*Mangifera indica* L.) and its Management** is a bonafide record of research work done by me during the course of research and that this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other university or society.

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my loving parents

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ABBREVIATIONS

CPLW	-	Cumulative Physiological Loss in Weight
PLW	-	Physiological Loss in Weight
TSS	-	Total Soluable Solids
m	-	metre
cm	-	centimetre
mm	-	millimetre
%	-	per cent
g	-	gram
Kg	-	Kilo gram
°bx	-	degree brix
ppm	-	parts per million

Introduction

INTRODUCTION

Mango (*Mangifera indica* L.) popularly known as the king of fruits, is the choicest fruit grown extensively in the tropics. India is the largest producer of mango in the world with an annual production of 9.22 million tonnes from 1.13 million hectares. During 1993-'94 India exported mangoes and mango products worth Rs. 438.7 millions (Chadha,1995). Major mango producing states in India are UP, Maharashtra, Madhya Pradesh, Tamil Nadu, Andra Pradesh, Karnataka, Gujarat and Kerala. Kerala has 77003 hectares under the crop and produces 275456 tonnes of mango annually. Harvest season in the state is early compared to other parts of the country which provides ample opportunities to exploit market potentials.

Substantial portion of the produce in the state comes from small holdings and comprises many varieties. Methods of harvest and handling have changed little from the traditional practices. Fruits from tall trees are harvested using nets attached to bamboo poles and are collected in bamboo baskets or gunny bags. Technological innovations on harvesting methods and handling practices for getting better quality produce have not received due attention. Optimum maturity at the stage of harvest, care taken during harvest and handling of the produce and postharvest treatments to reduce losses are some of the areas where attention is required. Estimates of postharvest losses in mango vary widely. Market surveys have revealed that more than 20 per cent losses occur in mango variety *Neelum* while it is more than 36 per cent in *Bangalora* (Madan, 1988). Realistic estimates of postharvest losses at different stages of handling and information on the causes are lacking. Information on varietal characteristics and extent of losses at different stages of handling will be useful for refining the practices to get optimum quality produce, incurring minimal losses.

The present study was thus taken up to describe the varietal characteristics of few important mango varieties at different stages of handling. The study envisaged design and evaluation of an improved mango harvester suitable for harvest from tall trees, in terms of harvesting efficiency and other desiarable attributes. It was also intented to compare different methods of collection and packaging of the produce in terms of quantitative and qualitative losses. Effects of few postharvest treatments on postharvest losses were also compared.

Review of Literature

REVIEW OF LITERATURE

The relevant literature related to the study is reviewed here under the following titles:

2.1. Flowering in mango
2.2. Harvest indices for mango
2.3. Harvesting techniques in mango
2.4. Collection and handling of harvested mangoes
2.5. Postharvest behaviour of mango
2.6. Packaging of mangoes and other fruits
2.7. Postharvest losses and their management
2.8. Fungicidal residues in treated fruits

2.1. Flowering in mango

The time of flowering in different regions is mainly governed by the local climatic conditions. Gandhi (1955) stated that flowering started from November in Andhra Pradesh and the South Konkan on the West Coast of India.

Singh (1990) reported that in Northern India mango flowered from February to March with a full bloom during March. Under milder climatic conditions of the Southern and Western India, mango started flowering from December itself, whereas under extreme climatic conditions of the north, the flowering was late (February - March). Bloom period, in eastern India is earlier than in north.

2.2 Harvest indices for Mango

Harkness and Cobin (1951) reported that mango fruits having a specific gravity between 1.01 to 1.02 were found to be in a satisfactory stage for picking. The mangoes so harvested had uniform ripening and keeping quality.

The criteria conventionally used for determining the maturity of mangoes were listed as nature and quantum of sap exuded from the fruit stalk on picking, appearance of 'bloom' and characteristic dots on the fruit skin and colour of the skin, besides typical morphological form, size, relative density and hardness of the fruit, and firmness of the flesh (Singh,1960; Jain, 1961).

Singh *et al* (1978) considered specific gravity, TSS percentage and starch: acid ratio as the indices of maturity in mango.

Joshi and Roy (1986) studied the maturity indices and their relation with fruit character. The TSS, starch, sugars, total carotenoid pigments and pH were positively correlated, while moisture, acidity, ascorbic acid and tannins were negatively correlated with fruit specific gravity at the time of harvest. Fruits with specific gravity > 1.0 were superior in quality to those with a lower specific gravity.

According to Tarmizi *et al* (1988) early harvesting at 1-2 weeks before normal harvesting stage slightly reduced fruit rot incidence.

Magdum *et al* (1992) reported that in mangoes, specific gravity between 1.00 and 1.02, 10 to 12 per cent starch, 10 to 12 percent TSS and a flesh firmness between 1.75 to 2 kg/cm^2 (judged by Magness Taylor Pressure tester) gave a fair index of maturity.

According to Oosthuyse (1991), among different indices for assessing fruit ripeness, viz; pulp penetration pressure, degrees of shoulder development, skin and pulp colouration and TSS content, pulp penetration was the best.

2.3. Harvesting techniques in mango

Eckert (1975) stated that injuries caused during harvest and handling of the fruits were the major sites of infection by wound pathogens in mango.

Method of harvest might affect the quality of produce. Majumder (1985) reported that mangoes harvested by shaking the branches had internal breakdown of the flesh.

Chadha (1989) stated that although the keeping quality of mango was a varietal character, it depended to a great extent on the method of harvesting. About 60 per cent of the fruits harvested using *local nipper* were without pedicel. Such fruits were injured at the point of separation, and the sap that oozed out, masked the original colour of the fruit and thereby reduced the market value. He further reported that mango harvester developed at Konkan Krishi Vidya peeth, Dapoli retained pedicel during harvest.

Use of harvest aids such as 'Nutan Zela' and 'Pusa fruit harvesters'having the facility of holding, pulling, and shearing or clipping, increased the efficiency and enabled the harvest of mango fruits with a small stalk attached. This increased their shelf life because of less mechanical injury and less susceptibility to microbial decay. (AICRP on PHT, 1990).

Effect of method of harvesting on the storage behaviour of Dashehari mango was studied by Singh *et al* (1993). Fruits picked using hand harvester with stalk showed a marked reduction in fungal attack, particularly due to stem end rot *(Diplodia natalensis)*. The rate of respiration one day after harvest was reduced and the shelf life increased by 2-3 days when fruits were picked with stalk. The harvesting method had no effect on fruit acidity or total carotenoid oontent.

According to Haque and Dhua (1993) fruits harvested with stalks were less susceptible to storage decay than fruits harvested without stalks and had higher fruit quality during storage.

2.4 Collection and handling of harvested mangoes

Zauberman *et al* (1979), studied the effect of transportation on storage of mangoes and found that during transportation of mango stored in large bins, containing about 350 Kg mango fruits, from the orchard to the packing house, only fruits touching the bottom of the bin was found bruised up to 70 per cent.

Cappellini *et al* (1988) tabulated arrival conditions of mango fruits to the New York market during 1972-85. In 717 mango shipments, 9 parasitic diseases in 1061 occurrences, 5 physiological disorders in 488 occurrences, and 61 occurrences of bruise damage were reported. More than 50 per cent of all occurrences reported were anthracnose. The most common physiological disorder was soft fruit.

If the mango fruits were transported by rail, the losses to the tune of 10 to 20 per cent occurred due to frequent delays in movement of the wagons (Singh, 1990).

During transportation of Dashehari mangoes from Lucknow to Delhi, although there was only 3.65 per cent physiological weight loss, the subsequent ripening loss was around 7.54 per cent and after ripening nearly 10 per cent of these fruits were lost each day (AICRP on PHT, 1990).

Quroshi and Meah (1991) noticed a linear relationship between transport distance from production site to retail location and the incidence of stem end rot.

2.5 Postharvest behaviour of mango

Thomas (1975) found that the storage temperature below ambient (25 °C) would adversely affect the development of typical aroma, flavour and carotene formation in *Alphonso* mangoes on ripening.

Thomas and Oke (1980) studied vitamin C levels in the peel of mature unripe *Alphonso, Dashehari, Langra* and *Pairi* mangoes. Fruit ripened for several days at ambient temperature (29-32 °C) lost vitamin C more rapidly than fruits stored at 20 °C.

Yuniarti (1980) studied different physico-chemical changes of *Arumanis* mango during storage at ambient temperature. No significant differences were noted in total solids, titrable acidity, sucrose or non-reducing sugar contents. Fruit texture deteriorated with time whereas pH increased. After 6 days, the skin colour was still attractive and yellowish-green and the flesh, firm. The best eating condition was reached in 8 to 10 days. After this, part of the pulp became brown and the fruit became over ripe. He recommended that for long to medium distance transport mangoes should not be held longer than 4 days after harvest.

Roe and Bruemmer (1981) found that water-soluble and alkali-soluble pectin declined and ammonium oxalate-soluble pectin increased as the mango lost its firmness. Polygalacturonase and cellulase activities of cell wall preparation increased markedly during ripening. The polygalacturonase activity were well correlated with the loss of firmness.

According to Ashraf *et al* (1981), mango peel had higher pectinesterase activity and ash content than the pulp. The moisture content increased in both the pulp and peels during ripening. The brix value and carotenoids increased up to six days after which these tend to decline. Vitamin C increased up to day five and then started declining.

Mango fruits cv. *Gaurjeet* were stored successfully for 6 days at room temperature (32-35 °C). Total soluble solids, total sugars, reducing sugars and ascorbic acid contents increased gradually with fruit ripening whereas acidity decreased. (Upadhyay and Tripathi, 1985).

Prasad and Nalini (1988) reported that size, weight and volume of mango fruits were positively correlated.

Tandon *et al*(1988) studied ripening pattern of specific gravity graded Dashehari mangoes. The fruits were harvested and then graded into three specific gravity grades, viz; < 1.0 (Gr.I), 1.00 to 1.02 (Gr.II) and >1.02 (Gr.III). The fruits of Gr.I were the biggest and those of Gr.III the smallest. Gr.III fruits ripened earliest (within 5 days) and their shelf life was less, compared with fruits of Gr.I and Gr.II. Gr.I fruits ripened with better quality and shelf life and retained marketability even after 11 days of storage. The development of carotenoids and the rate of starch depletion was slow in Gr.I and so was the senescence, compared with Gr.II and Gr.III fruits.

Tripathi (1988) assessed that fruit flavour and quality of *Gaurjeet* mango were best on the sixth day of storage.

Dietz *et al*(1989) studied influence of cuticles and lenticels on weight loss of mango fruit and found that weight loss was not significantly correlated with cuticular thickness.

Sahni and Khurdiya (1989) reported that the stage of ripening of the fruit had a considerable bearing on the physico-chemical constituents of the fruit and ultimately on the quality of the processed products in terms of colour, flavour and texture. An increase in pH, TSS, carotenoids and sugars was observed in the ripe fruits, while specific gravity, acidity and ascorbic acid declined.

Sethi and Maini (1989) reported that ripening process could be controlled by the proper use of fungicides for controlling spoilage. Frutox (fungicidal waxol 3%) and Tal Prolong (1.0-1.5%) retarded ripening in mango varieties *Alphonso* and *Pairi* but they turned soft at ripening.

Loveys *et al* (1992) found that damage caused to the skin of mango fruits by contact with sap exuded from the cut or broken pedicel reduced consumer acceptance and storage life in cv.*Kensington*. They reported that the primary cause of sapburn was the entry of volatile sap components through the lenticels, resulting in tissue damage and enzymatic browning.

Robinson *et al*(1993) found that sap and skin of ripe mango (cv.*Kensington*) fruits contained considerable polyphenol oxidase (PPO) activity. Sap induced skin browning (sap burn) was predominantly catalysed by PPO in the skin which was unlikely to be prevented by heat treatment of the fruits.

Agnihotri *et al* (1963) reported that on storage, mangoes gradually become milder in texture, colour changed from green to light yellow and finally deep orange. Fruits started shrinking in dimensions and developed wrinkles on the surface. Gradual weight loss also was observed. In the early stages of storage, the fruits developed a characteristic flavour and taste most acceptable for table consumption.

During ripening of mango (cv. *Dashehari*) there was a gradual increase in the contents of carotenes in the flesh, resulting in a deep yellow colouration of the ripe fruits. Changes in carotenes were accompanied by a decrease in pressurometer readings, fruit acidity and ascorbic acid content and an increase in sugars and TSS (Verma *et al*,1986).

2.6 Packaging of mangoes and other fruits

Cylindrical bamboo baskets are commonly used for packaging mangoes all over India. According to Naik (1949), bamboo baskets with paddy straw as cushioning material were preferred because of their low cost and easy availability.

Bamboo basket was unsatisfactory under conditions of delayed transit and rough handling (Contractor, 1951). Ventilated wooden boxes of different sizes were recommended for packing mangoes. (Cheema, *et al* 1954, Gandhi, 1955).

Gandhi (1955), reported that in addition to bamboo baskets with paddy straw as cushioning material, different sized wooden boxes, fibre board boxes and corrugated or cardboard boxes of different dimensions with suitable cushioning material were used depending on variety and quantity of mangoes packed.

According to Tandon (1967) and Madhava Rao (1974), use of newspaper wrappers and baskets with paddy straw decreased postharvest spoilage of fruits.

Ventilated wooden boxes with paper shavings in alternate layers as cushioning material have been reported to be ideal by Subrahmanyam *et al* (1969) for transportation of mangoes.

Lakshminarayana *et al* (1971), compared the efficiency of different containers. Ventilated wooden cases (45 x 32 x 30 cm) with a cushion of paper cuttings was better than the conventional bamboo or *arhar* stem baskets during transportation in terms of quality and appearance.

Garg *et al* (1971) reported that storage of mango in 200 guage polyethylene with 0.6 per cent ventilation reduced weight loss and spoilage with better retention of vitamin c and acidity.

Road and rail transportation studies were carried out to develop new package designs (Lakshminarayana *et al*,1971; CFTRI, 1976). When fresh mangoes, packed in the common bucket-shaped bamboo baskets and in the improved rectangular containers were transported in the conventional all-steel wagons, a temperature of 12-16 °C higher than ambient was built up along with a higher relative humidity making it unsuitable. Covering of the fruits with fungicide treated wrappers minimised the spoilage. However, when *Banganappalli* and *Dashehari* mangoes were transported in ventilated wooden boxes using different packages, cushioning materials and fungicidal wax treatments, excessive temperature build up was not noticed.

Individual wrapping of mangoes improved external appearance and developed an attractive skin colour. (Mukherjee, 1972).

Importance of packaging on the postharvest behaviour of mango was studied by Yagi (1980). Packaging materials reduced the level of transport bruising, encouraged the development of yellow colour and improved keeping quality of mangoes. All packaging materials significantly reduced the rate of weight loss and amount of shrivelling.

Increased decay and breakdown of mango fruits were observed with individual wrapping in shrink film. (Spalding and Reeder, 1978).

Joshi and Roy (1986) found that fruits packed in CFB boxes with partition showed slow rate of ripening, spoilage, bruises and shrivelling of fruits during storage. It also recorded less physiological loss in weight.

When mango fruits were handled and transported without packing, loss was 29 per cent in *Totapuri*, while no losses were observed in *Dashehari* when carefully packed. (AICRP on PHT, 1988).

According to Kiss (1988), storage of mangoes in plastic boxes showed greater adaptability and maintained their quality. Although their use meant greater costs, the higher sales receipts realized by making better quality products might imply economic advantage.

Parmar and Chundawat (1989) stated that wrapping of individual fruits in tissue paper and packing in ventilated cardboard boxes delayed ripening and reduced shrinkage in mango.

Singhrot *et al* (1987) stored kinnow mandarines for up to 90 days at room temperature in wooden boxes with paper linings and / or individual wrapping for cushioning. The cushioning material was either untreated or dipped in diphenyl solution dissolved in acetone. Half the fruits were dipped in waxol 0-12. Minimum physiological weight loss was observed in waxol-coated fruits packed with a lining of diphenyl-treated paper. Percentage decay loss was also least with waxol and diphenyl. Of the cushioning material, paper lining was better than individual wrapping.

Sethi and Maini (1989) reported that the existing practices of packaging of fruits and vegetables in gunny bags, woven baskets and traditional wooden crates resulted in excessive mechanical damage resulting in heavy economic losses. Plastic crates showed less bruising losses as compared to conventional field baskets for collecting fruits from the field. For *Dashehari* mangoes both three ply corrugated boxes and wooden ply woven veneer boxes were found to have good potential.

Packaging is a vital component of postharvest management to assemble the produce in convenient units and to protect it from deterioration during handling and marketing. Adequate packaging protects the fruits from physiological, pathological and physical deterioration in the marketing channels and retains their attractiveness (Maini *et al,* 1993).

A comparison of the advantages and disadvantages of various types of packaging materials have been made in a study by FAO (1989).

Advantages of moulded plastic containers as packaging material was described by Pruthi (1993).

Chikoye (1994) reported that damage of tomato fruits in wooden boxes was mainly due to transportation of over ripe fruits on bumpy roads. Regarding the open metal basins and grass baskets, damage was caused by stacking the container, on top of each other as well as having different types of produce on top.

2.7 Postharvest losses and their management

From the time of harvest until the fruit reaches the consumer, there are many occasions for quantitative and qualitative losses. Estimates of 20-30 per cent loss have been made in some studies. (Parpia, 1976; FAO,1977).

Tindal and Proctor (1980) opined that deterioration results from the cumulative insults during postharvest handling and expressed the need for investigations on causes of losses in horticultural commodities in the tropics in specific areas and conditions, in order to identify causes and adoption of preventive measures.

Considerable losses occur during transport to various destinations. Neelgreevam *et al* (1985) and Subrahmanyam (1986) found that the losses during transport might increase the cost upto 24.2 per cent.

A working group sponsored jointly by the Indian National Science Academy and the National Academy of Science, USA estimated in 1979, that postharvest losses in fruits and vegetables in India were 30 per cent or more (Subrahmanyam, 1986).

Bourne (1988) grouped causes of postharvest crop losses in developing countries into primary losses (insects, rodents, birds, microbes, contamination, sprouting and mechanical damage) and secondary losses (inadequate drying, storage, cooling and transportation facilities).

Madan (1988) estimated postharvest loss of mango at collection centres as 14.3 per cent. He categorised these losses as (1) damaged by birds and rodents (2) injured and (3) unmarketable shape and size. Postharvest loss at retailers end was 27.78 per cent and that at processing centres 15.89 per cent.

The characteristics of varieties as a factor in postharvest losses were studied by Madan (1989). Postharvest loss of 36.7 per cent was noticed in *Bangalora*, while in *Neelum* and *Banganappalli*, it was 22 and 20 per cent respectively.

The main pathogens responsible for postharvest diseases of mango were *Colletotrichum gloeosporioides, Dothiorella dominicana, Botryodiplodia theobromae, Aspergillus niger* and *Penicillium cyclopium* (Palejwala & Modi, 1985; Johnson *et al*, 1989).

Sethi and Maini (1989) reported that the principal cause of postharvest losses in fruits and vegetables were mechanical injuries, wilting, water loss, shrivelling, bruising, improper curing, over ripening, sprouting and rooting, high respiration rate, chilling injury and decay.

Storage conditions also affected postharvest losses. Fornaris-Rullan *et al* (1990) reported that, higher storage temperature caused some increase in anthracnose and stem end rot in mango.

The practice of harvesting the entire orchard irrespective of maturity of fruits in different trees is the prime cause resulting in postharvest losses. (Madan and Ullasa, 1993).

Losses during handling and marketing of tropical produce were often high with postharvest losses sometimes exceeding 50 per cent. Campbell (1994) reported that this was due to inadequate equipment or technology and long marketing chain.

Various management practices have been evolved to control postharvest losses. Postharvest hot water treatment of fruit to control spoilage organisms has been known since 1922.

Lakshminarayana *et al* (1974) reported that hot water treatment of *Alphonso* mangoes at 54 ± 1 °C for five minutes to regulate ripening and control postharvest microbial spoilage. The treatment accelerated ripening and reduced spoilage by more than 50 per cent compared with untreated fruits. Fruits at an early stage of maturity generally ripened more slowly and therefore had a longer storage life compared with fully mature fruits. In such fruits hot water treatment hastened the onset of the respiratory climacteric by three to six days, but had no effect on more mature fruits. Fruit treated with hot water showed a higher physiological weight loss and improved surface colour and marketability without affecting flavour.

Chang (1975) found rotting due to anthracnose was reduced by immersing fruits for 10-30 minutes in water at 52-54 °C or 5-10 minutes in water at 56 °C. Fungal infections could not be prevented by hot water treatment, but lesions did not increase in size nor did future lesions appear if treated fruits were stored for a number of days after treatment. The most suitable storage period was one week at 20 °C.

Spalding and Reeder (1978) reported that dipping mangoes for 1 to 3 minutes in hot water (52 °C) containing 0.1% benomyl was effective in controlling postharvest decay. The percentages of decayed *Tommy Atkins* and *Keitt* mangoes after storage for 17-18 days at 13°C followed by softening at 22 °C were 17 and 25 per cent respectively with this treatment while it 64 and 67 per cent when benomyl was not used.

Sampaio *et al* (1979) reported that hot water treatment did not adversely effect the fruit quality,at the same time gave very good control during storage at 24 to 26 °C for 10 days. They also found that best control of *Colletotrichum gloeosporioides* was obtained by immersion in water at 50 °C for 30 minutes or at 55 °C for 10 minutes. The treatment had no adverse effects on fruit appearance or quality.

Mango fruits treated with hot water had best appearance and lowest fungal spoilage at the end of storage (Kalra and Tandon, 1983).

Srivastava (1984) reported that decay of *Dashehari* mango was considerably reduced by a postharvest dip in 0.1 per cent bavistin or 0.2 per cent captan for 2 minutes or by hot water treatment (50 °C) for 5 minutes.

Hot water dip had indicated stimulation of ripening by increasing sugars, TSS and β-Carotene, at the same time decreasing acidity, vitamin c, tannins etc. Hot water dip accelerated the physiological reactions in the fruit and the ripening phenomenon was hastened. (Kalra and Tandon, 1984).

Palejwala and Modi (1985) found that bavistin (Carbendazim) completely inhibited spore germination of *Penicillium Cyclopium* at 100 mg/l. A postharvest dip (One minute) of unripe *Langra* mangoes in an aqueous solution of this fungicide considerably reduced the degree of spoilage.

Chauhan *et al* (1987) reported that mango fruits dipped in hot or cold water were the best as there was minimum weight loss and decay.

Cheriyan (1987) reported that bavistin 500 ppm was effective in controlling postharvest disease of mango up to a period of 35 days.

According to Narasimhudu *et al* (1987) application of bavistin 0.1 per cent for 5 minutes was found to be best for controlling black banded disease of mango, caused by *Peziotrichum Corticolum*.

Thangaraj and Irulappan (1988) assessed that among different postharvest treatments of mango cultivar *Neelum*, least weight loss (2.3 %) and the longest shelf life (9.7 days) were obtained with hot water treatment (52 $\pm$ 1 °C) waxing with 10 % Frutox + cool chamber storage.

Om Prakash and Misra (1988) found that 3 to 4 application of 0.1 per cent Bavistin (Carbendazim) at 15-20 day interval as preharvest spray was best against *Glomerulla cingulata*.

Sharp and Picho Martinez (1989) stated that immersing mango fruits infested by *Ceratilis capitata*, *Anastrepha obliqua* and *A.*

frateculus in hot water (46.1 °C ± 0.25) for 10-70 minutes reduced the number of surviving pupae.

Sethi and Maini (1989) reported that wastage due to spoilage in mango could be controlled by the use of fungicide like bavistin, captan (500 ppm each), chlorine at 100 ppm or by use of other chemicals in water used for precooling. Benlate was the best to control the fungal spoilage from 30 per cent to 10 per cent during ripening of *Alphonso* and *Pairi* mangoes. These treatments retarded ripening. In mango cv. *Neelum*, hot water treatment followed by skin coating with frutox had a pronounced effect in the reduction of PLW from 21.5 to 10 per cent and delayed ripening by 10 days.

Parmar and Chundawat (1989) found that bavistin (100 ppm) + GA (150 ppm) delayed ripening by about two days, and gave the highest percentage marketable fruits after storage.

Detergent dips prior to removal of the peduncle or dipping or spraying with detergent immediately after harvest reduced sap burn incidence of mango (Holmes *et al*,1993)

Postharvest treatment of litchi with 100 ppm Borax minimised the loss in fruit weight and prolonged the storage life by 11.5 days (Sharma and Ray,1987).

According to Shetty *et al* (1989), papayas infested with eggs and first instar larvae of the oriental fruit fly (*Dacus dorsalis* Hendel) showed a reduction in the number of insects present when the fruits were subsequently wrapped for at least 96 hrs with plastic shrink-wrap film. In a related study, individually wrapped mangoes that were artificially infested with larvae of *Drosophila melanogaster* no longer harboured living larvae when the wrap remained for 72 hours.

Singh *et al* (1992) conducted experiments for extending the shelf life of fresh litchi fruits. The treatments included dipping of fruits in 2,4 and 6 per cent solution of thiourea, 125, 250 and 500 ppm solution of Bavistin; 1,2 and 3 per cent soultion of sodium hypo chlorite and 0.25, 0.50 and 1.00 per cent solution of copper sulphate, besides control. Best retention of general appearance including colour, dessert quality and minimal loss in weight were obtained in fruits dipped in 4 per cent thiourea solution for 8 minutes. The next best treatment was dipping fruits in Bavistin followed by sodium hypochlorite and copper sulphate.

2.8. Fungicide residues in treated fruits

Chauhan *et al* (1988) studied the fungicidal residue present is *Alphonso* mango dipped in warm water 52 $\pm$ 1 °C containing carbendazim (300 ppm). They showed that fungicide persisted in the pericarp for upto 15 days. No residue were present in the pulp after 8 days.

Chauhan and Joshi (1990) found that carbendazim (0.05 %) was the most effecive control against anthracnose. Carbendazim left residues in the pulp.

Bushway *et al* (1991) reported that a fluorescent reversed-phase high performance liquid chromatographic method was developed for the analysis of carbendazim residues in blue berries. Confirmation of carbendazim in the blue berry samples was made by enzyme immunoassay and UV photodiode assay.

Effect of storage condition on the retention of residues was reported by Sharma *et al* (1991). Residue levels increased with original concentration of fungicide and with duration of exposure. Residue concentration decreased faster when fruit was stored at ambient temperature than in refrigeration.

According to Sharma *et al* (1992), the health risk in carbendazim treated rhizome was low if they were consumed after peeling, compared to mancozeb.

Awasthi (1986) reported that some handy practices like prewashing of the commodity with ordinary water, salt water (2% table salt solution), 2 per cent sodium hydroxide solution, 2 per cent acetic acid solution and detergent solution were found to dislodge surface residues from 20 to 60 per cent depending on the chemical and commodity surface.

Materials and Methods

MATERIALS AND METHODS

Investigations on certain aspects of Postharvest losses of mango (*Mangifera indica* L.) were conducted in the Department of Processing Technology, College of Horticulture, Vellanikkara, Thrissur, Kerala (10° 32′ N latitude, 76°E longitude, 40 m above MSL) from February 1994 to July 1995.

Three experiments were done to estimate postharvest losses during different stages of handling and to evaluate the efficacy of few practices in reducing the extent of losses. The experiments were :

1. **Quantification of harvest and handling losses and evaluation of modified harvesting practices for loss reduction in mango.**
2. **Effect of modified handling practices on the postharvest losses in mango.**
3. **Effect of postharvest treatments on quality and postharvest losses in mango.**

Five mango varieties available at the Instructional Farm, Vellanikkara and the orchard attached to Department of Pomology and Floriculture, College of Horticulture were selected for the study. Postharvest experiments were carried out in the Analytical laboratory attached to the Department of Processing Technology.

Experimental material

Five varieties of mango viz: *Prior*, *Neelum*, *Bangalora*

(Totapuri, Salem), Muvandan and Olour were selected for the experiment. *Prior and Neelum* are two important table varieties and *Bangalora* is a popular variety used for processing purposes. *Muvandan* and *Olour* are two important local varieties commonly found in the homesteads of Central Kerala. Two trees aged 20 years were selected from each variety for collecting the fruits. The orchard is maintained as per KAU recommendati ons. Morphological parameters of the ten selected trees under the five varieties are given in Table 1.

3.1. Preliminary evaluation of varieties

Observations on fruit size, colour and skin characteristics of fruit were used as maturity indices for harvest. The following observations on fruit characters were recorded.

3.1.1. Specific gravity

Harvested fruits were sorted into three specific gravity groups, viz; < 1 , 1.00 to 1.05 and > 1.05 . Fruits which floated in distilled water were included in the first group. Fruits which sank in distilled water were further sorted by floatation in 1.05% brine to separate those having specific gravity > 1.05. Physico-chemical characters were observed in fruits having specific gravity between 1.00 and 1.05. Three replications with five fruits per sample was used for the purpose.

3.1.2. Fruit weight

Total weight of five fruits selected at random from fruits having specific gravity between 1.00 and 1.05 were recorded and mean weight was expressed as gram.

Table 1. Growth measurements of selected experimental trees

Variety	Girth at 10 cm above ground level	Height (m)	Spread (m)		No. of main branches
			EW	NS	
Muvandan	58.5	5.4	6.1	5.3	8.0
	50.2	6.3	5.3	6.2	4.0
Olour	64.3	8.4	12.2	11.2	7.0
	62.6	6.5	9.1	9.3	6.0
Prior	70.5	6.6	9.1	10.4	8.0
	68.4	9.5	14.2	13.4	10.0
Neelum	60.8	6.8	6.2	7.3	5.0
	59.2	5.4	4.4	4.2	3.0
Bangalora	66.6	8.4	6.4	6.1	6.0
	59.4	5.3	5.5	7.4	5.0

3.1.3. Fruit length

Fruit length was measured in the sample from stalk end to apex with vernier callipers and mean length was expressed as centimetre.

3.1.4.Fruit circumference

Fruit circumference was measured using a piece of twine running around the fruit at the largest shoulder point and was expressed as centimetre.

3.1.5.Shape index

Maximum fruit diameter was calculated from the circumference recorded and shape index of the fruit was calculated as the ratio of the fruit length to fruit diameter.

3.1.6.Skin thickness

A small cut was made on the ripe fruit using a knife for facilitating peeling. Pulp and fibres attached to the skin were removed by washing. Thickness of skin was measured using a screw guage and expressed as millimetre.

3.1.7.Firmness of flesh

Firmness of flesh at ripe stage was determined using Fruit Pressure Tester (mod.FT 327, manufactured by M/s Facchini, 48011, Alfonsine, Italy). Outer skin of the ripe fruit was removed using the peeler supplied with the pressure tester. Fruit firmness was recorded as per manufacturers direction: Fruit was held firmly in the left hand. The fruit tester was held between the thumb and forefinger of the right hand. The button command indicator was pushed to set zero reading in the dial. The plunger was placed vertically above the peeled portion and pressed downwards with increasing strength until the plunger top penetrated into the pulp, up to the notch. The reading on the dial was recorded and fruit firmness was expressed as Kg/cm^2 .

3.1.8. Changes in specific gravity during ripening

Change in specific gravity during ripening was estimated by water displacement method.

3.1.9. Total sugars, reducing sugars and non-reducing sugars

Total sugars,reducing sugars and non-reducing sugars were estimated by the Lane and Eynon method as outlined by Ranganna(1977) and were expressed as grams of glucose per hundred grams of fruit.

3.1.10. Total soluble solids (TSS)

TSS was determined in the freshly extracted juice of ripe fruit using Erma hand refractometer, range 0-30 °brix and expressed in degree brix (A.O.A.C.,1975).

3.1.11. Acidity

Acidity in pulp at ripe stage was estimated by titrating against N/10 Sodium hydroxide solution using phenolphthalein indicator as described by Ranganna (1977) and expressed as percent malic acid.

3.1.12. Sugar:acid ratio

Sugar:acid ratio was worked out from total sugars and acidity estimated.

3.2. Harvesting details

The season of harvest, number of harvests and proportion of fruits in each harvest were recorded (Figure 2).

EXPERIMENT 1

QUANTIFICATION OF HARVEST AND HANDLING LOSSES AND EVALUATION OF MODIFIED HARVESTING PRACTICES FOR LOSS REDUCTION IN MANGO.

The experiment comprised the following treatments.

T1 - Traditional harvesting and collecting system.

T2 - Traditional harvesting and modified collecting system.

T3 - Modified harvesting and traditional collecting system.

T4 - Modified harvesting and modified collecting system.

3.3. Traditional harvesting system

The traditional mango harvester widely used in Kerala has a collecting net attached to a thin bamboo pole of approximately three metre length. Collecting net is made up of interwoven thick cotton threads. This net is tied around a flexible twig in an elliptic shape.(plate 1, Figure 1). The harvesting operation involves the following steps. 1. Location and visual assessment of maturity of fruits. 2. Guiding the fruit to the net of the harvester. 3. Harvesting . Harvesting action involves pulling of the harvester along with fruit which is trapped in the net. During the process fruits sometimes escape from the net and fall down. Chances of fruit fall during the course of harvest

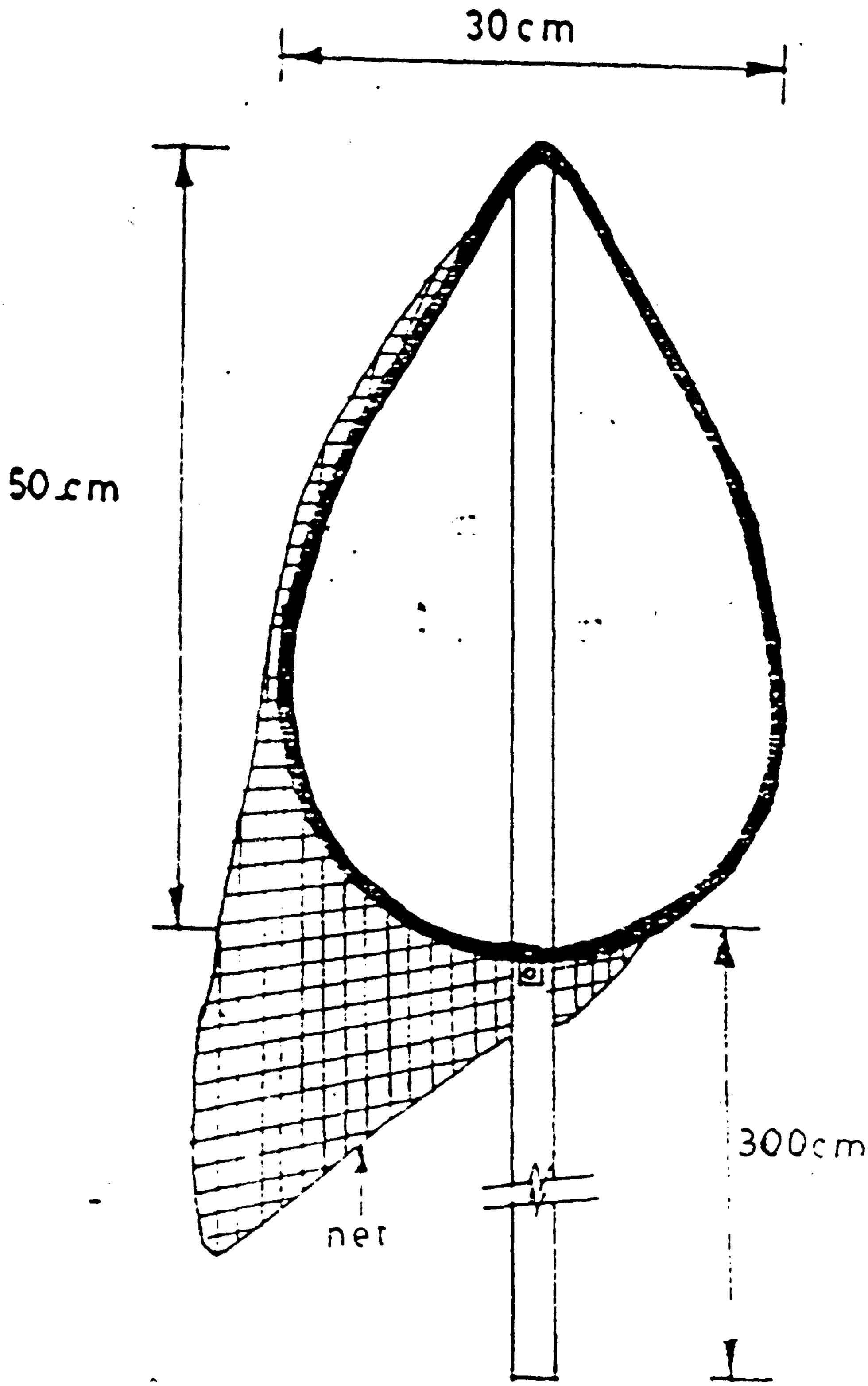
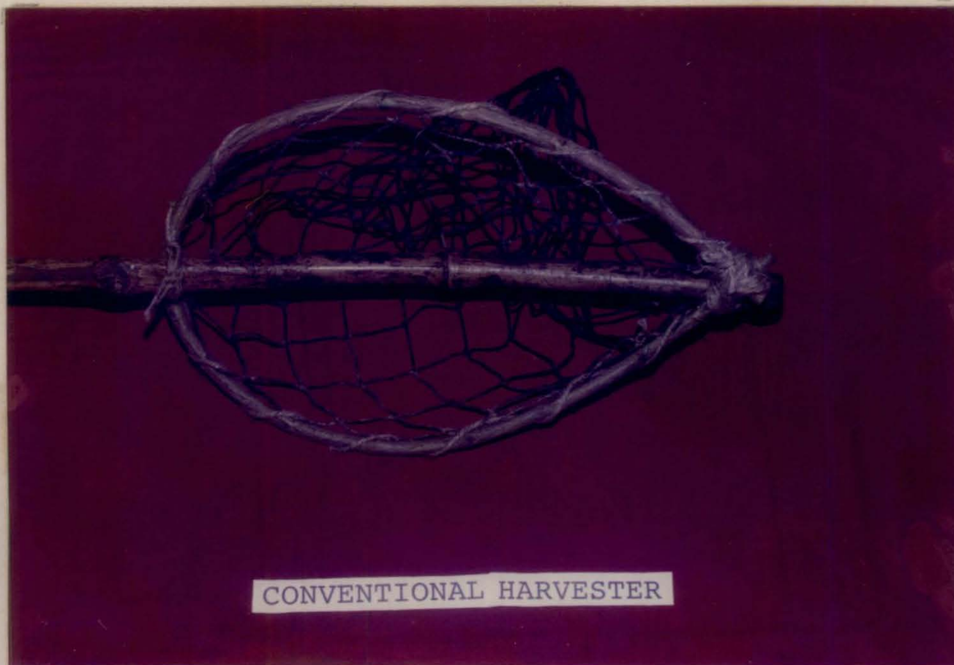
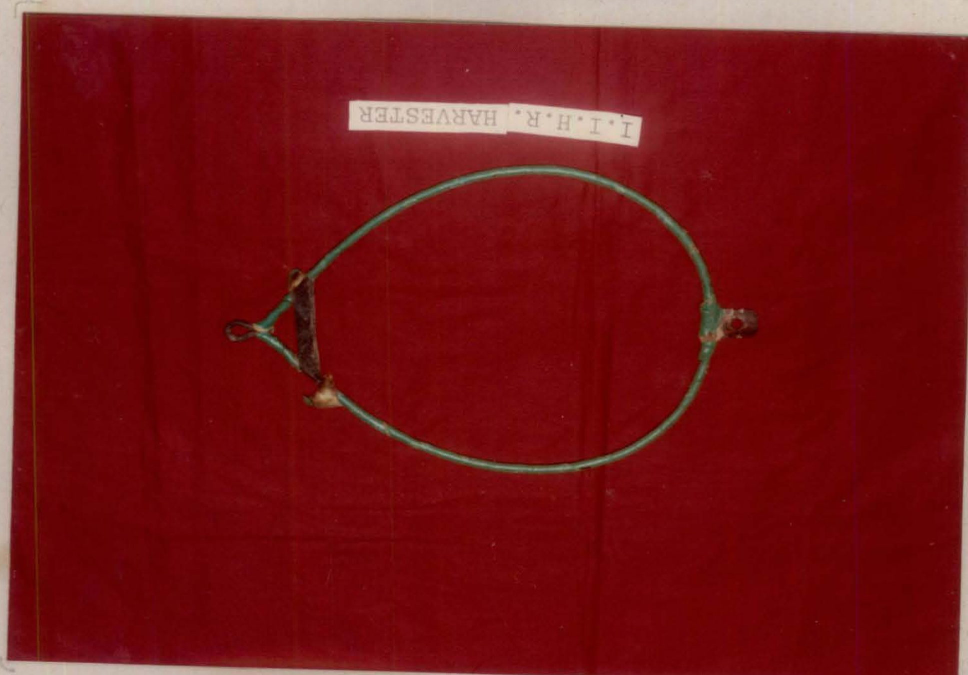


Fig 1- Traditional mango harvester

Plate 1 Conventional mango harvester

Plate 2 IIHR mango harvester


CONVENTIONAL HARVESTER


I.I.H.R. HARVESTER

vary depending on the angle at which the harvester is operated. Losses due to such damage can be substantial when traditional harvester is used. The fallen fruits become unmarketable at ripe stage. Attempts were made to design and fabricate modified harvesters in order to reduce the number of fruits falling during harvest and improve the efficiency of harvesting. Details of design, fabrication and testing are described below:-

3.4. Design and fabrication of modified harvester

The basic pattern of the traditional harvester was retained as it was found satisfactory for easy separation of the fruit. For developing prototype I of the modified harvester, the basic design of the IIHR mango harvester was used (Mandhar and Kumaran, 1993).

The following modifications were made in the IIHR type harvester (Plate 2):

1. A slightly curved knife was used to facilitate easy fixing of the pole and reduce the chances of cut injury.

2. Two 'arc' shaped guide rods were introduced to reduce the chances of fruit fall (Figure 2 and Plate 3).

The bamboo pole passed along the central portion of the frame and was fitted in position using coir/ G.I. wire in KAU mango harvester I.

On field testing, it was found that the knife caused cut injuries on the fruit especially when the fruit shoulders were narrow as in the variety *Banglora*. Also, on many occasions, the

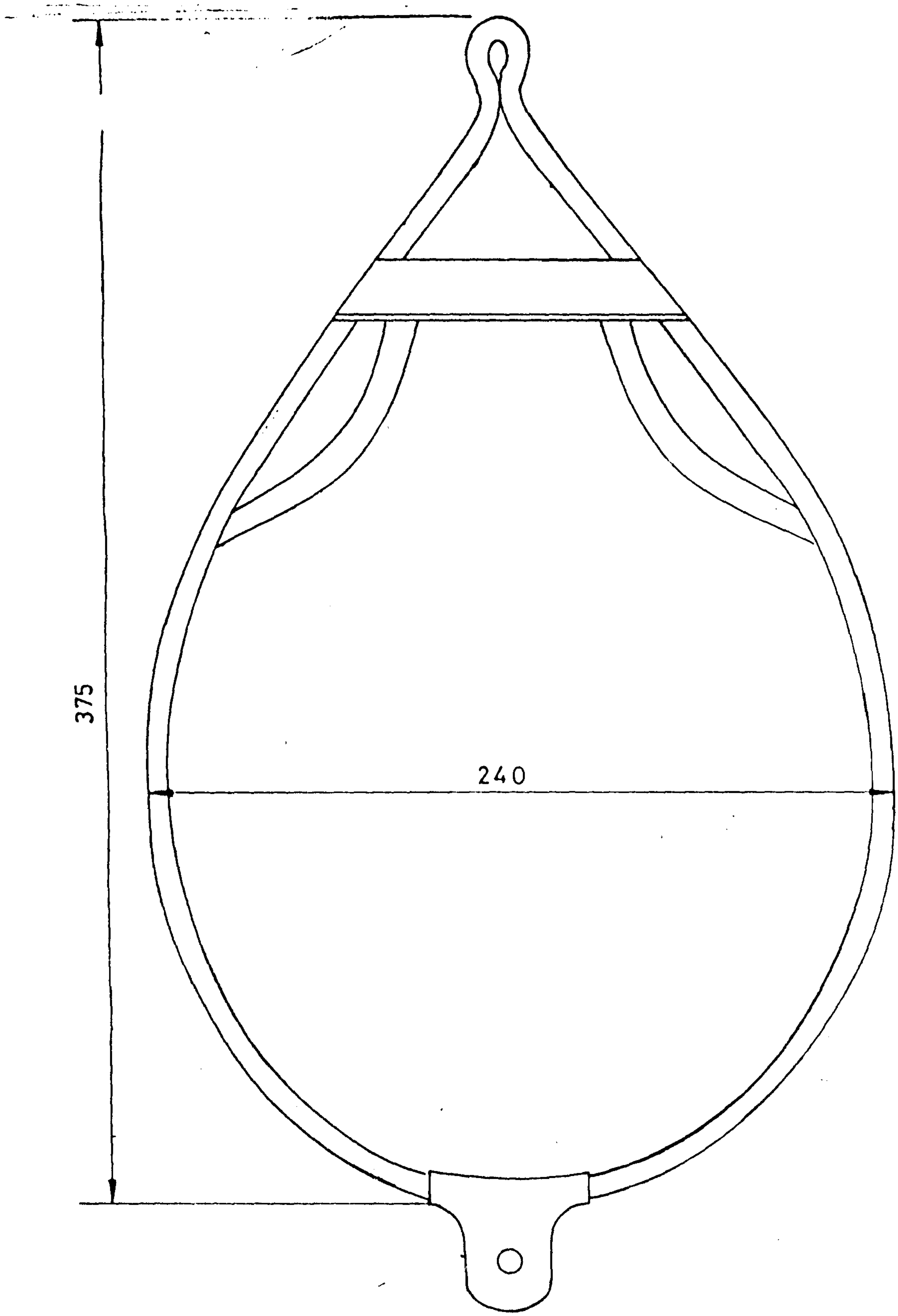
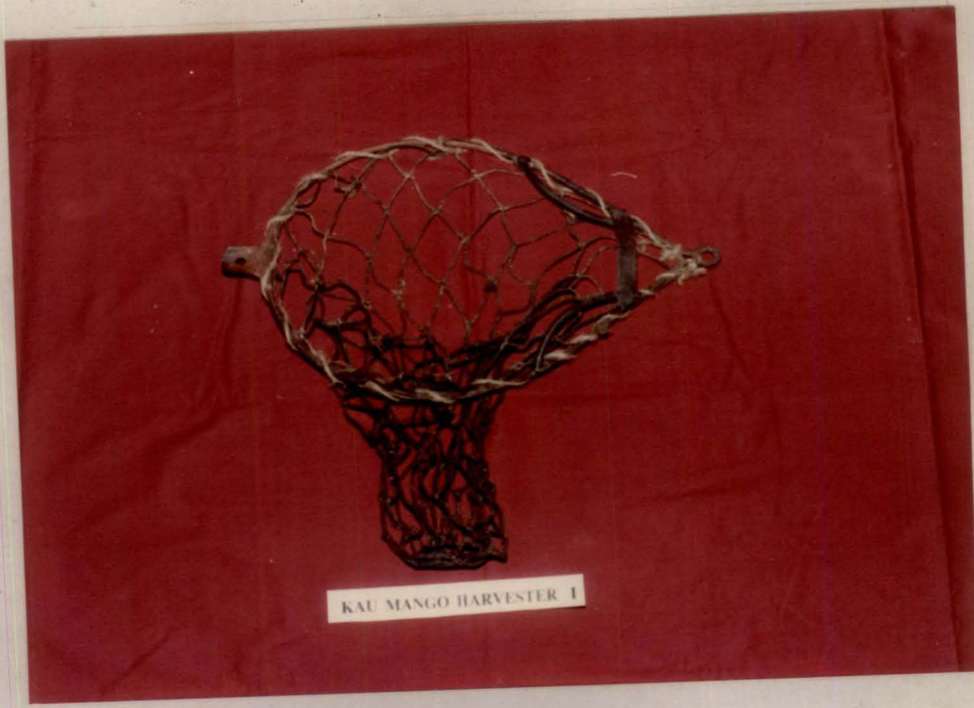


Fig. 2- KAU mango harvester I

Plate 3. KAU mango harvester I

Plate 4. CIHNP mango harvester


KAU MANGO HARVESTER 1


C.I.H.N.P. HARVESTER

fruits slipped out through the gap of the pole and the frame of the harvester and fell as in the traditional harvester. This necessitated further modifications in the prototype.

For designing the prototype II, the mango harvester developed by CIHNP was considered as the base model. (Plate 4) An inverted V shaped knife was fixed at a level of 1.5 cm above the frame of the harvester. The bamboo pole was fitted to the bottom end of the frame with the help of a metal piece of length 10 cm and 3.5 cm width with two holes of one centimetre diameter using coir/G.I. wire (KAU mango harvester II). (Plate 5, Figure 3). In this model the cut injuries were less during harvest. However, fruit fall during harvest was substantial.

A third prototype was designed and fabricated (KAU mango harvester III) incorporating the features of both prototype I and II. Besides, the flat configuration of the frame was modified by bending the frame downward subtending an angle of 155° on the lower side of the harvester. The bending was introduced eleven centimetre from the distal end of the harvester . As in prototype I, two guide rods were also provided. The knife was fixed above guide rods. To fix the bamboo pole, a bent iron rod was fixed at the base of the harvester (Plate 6, Figure 4).

On field testing, KAU mango harvester III gave satisfactory results. Thus it was selected as the modified harvester in experiment I.

3.5. Traditional collecting system

Harvested fruits are collected in bamboo baskets when

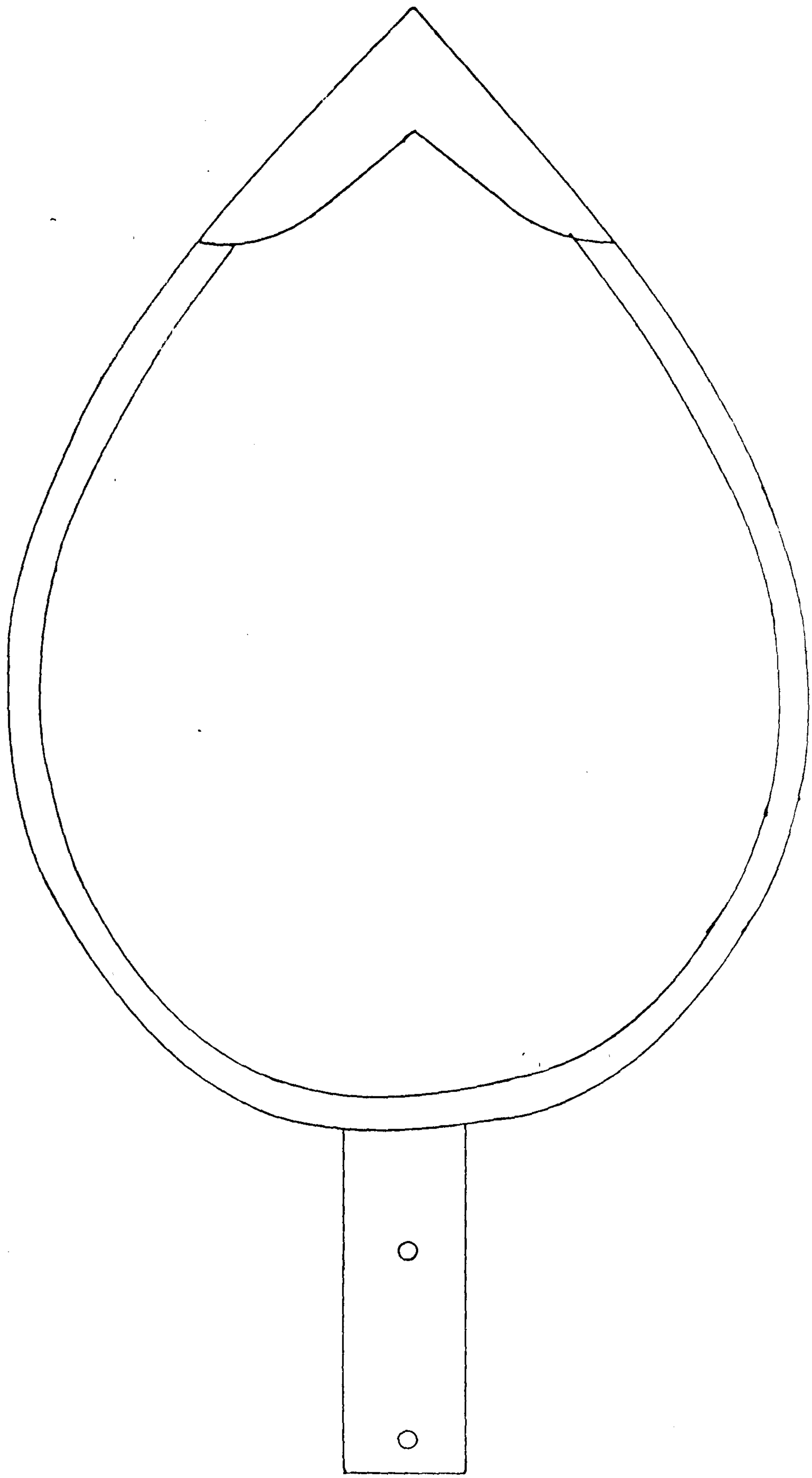
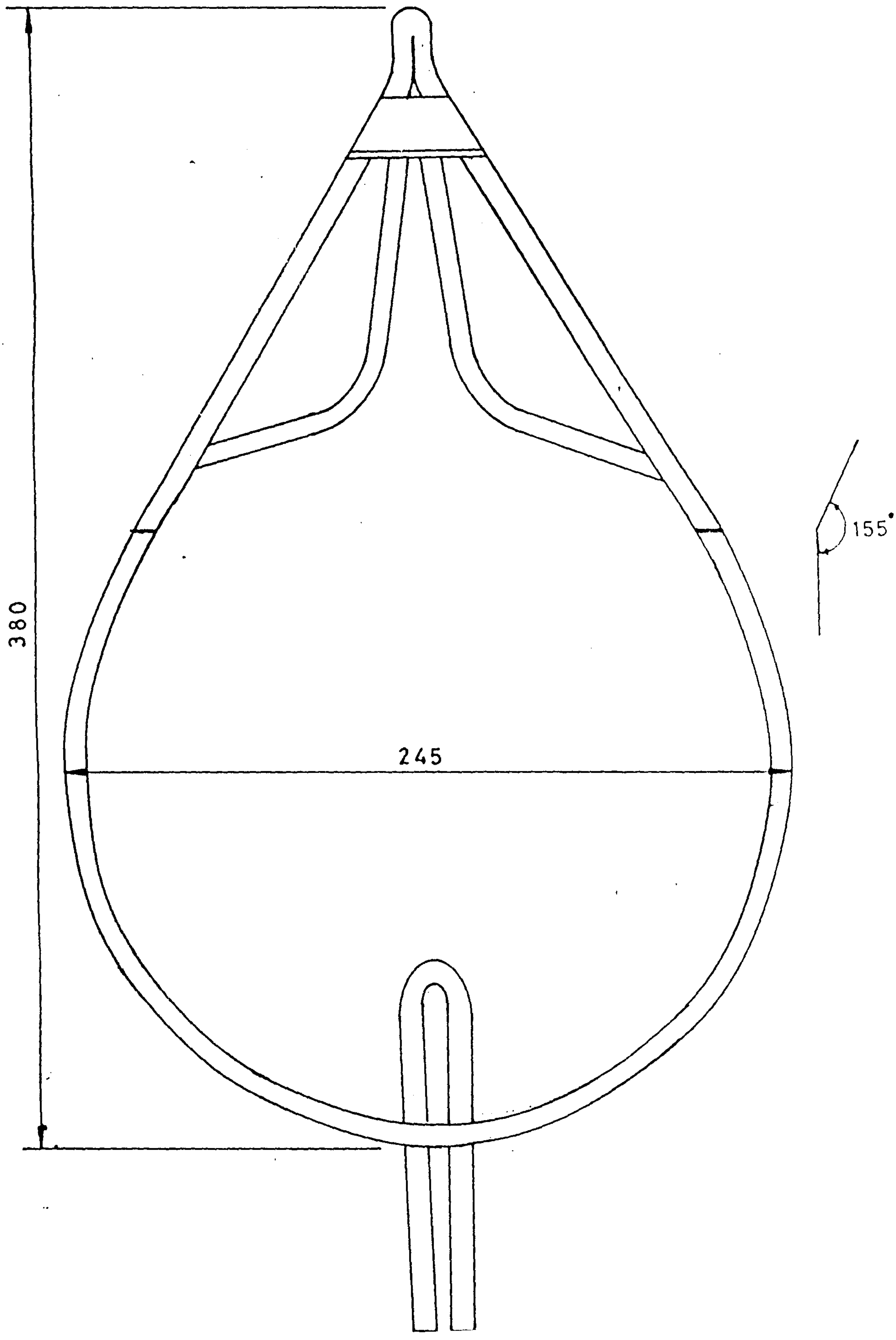


Plate 5. KAU mango harvester II

Plate 6. KAU mango harvester III

KAU MANGO HARVESTER II

KAU MANGO HARVESTER III


380
245
155°

harvest is made from tall trees and lowered to the ground using coir rope. Collection in bamboo baskets was used as traditional collecting system in the experiment. (Plate 7 and 8).

3.6. Modified collecting system

Collectiion of fruits in bamboo baskets causes bruises, thereby increasing the chances of postharvest losses. Modification of this system was done by providing an inner lining for the bamboo basket using 6 mm thick padding with polyurethane foam. This was done for reducing chances of injuries on the fruits. (Plate 9 and 10).

3.7. Harvesting efficiency

Persons with experience in harvesting of mangoes were engaged for the operation. Harvesting was done from the selected mango trees using the traditional and modified harvesters on a fixed time basis. Total quantity of fruits harvested per hour was recorded for all combinations of varieties and harvesters for estimation of harvesting efficiency.

3.8. Fruits harvested with pedicel

Out of the total fruits harvested, the number of fruits retained pedicel with a length of 1 cm or more was counted and expressed as percentage. Length of pedicel of such fruits was measured and the mean worked out.

3.9. Quantification of harvest and handling losses

3.9.1. Injured and bruised fruits

Injuries and bruises occur during harvest and handling. Damages due to fall during harvest, bruises due to contact with

Plate 7 & 8 Bamboo basket used for collection


BAMBOO BASKET


BAMBOO BASKET

Plate 9 & 10 Padded bamboo basket


PADDED BAMBOO BASKET


PADDED BAMBOO BASKET

hard or rough surface during handling are possible. Fruits with bruises and injuries, which was evident on visual observations were sorted out from the collection basket and from the fallen fruits and expressed as per cent of the total.

3.9.2. Effect of harvesters and collecting system on the postharvest behaviour of mangoes

In order to assess the effects of harvesting and collecting systems on the postharvest behaviour of the selected varieties, the fruits from each treatment under experiment I were allowed to ripen under normal atmospheric conditions.

Samples of ten fruits from each variety were randomly selected from the harvested lot with specific gravity between 1.00 and 1.05 were used. Fruits were kept on paddy straw spread on the floor at a thickness of 5 cm and covered with straw for ripening. The following observation were recorded:

3.9.2.1. Physiological loss in weight (PLW)

The loss in weight of fruits was recorded at two days interval until two fruits of each lot became unmarketable due to spoilage. The cumulative PLW at this point was estimated and expressed as percentage.

3.9.2.2. Number of marketable fruits

The number of fruits that ripened normally and found suitable for marketing was observed in each case and the total weight and number of such fruits was expressed as percentage of marketable fruits.

3.9.2.3. Incidence of spoilage

Development of spoilage symptoms in the fruits was recorded. Fruits that became unmarketable due to spoilage before attaining optimum ripening stage were sorted and their number and weight was recorded.

EXPERIMENT II

EFFECT OF MODIFIED HANDLING PRACTICES ON THE POSTHARVEST LOSSES IN MANGO.

Field handling of fruits after harvest involved collection in suitable containers and transport to packing stations or markets. Gunny bags and bamboo baskets are usually used as containers for the purpose by farmers and traders. In this experiment the following modified handling practices were evaluated along with the traditional practices for comparison of postharvest losses. Fruits harvested and collected under the traditional method were used for the study.

Treatments

T1- Pattern packing in cardboard boxes.

T2- Pattern packing in rectangular plastic crates

T3- Pattern packing in circular plastic containers.

T4- Random packing in bamboo baskets.

T5- Random packing in gunny bags (6 Kg).

T6- Control (Random packing in gunny bags to capacity - traditional practice).

The experiment was done in a completely randomised design (CRD) with five replications.

Inner dimensions and other features of different containers used in this experiment were the following.

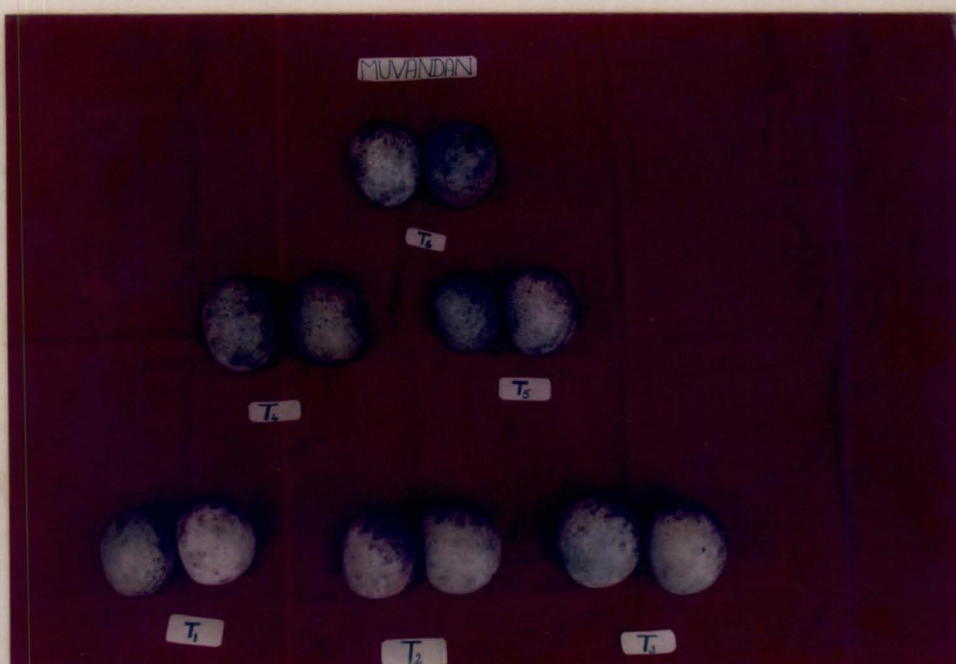
1. Cardboard box(three ply)-		40 cm x 20 cm x 25 cm.	
		Ventilation - nil	
2. Rectangular plastic crates	-	45 cm x 30 cm x 20 cm	
		Ventilated	
3. Bamboo baskets	-	top diameter	17.2 cm
		bottom diameter	10.8 cm
		height	23 cm
		Ventilated	
4. Circular plastic container	-	top diameter	14.65 cm
		bottom diameter	12.75 cm
		height	28 cm
		ventilated	
5. Gunny bag	-	length	75 cm
		breadth	40 cm

Pattern packing and random packing were done as explained by Peleg (1985).

Newspaper was used as lining materials in T1, T2 and T3. Straw was used in T4.(plate 11). Five layers of newspaper were placed at the bottom for providing cushioning effect. One layer was provided between two layers of fruits packed. Two varieties, viz; *Muvandan and Prior* were used for this study. Containers were filled to capacity except T5 in which partial filling was done

Plate 11. Containers used for handling mango

Plate 12. Effect of various postharvest treatments on variety *Muvandan*


MUVANDAN
T_6
T_4
T_5
T_1
T_2
T_3

for comparison with other treatments. Following observations were recorded :

3.10.1. Volume of the container

Volume of the cardboard box and rectangular plastic container was measured using the formula, length x breadth x height. Circular plastic containers and bamboo baskets were lined with polythene sheet and volume of water required to fill the container was recorded. Volume of gunny bags was also estimated in the similar way using polythene containers of similar size.

3.10.2. Packing density

Packing density was calculated as percent of the total volume of the container actually utilized for carrying the fruits.

3.11. Transportation

To simulate actual conditions of transportation, fruits packed in different containers were transported over a distance of 25 Km in an autorickshaw (three wheeler) through the PWD road in Madakkathara Panchayat.

After reaching the collecting centre (Analytical Laboratory, Department of Processing Technology) ten fruits from each container were taken out and kept on a layer of straw spread on the floor for studying the ripening behaviour under ambient conditions (temperature 30- 33 °C, Relative humidity 7o-80%). The fruits were examined from the second day onwards. The ripe fruits, distinguishable from unripe by virtue of their softness, aroma and colour were sorted out. Following observations were recorded:

3.11.1. PLW

The loss in weight of the fruits were recorded at two days interval until two fruits of the lot became unmarketable due to spoilage. The mean value was expressed as mean PLW/day.

3.11.2. Marketable fruits

Number of marketable fruits were assessed by visual observation and expressed as percentage.

3.11.3. Ripening pattern

Total number of fruits ripened each day were sorted out and their number and weight was recorded.

3.11.4. Spoilage of fruits

Spoiled fruits were sorted and recorded under different categories as follows:

3.11.4.1.Deformed fruits

Fruits with apparent deformation in shape were recorded and expressed as percentage.

3.11.4.2.Discoloured fruits

Fruits showing discolouration at ripe stage were sorted out and their number expressed as percentage.

3.11.4.3. Diseased / decayed fruits

Fruits showing symptoms of decay due to microbial infection were grouped in this category and expressed as percentage. The causal organisms were identified.

3.11.4.4. Fruitfly infected fruits

The fruitfly infection was difficult to detect from external appearance. Fruits were examined after cutting and number of affected fruits were recorded.

EXPERIMENT III

EFFECT OF POSTHARVEST TREATMENTS ON QUALITY AND POSTHARVEST LOSSES IN MANGO

Ten fruits from five varieties were used for this experiment after imposing various postharvest treatments. Following postharvest treatments were given.

Treatments

T1 - Washing in tap water

T2 - Dipping in warm water (52 °C)for five minutes.

T3 - Dipping in warm solution (52 °C) of Bavistin 0.1% (Carbendazim 0.05 %) for five minutes.

T4 - Dipping in 6% solution of Borax for five minutes.

T5 - Dipping in water containing bleaching powder at the rate of 1 g/l for five minutes.

T6 - No treatment (control).

The experiment was done in 5 x 6 factorial CRD with three replications. Bavistin 0.1% (carbendazim 0.05%) was prepared by dissolving one gram of Bavistin in one litre of water. Three litres of solution were used for dipping mango fruits in treatments one to five. For preparing six per cent Borax solution, sixty grams of Borax was dissolved in one litre water. One gram of bleaching powder was thoroughly dispersed by vigorous stirring in one litre water for preparing 0.1 per cent bleaching powder solution. Freshly prepared solution was used every time in this case.

Fruits harvested and handled using traditional methods were used for this experiment. Fruits were given different postharvest treatments as explained above. After soaking, fruits were wiped with clean dry towel to remove water from the surface. It was then kept for ripening in bamboo baskets. Straw was given as lining material and fruits were allowed to ripen under ambient condition (temperature 30 - 33 °C, RH - 70-80%). Following observations were recorded.

3.12.1. PLW

PLW was recorded at two days interval until two fruits in each lot became unmarketable.

3.12.2. Fruits spoiled at ripe stage

Number of spoiled fruits at full ripe stage was recorded as per cent. Spoilage of fruits was grouped into four categories namely shrinkage, discolouration, decay due to diseases and damage by fruitfly infection.

3.12.2.1. Shrinkage

Fruits deformed or with apparent symptoms of shrinkage were sorted out by visual observation and expressed as percentage.

3.12.2.2. Discolouration

Development of abnormal colours on the fruits was noted and number of discoloured fruits was recorded as percentage.

3.12.2.3. Disease incidence

Number of fruits spoiled by disease incidence were recorded as per cent and the causal organisms were identified.

3.12.2.4. Spoilage due to fruitfly

Fruits damaged by fruitfly infection was recorded as mentioned under experiment II.

3.12.3. Effect of postharvest treatments on ripening pattern of selected varieties

Total number of fruits ripened on each day were recorded and expressed in percentage. This was continued until all the fruits in a lot were ripe.

3.12.4. Effect of postharvest treatments on colour of ripe fruits

A panel of judges comprising six semi-skilled persons was engaged in assessing the colour of ripe fruits. Numerical scoring test (colour score) as described by Ranganna (1986) was adopted. Details are given below:

Score	Quality description
90	Excellent
80	good
70	Fair
60	Poor

3.13. Residues of carbendazim

A Hundred gram sample of ripe fruit flesh was macerated with 300 ml ethyl acetate. The supernatant organic phase was decanted into a one-litre glass beaker and the residue was extracted once more with ethyl acetate. The combined ethyl acetate extract were desiccated over 10 gram Sodium sulphate and filtered into a one- litre flask and reduced to approximately 25 ml by evaporation. Twenty five millilitre of 1N sulphuric acid was added and was shaken vigorously for two minutes.

The suspension was then transferred to a 250 ml separating funnel with 100 ml distilled water. The aqueous phase was run off into a one litre separating funnel and was neutralised by addition of 30 ml saturated Sodium bicarbonate solution. This was then extracted twice with 25 ml portions of chloroform and the combined extracts was transferred to a 150 ml separating funnel. Ten millilitre of 1N sulphuric acid was added and shaken for ten minutes. The chloroform phase was discarded and the sulphuric acid layer was analysed Spectrophotometrically using Systronics-UV-VIS-Spectrophotometer-108 at 281 nm, against 1N sulphuric acid as blank.

3.13.1. Preparation of standard

Standard curve was prepared by using commercial grade Bavistin having 50 per cent Carbendazim. The concentration of acid in the standards prepared varied from 50 to 175 ppm.

3.14. Statistical analysis

The data generated from the three experiments were subjected to statistical analysis as suggested by Panse and Sukhatme (1957).

Results and Discussion

RESULTS AND DISCUSSION

The results obtained from the experiments concluded under the study are presented and discussed in this chapter.

4.1. Specific gravity

Many workers had indicated specific gravity as a dependable guideline for judging maturity of mangoes (Harkness and Cobin,1951; Singh *et al*,1978; Joshi and Roy,1986; Magdum *et al*,1990).

In the present study the harvested fruits were separated into three specific gravity groups, viz; < 1, 1.00 to 1.05 and > 1.05. Majority of the fruits in a given harvest fell in group III with specific gravity ranging between 1.00 and 1.05. (Table 3). In *Prior*, 80 per cent of the harvested fruits were within this range. In *Olour and Bangalora,* 60 per cent of the fruits were within this range while in varieties *Muvandan and Neelum* 50 per cent came under this group. Fruits with specific gravity < 1.00 accounted for less than 20 per cent per harvest in all the varieties. A specific gravity of < 1.00 indicate immaturity. The data indicated that 80 per cent of the fruits harvested by an experienced person can be of optimum maturity. Because of the staggered flowering pattern in mango the scope of a once-over harvest especially by mechanical means is remote. Thus we have to depend on manual means for harvest of mango. The present study indicated that by further refining of visual standards for maturity assessment on the basis of variety,

Table 2. Distribution of fruits according to specific gravity in harvested mangoes (%)

Variety	Specific gravity		
	< 1.0	1-1.05	> 1.05
Muvandan	10.3	51.6	38.1
Olour	10.6	60.5	28.9
Prior	9.9	80.1	10.0
Neelum	19.6	55.4	25.0
Bangalora	19.4	60.6	20.0

maturity assessment on the basis of variety, more fruits with optimum maturity could be harvested. A number of workers had studied the maturity standards for determining the maturity of mango. Nature and quantum of sap exuded from the fruit stalk on picking, appearance of 'bloom' and characteristic dots on the fruit skin and colour of the fruit skin, besides typical morphological form, size, relative density and hardness of the fruit, and firmness of the flesh are some of the maturity indices (Singh,1960; Jain,1961). Singh *et al* (1978) reported that specific gravity, TSS percentage and starch:acid ratio were considered to be the best indices of maturity of mango. Some other maturity indices are pulp penetration pressure, degree of shoulder development, skin and pulp colouration (Oosthuyse,1991).

4.2. Physical and chemical characters of selected mango varieties

Data on the physical characters of selected varieties namely, *Bangalora, Neelum, Prior, Muvandan* and *Olour* are given in Table 3 and chemical characters in Table 4.

4.2.1. Fruit weight

The average fruit weight in the five varieties ranged from 177 g to 439 g. The lowest fruit weight was recorded in *Muvandan* and the highest in *Bangalora*. Mean fruit weight recorded for *Prior* was 182 g, while that of *Neelum* and *Olour* was 219 g and 233 g respectively.

Reddy and Singh (1989) had reported a mean fruit weight of 205.60, 305.80 and 239.94 g in varieties *Olour, Prior* and *Muvandan* respectively under Bangalore conditions. Prasad and

Table 3. Physical characters of selected mango varieties

Variety	Fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Fruit circum-ference (cm)	Shape index	Skin thickness (mm)	Firmness of fruit (kg/cm^2) Ripe fruit	Specific gravity Before ripening	After ripening
Muvandan	177.1	9.8	8.4	20.6	1.16	0.81	0.66	1.11	1.05
Olour	233.3	11.5	9.2	21.7	1.25	0.65	0.72	1.08	1.04
Prior	182.4	7.6	5.7	21.0	1.33	0.54	0.71	1.04	0.96
Neelum	219.2	8.8	6.7	21.7	1.30	0.94	0.73	1.02	0.99
Bangalora	439.1	13.3	6.3	26.4	2.11	0.34	0.58	1.02	1.0

Nalini (1988) reported a mean fruit weight of 315 g for variety *Bangalora* under Kanpur condition. Kuriakose (1982) had reported a mean fruit weight of 231 g for variety *Neelum* under Vellanikkara condition.

The mean fruit weight of the varieties selected for the present study fall in a range, which is generally accepted by the trade. The high mean weight of *Bangalora* is important from the processing point of view. Mangoes are handled manually during ripening and peeling operations in the processing units. Small fruits may necessitate handling of more number of fruits for extracting unit quantity of pulp, whereas varieties like *Bangalora* with higher mean fruit weight will be of advantage. The variation in fruit weight in the different locations may be due to the soil and climatic factors, rootstock effects and differences in the cultivation practices followed.

4.2.2. Fruit length

The fruit length in the selected varieties ranged from 7.6 cm to 13.3 cm. *Prior* recorded the minimum length and *Bangalora,* the maximum. *Neelum* had a mean fruit length 8.8 cm, *Muvandan* 9.8 cm and *Olour* 11.5 cm. Fruit length can influence the packaging and processing operations. Reddy and Singh (1989) had reported that in *Olour, Prior* and *Muvandan* the mean fruit length was 9.91, 10.89 and 9.55 cm respectively. Prasad and Nalini (1988) reported that *Bangalora* had a fruit length of 14.2 cm under Kanpur condition. *Neelum* had a fruit length of 9.75 cm under Vellanikkara condition (Kuriakose,1982).

4.2.3. Fruit diameter

Among the varieties, Prior had minimum diameter of 5.7 cm while *Olour* had the maximum diameter of 9.2 cm. Reddy and Singh (1989) reported a fruit diameter of 7.3, 8.6 and 7.2 cm in *Olour, Prior* and *Muvandan* respectively.

4.2.4. Fruit circumference

The data on fruit circumference showed that *Bangalora* had the maximum circumference of 26.4 cm. *Olour* and *Neelum* recorded 21.7 cm each while *Prior* had 21.0 cm and *Muvandan* 20.6 cm. Fruit circumference also is an important consideration while packaging. Fruits with higher circumference tends to occupy more space in packages increasing packaging density.

4.2.5. Shape index

Each variety of mango has its own distinctive form and configuration when it reaches full physical development. Shape index expressed as the ratio of fruit length to fruit diameter showed that *Muvandan* had the minimum index of 1.16 followed by Olour 1.25, *Neelum* 1.30, *Prior* 1.33 and *Bangalora* 2.11. A shape index of unity indicates a typical spheroid shape which is preferred for mechanical handling, packaging and processing operations. In the present study, all varieties except *Bangalora* had shape indices near to unity, whereas *Bangalora* with a shape index of 2.11 was distinctly different in shape from the other four varieties.

Shape index gives a better guideline for standardising handling practices than fruit length or fruit diameter considered individually.

4.2.6. Skin thickness

Among the varieties studied, *Neelum* had the thickest skin with 0.94 mm followed by *Muvandan* with 0.81 mm, *Olour* 0.65 mm, *Prior* 0.54 mm and *Bangalora* 0.34 mm. Thin skin results in lesser quantity of process waste making the variety preferable for processing. Reverse was the case in the variety *Neelum* with a thicker skin. However, skin thickness is only one of the attributes that finally decide the table or processing quality of a variety.

4.2.7. Firmness of flesh

Firmness of the flesh of the ripe fruit measured using the pressure tester revealed that there existed variation between varieties. The variety *Neelum* recorded a relatively high firmness of 0.73 Kg/cm^2 closely followed by *Olour* (0.72 Kg/cm^2) and *Prior* (0.71 Kg/cm^2). *Muvandan* recorded a flesh firmness of 0.66 Kg/cm^2 while *Bangalora* registered minimum flesh firmness of 0.58 Kg/cm^2. A high flesh firmness at ripening can be an indication of better shelf life. Many workers had reported the decreasing trend of fruit firmness due to storage and ripening in mango (Kalra and Tandon,1984; Sahni and Khurdiya,1989; Kaushik and Kumar,1992).

4.2.8. Specific gravity

The specific gravity showed a decreasing trend during ripening. The ripening process results in loss of moisture and break down of food reserves due to increased respiratory activity, subsequently resulting in a decrease in specific gravity (Sahni and Khurdiya,1989). It was observed that the pattern of reduction of specific gravity was almost uniform in all the varieties except *Prior*, which showed comparatively higher drop in specific gravity from 1.04 to 0.96. This might be a varietal attribute of having a higher rate of respiration or enhanced moisture loss.

4.2.9. Total, Reducing and Non-reducing sugars

The content of total sugars varied between 9.5 and 14.4 per cent among the varieties at ripe stage. The maximum value of 14.4 per cent was recorded by *Neelum,* followed by *Prior* 10.4 per cent. *Olour* recorded a total sugar content of 9.6 per cent while *Muvandan* and *Bangalora* recorded 9.5 per cent each. The higher values of total sugar for *Prior* and *Neelum* justifies their acceptability as table varieties.

With reference to the reducing sugars, variety *Neelum* recorded the highest value of 3.3 per cent closely followed by *Muvandan* (3.1 %) and *Bangalora* (2.9 %). The reducing sugar content in *Prior* was 2.2 per cent and in *Olour*, it was the lowest (1.2 %).

Non-reducing sugar content was maximum in *Neelum* (11.1 %). Other varieties namely *Olour, Prior, Bangalora* and *Muvandan* contained non-reducing sugar to the extent of 8.4, 8.2, ~~2.0~~, 6.5 and 6.4 per cent respectively. Prasad and Nalini (1988) reported that *Bangalora* had a reducing sugar content of 7.45 per cent and non-reducing sugar content of 4.75 per cent.

Table 4. Chemical characters of ripe and decayed fruits of selected mango varieties.

	Ripe fruits						Decayed fruits	
	Reducing sugars(%)	Non-reducing sugars(%)	Total sugars (%)	TSS (°bx)	Acidity (%)	Sugar: acid ratio	TSS (°bx)	Acidity
Muvandan	3.1	6.4	9.5	13	0.24	39.6	10	0.49
Olour	1.2	8.4	9.6	17	0.12	80.0	13	0.37
Prior	2.2	8.2	10.4	17	0.11	94.6	11	1.49
Neelum	3.3	11.1	14.4	19	0.17	84.7	16	0.29
Bangalora	2.9	6.5	9.5	15	0.12	79.2	11	0.28

4.2.10. Total soluble solids (TSS)

The TSS measured using the refractometer is the general and simple guideline used for assessment of sweetness of fruits. It is regarded that higher the TSS sweeter is the variety. Out of the five varieties included in the study, the maximum TSS was recorded in *Neelum* (19° bx). It was followed by *Prior* and *Olour* with 17 degree brix and *Bangalora* with 15 degree brix. The lowest TSS was recorded in *Muvandan* (13° bx). Prasad and Nalini (1988) reported that *Bangalora* had a TSS of 16.56 per cent under Kanpur condition. Reddy and Singh (1989) reported that TSS of *Olour, Prior* and *Muvandan* was 14.10, 13.10, and 15.20 degree brix respectively.

4.2.11. Acidity

Maximum acidity was observed in *Muvandan* (0.24 %) followed by *Neelum* (0.17 %). Varieties *Olour* and *Bangalora* registered 0.12 per cent acidity and the lowest acidity was shown by *Prior* (0.11 %). The varieties *Prior, Bangalora* and *Olour* had recorded relatively lower acidity values and are generally considered as less sour varieties. Many scientists had reported variation in acidity levels of mango varieties. (Prasad and Nalini,1988; Reddy and Singh,1989).

4.2.12. Sugar:acid ratio

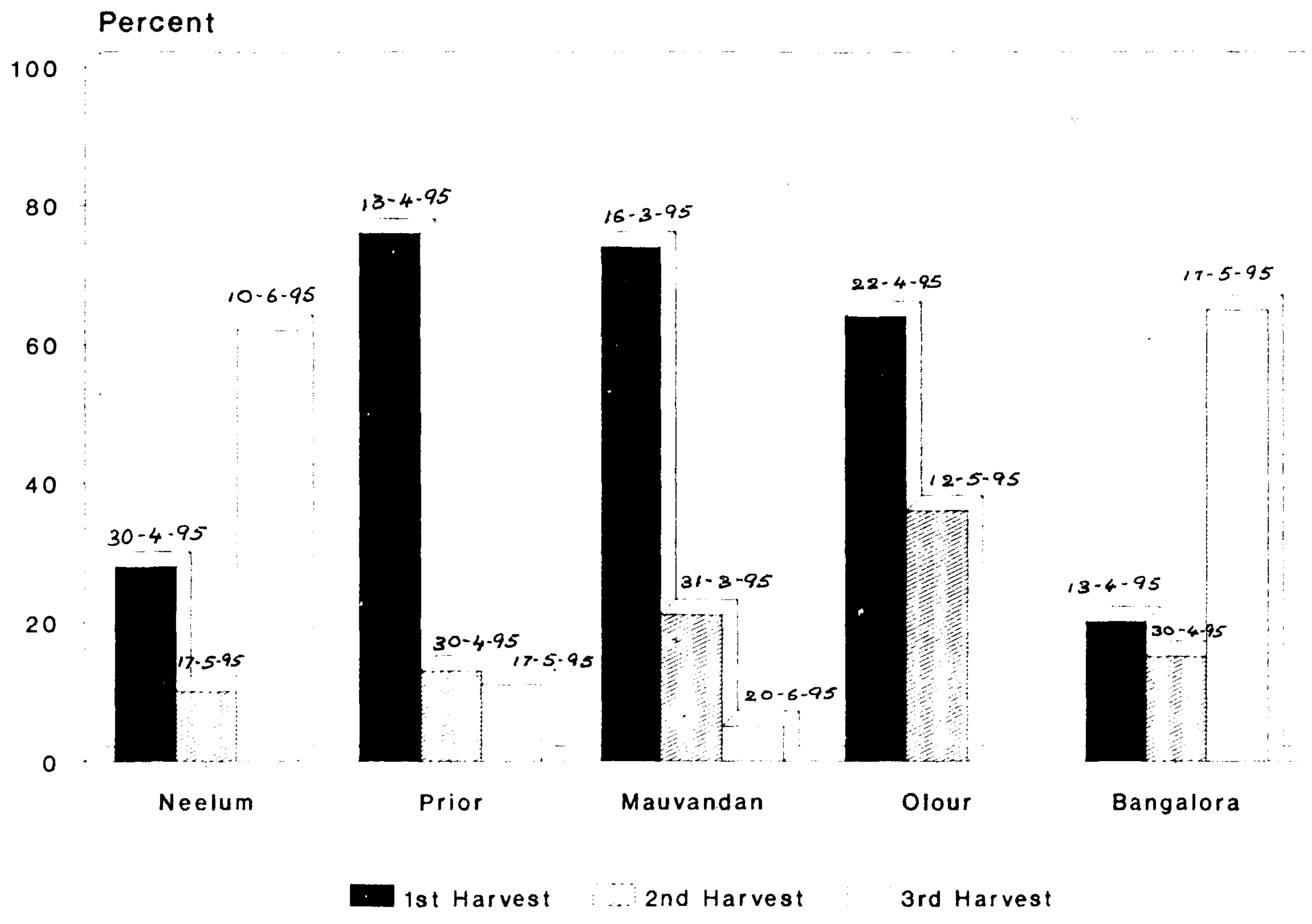
The sugar:acid blend has a specific influence on the taste of the fruit. A high sugar:acid ratio indicates a better sugar:acid blend. In the present study *Prior, Neelum, Olour* and *Bangalora* showed high sugar:acid ratio indicating a better taste. The local variety *Muvandan* registered the lowest sugar:acid ratio due to the low level of total sugars and a higher titrable acidity. It is generally accepted that *Mùvandan* variety has a striking sourness even at ripe stage.

In decayed fruits, TSS was lower in all the cases than in normally ripened fruits. Maximum TSS was recorded in *Neelum* (16° bx) and the minimum of 10 degree brix in *Muvandan.* Decay of fruit in most of the cases was the result of microbial proliferation for which soluble and insoluble solids of the fruit from the substrate. On the contrary the acidity showed an upward trend due to decay in all the five varieties tested. This could be due to the break down of sugars resulting in the production of organic acids. Cheriyan (1987) showed significant reduction in total sugar content due to infection by *Colletotrichum gloeosporioides* and *Aspergillus flavus.* Significant increase in acidity was also noticed due to microbial infection.

4.3. Harvesting interval

A one-time harvest would be ideal in mango but it is seldom realised. Minimising the number of harvests has many advantages. In the present study the processes of flowering and fruit set are staggered over a few weeks. In *Olour* the harvest could be completed in two rounds during fourth week of April and second week of May. In other varieties three rounds of harvest were necessary. In variety *Muvandan* although > 40 per cent of produce could be harvested by third week of March, due to staggered flowering the final harvest could be made during second week of June only. In variety *Neelum* also, harvest season extended upto second week of June (Figure 5).

Fig.5-Harvesting interval and proportion of fruits per harvest



EXPERIMENT - I

QUANTIFICATION OF HARVEST AND HANDLING LOSSES AND EVALUATION OF MODIFIED HARVESTING PRACTICES FOR LOSS REDUCTION IN MANGO.

4.4. Comparison of harvesters

Data collected on various aspects related to the harvesting efficiency of KAU mango harvester III and that of traditional harvester are presented in Table 5 and Figure 6. Results revealed significant difference between the two harvesters with respect to harvesting efficiency, percentage of fruits harvested with pedicel, mean pedicel length and percentage of injured and bruised fruits.

4.4.1.Harvesting efficiency

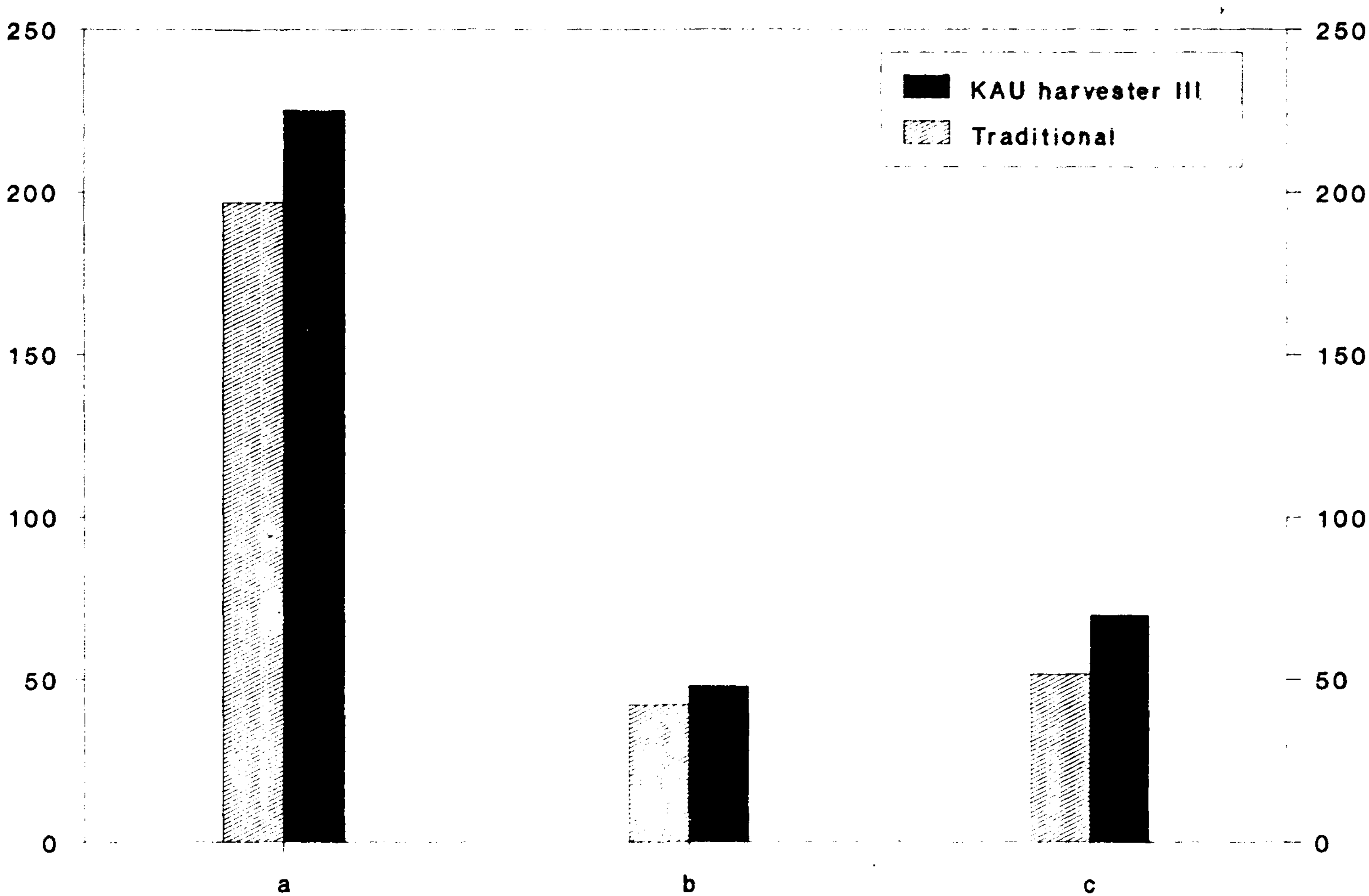
The harvesting efficiency recorded in terms of the number of fruits harvested per hour was significantly higher for KAU mango harvester III. It harvested an additional 28.4 fruits on number basis or 5.78 Kg on weight basis per hour on average.That is 14.45 and 13.70 per cent increase respectively.

With modified harvester, the number of fruits harvested per hour ranged from 81 in *Bangalora* to 332 in *Muvandan* and with traditional harvester it ranged between 76 in *Bangalora* to 285 in *Muvandan*. This variation among varieties resulted from the nature of bearing. The number of fruits per unit area of canopy, number of fruits per panicle and nature of pedicel could have influenced the harvesting efficiency. Mandhar and Kumaran (1993)have reported that harvesting capacity was dependent on yield of fruits per tree. The hand plucking of fruits was a slow

Table 5. Comparison of KAU mango harvester III and traditional harvester.

Variety	Harvester	Harvesting Capacity: No. of fruits harvested/hr (Average)	Harvesting Capacity: Quantity of fruits per hr (kg)	Fruits dropped (%)	Injured & bruised fruits (%)	Fruits harvested with pedicel (%)	Average Pedicel length (cm)
Muvandan	KAU mango harvester III	332	58.1	1.7	1.3	55.0	1.4
	Traditional harvester	285	49.8	2.9	2.7	39.3	1.2
Olour	KAU mango harvester III	261	60.0	1.1	1.0	75.2	1.3
	Traditional harvester	232	53.4	2.3	2.1	54.7	1.1
Prior	KAU mango harvester III	256	46.0	1.7	1.4	77.7	1.8
	Traditional harvester	229	41.2	1.7	1.5	55.3	1.0
Neelum	KAU mango harvester III	195	40.9	2.3	2.1	57.3	1.5
	Traditional harvester	161	33.8	2.9	2.6	44.7	1.1
Bangalora	KAU mango harvester III	81	34.8	1.9	1.1	83.5	2.3
	Traditional harvester	76	32.7	2.6	2.0	64.5	1.7
	KAU mango harvester III (average)	225	47.96	1.74	1.38	69.74	1.66
	Traditional harvester (average)	196.6	42.18	2.48	2.18	51.7	1.22
	CD (0.05)	18.91*	2.12**	0.358*	0.392*	0.299**	0.326*

Fig.6. Comparison of KAU mango harvester III and Traditional harvester



a. Harvesting capacity No. of fruits/hr
b. Harvesting capacity Qty. of fruits.hr (kg)
c. Fruits harvested with pedicel (%)

process and harvesting fruits with pedicel further reduced the harvesting capacity. This resulted in higher costs of harvesting in hand plucking. Varieties *Muvandan, olour* and *Prior* with their prolific bearing habit could have made the harvest operation easier, compared to *Neelum* and *Bangalora*. Colour of fruit could also become a factor here for locating the fruit and assessment of maturity. The dark green colour of fruits of variety *Neelum* could also have thus reduced the harvesting efficiency.

4.4.2. Fruits harvested with pedicel

With KAU mango harvester III, pedicel could be retained in 69.74 per cent of the fruits on an average compared to 51.7 per cent in traditional harvester. The length of pedicel retained was also more when KAU harvester was used. Advantages of harvesting mangoes with pedicel have been cited by many workers. (Chadha,1989; Haque and Dhua,1993; Singh *et al*,1993).

4.4.3. Injured and bruised fruits

Fruits dropped during the process of harvest varied with the types of harvester. When KAU mango harvester III was used 1.74 per cent of the harvested fruits dropped as against 2.48 per cent in the case of the traditional harvester. Experimental plants had a mean height of 6.8 m and a drop from such height can cause injuries or bruises leading to losses. In other words the quantity of fruits dropped is the first component of the postharvest loss resulting in reduction of saleable weight. From this angle the KAU mango harvester III is superior to the traditional harvester. The pulling force required to sever the fruit was less for KAU mango harvester III. The guide rods fixed at the distal end could have also prevented the fruits slipping out of the trap during harvest. The bend introduced in the frame could have also reduced the chances of drop damage when fruits at a height were harvested.

The quantity of injured and bruised fruits while using the two harvesters were assessed based on external symptoms. KAU mango harvester III caused damage to 1.38 per cent of the fruits harvested whereas the traditional harvester damaged 2.18 per cent fruits. Damage to the fruits occurs by either the contact of harvesting blade or the fall of fruits out of the net during harvesting. (Mandhar and Kumaran,1993). It had been noticed for IIHR, IARI and conventional harvesters that fruits falling out of net was more when the pole angle was more than 6o degrees with horizontal. Injured and bruised fruits serve as initial entry points for pathogenic microorganisms (Eckert,1975) and therefore, under a hygienic postharvest handling system all injured and bruised fruits should be discarded. The modified harvester could reduce the injuries and bruises during harvest to some extent.

4.5. Effect of harvesters and collecting systems on the postharvest behaviour of mangoes

Fruits collected under experiment I, after discarding the injured and bruised fruits, were used for this study. the data collected are presented in Table 6.

4.5.1. PLW

PLW is one of the most important factor that affect the shelf life of harvested fruits and vegetables. Loss of moisture

Table 6. Effect of harvesters and collecting system on physiological weight loss and spoilage in selected mango varieties.

		Fruits spoiled on number basis (%)	Weight loss (%)	Edible fruits on weight basis
Variety	*Muvandan*	5.0	9.58	74.75
	Olour	18.75	11.53	74.0
	Prior	20.0	8.95	69.25
	Neelum	3.75	14.20	75.75
	Bangalora	17.5	11.90	68.0
	CD (0.05)	NS	NS	NS
Harvester	KAU mango harvester III	10.0 (0.341)	11.32 (-2.085)	72.9 (0.984)
	Traditional harvester	13.6 (0.357)	11.14 (-2.078)	71.8 (0.962)
	CD (0.05)	NS	NS	NS
Collecting system	KAU mango harvester III	11.0 (0.315)	11.13 (-2.072)	74.0 (0.998)
	Traditional harvester	14.0 (0.383)	11.33 (-2.091)	70.7 (0.948)
	CD (0.05)	NS	NS	NS
Treatments (harvests & collecting system)	T_1	17.0 (0.40)	11.1 (-2.101)	69.0 (0.944)
	T_2	13.0 (0.315)	11.18 (-2.056)	74.6 (0.979)
	T_3	11.0 (0.367)	11.56 (-2.082)	72.4 (0.951)
	T_4	9.0 (0.315)	11.08 (-2.088)	73.4 (1.016)
	CD (0.05)	NS	NS	NS

Figures in parenthesis indicate transformed values from harvested fruits and vegetables resulted in the direct loss of saleable weight (Wills *et al*,1989).

PLW ranged from 8.95 to 14.2 per cent in the varieties studied. Minimum cumulative weight loss was recorded in *Prior* with 8.95 per cent over a period of twelve days. The time taken for ripening varied among varieties. Therefore, a meaningful comparison of PLW would be possible only when it is done on a per day basis. Minimum PLW on per day basis was recorded by *Bangalora* (0.74 %) followed by *Prior* (0.75 %), *Neelum* (0.89 %), *Olour* (0.96%). *Muvandan* registered the maximum mean PLW of 1.2 per cent. This indicated that though *Muvandan* took only eight days to reach ripe stage, the rate of weight loss was the highest. When a variety has a higher PLW, its shelf life will be less. The harvesting and collecting systems evaluated in the experiment had no effect on the PLW. Since there was an initial sorting to remove injured or bruised fruits before keeping them for ripening, such an observation is possible.

4.5.2. Number of marketable fruits

General indications for unmarketable fruits after ripening are microbial infection, discolouration and shrivelling. Fruits without any of the above mentioned indications at ripe stage were considered as marketable fruits and the recovery of such fruits ranged from 68.00 per cent (in *Bangalora*) to 75.75 per cent (in *Neelum*). The portion of unmarketable fruits ranged from 24.25 to 32 per cent in the varieties. This indicated the necessity of bestowing more attention to the various postharvest practices to increase the number of marketable fruits. Indian Institute of

Socio-Economic studies estimated the losses in different stages of marketing of horticultural crops. They had shown that it was around 15 per cent in Bangalore market consisting of three per cent while loading and unloading, three per cent during transport, two per cent due to poor packing, four per cent due to poor quality and three per cent due to other reasons.

4.5.3. Incidence of spoilage

In most cases, incidence of postharvest spoilage in mango is due to microbial infection. This might be due to a latent field infection or infection at postharvest stages. In the present study the percentage of fruits that exhibited the symptoms of spoilage (on number basis) before reaching optimum ripening varied from 3.75 to 20 per cent.(Table 6). Though there was no significant difference between varieties in this aspect, it is worth mentioning that a relatively high spoilage was observed in *Prior, Olour* and *in Bangalora*. It was relatively less in *Neelum* (3.75 %) and *Muvandan* (5.00 %). The problem of residual toxicity causes serious limitations on the use of fungicides, bactericides etc after harvest, for preventing such spoilages. Varieties with an inherent potential to withstand microbial infection may be of greater significance. Lesser spoilage observed in varieties *Neelum* and *Muvandan* indicated the varietal variation in microbial spoilage.

The harvesters used for the operation did not influence recovery of marketable fruits and incidence of spoilage. However the KAU mango harvester III gave slightly higher out turn of marketable fruits.

The collecting systems did not influence the ripening and spoilage of fruits. Though the modified system indicated slight advantage in absolute terms, statistical analysis indicated that it is not significant. Thus provision of padding in collection baskets did not give advantage over the traditional system.

The overall effect due to use of modified harvesting and collecting system on PLW, spoilage and recovery of marketable fruits were also not significant. Thus it can be stated that the system of collection of harvested fruits in bamboo baskets during harvest operation do not contribute towards the postharvest losses if sufficient care is taken.

EXPERIMENT II

EFFECT OF MODIFIED HANDLING PRACTICES ON THE POSTHARVEST LOSSES IN MANGO

4.6. Comparison of containers

The observations on comparison of different containers used for handling of fruits are showed in Table 7. Packing density was maximum for cardboard boxes and rectangular plastic containers (0.55 and 0.50). Gunny bags were the next best (0.49) followed by bamboo basket and circular plastic container (0.4 and 0.35). The rectangular containers will be advantageous during transportation also. The plastic crates will be ideal for stacking with no risk of damage to fruits, which is a drawback in all other containers. A comparison of costs involved shows that plastic crates is costlier than other containers, but can serve for many years.

Table 7. Comparison of containers.

Container	Packing capacity: No. of fruits	Packing capacity: Wt. (kg)	Volume of container (m^3)	Volume of fruits packed (m^3)	Packing density	Cost/unit (Rs)
Cardboard box	45	10.43	0.020	0.011	0.550	8.00
Rectangular plastic crate	59	14.15	0.027	0.014	0.504	480.00
Circular plastic container	30	6.50	0.017	0.006	0.352	20.00
Bamboo basket	29	6.10	0.014	0.006	0.414	8.00
Traditional packing (control)	176	35.20	0.068	0.034	0.499	6.00

4.7. Effect of containers and handling systems on postharvest behaviour of mango

The effect of different handling practices on postharvest attributes were studied in two varieties *Prior* and *Muvandan*.

Variety *Prior*

The observations on the effect of containers and handling systems on postharvest behaviour of mango variety *Prior* are given in Table 8 and Figure 7.

4.7.1. PLW

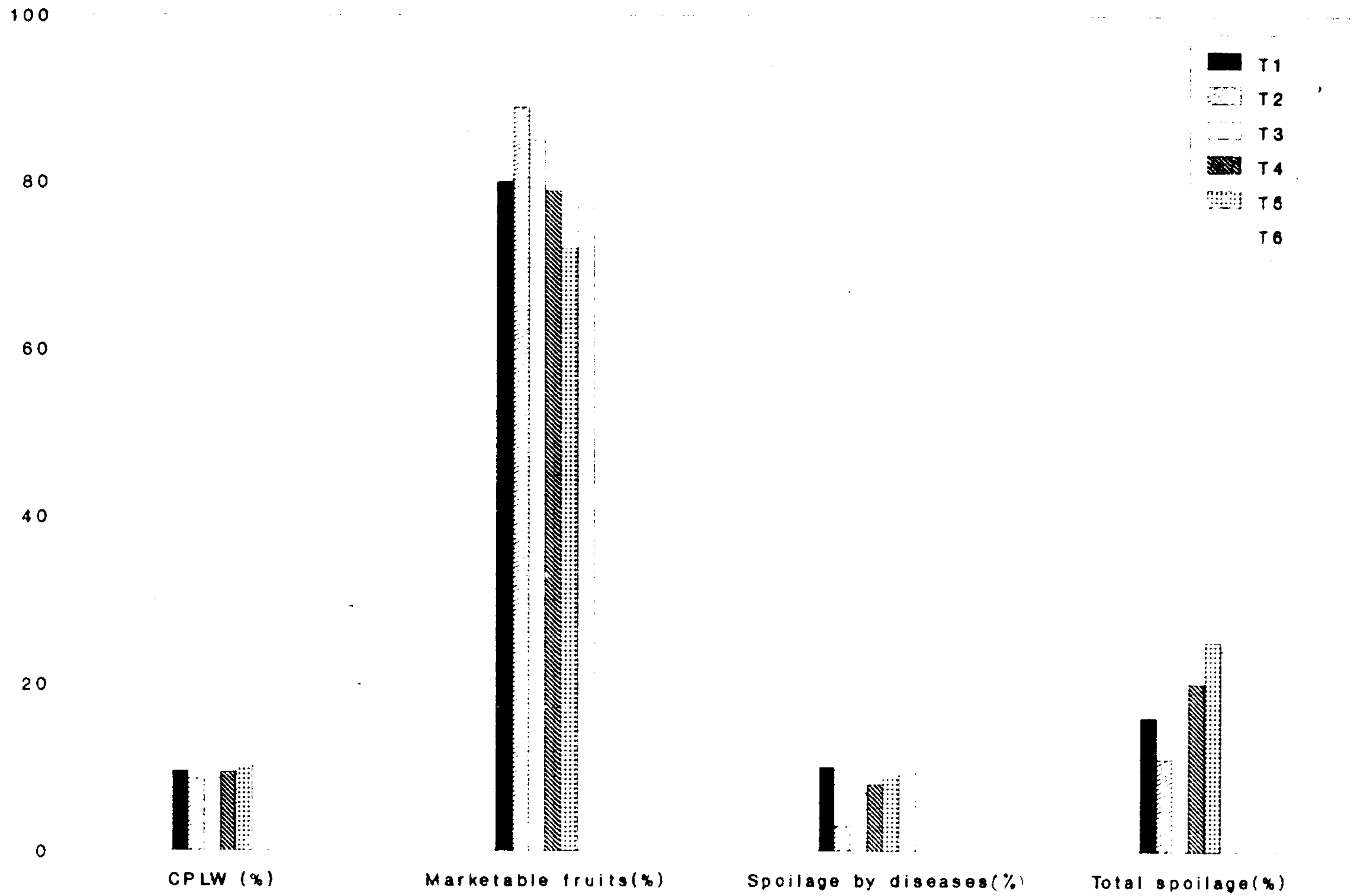
The containers used for handling and transportation had significant influence on PLW in *Prior*. The treatments T5 and T6 (gunny bag) recorded maximum PLW of 10.2 and 10.0 per cent respectively after eight days storage under ambient conditions. The minimum PLW was recorded by T2 (plastic crate) with 8.6 per cent weight loss . It was on par with T3 (circular container)with a weight loss of 8.7 per cent. It may be noted that treatments T2 and T3 had non-moisture absorbing substance (plastic) compared to containers like corrugated fibre board box, bamboo basket and gunny bags. The chances of physical damage during transportation is less in the rigid containers with pattern packing. Higher PLW in fruits packed in gunny bags and bamboo baskets could have resulted from increased respiratory activity due to physical damage during transportation.

The plastic containers though requires higher initial investment, may prove cheaper in the long run since it can be

Table 8. Effect of modified handling practices on postharvest losses in mango var. *Prior*.

Container	Cumulative wt. loss at ripe stage (%)	Marketable fruits on number basis (%)	Edible fruits on wt. basis (%)	Ripening pattern (%)				Spoilage (%)				
				2 days	4 days	6 days	8 days	Fruitfly	Diseases	Discolouration	Deformation	Total (excluding fruitfly infestation
T_1	9.5 (-2.252)	80.0 (1.102)	76.0 (1.136)	0.0	23.0 (0.486)	73.0 (1.034)	100.0	3.0 (0.186)	10.0 (0.312)	1.0 (0.162)	2.0 (0.176)	13.0
T_2	8.6 (-2.375)	89.0 (1.231)	81.0 (1.421)	0.0	24.0 (0.478)	75.0 (1.060)	100.0	6.0 (0.245)	3.0 (0.186)	1.0 (0.162)	1.0 (0.162)	5.0
T_3	8.7 (-2.365)	85.0 (1.178)	77.0 (1.315)	0.0	17.0 (0.379)	85.0 (1.178)	100.0	11.0 (0.340)	7.0 (0.267)	1.0 (0.162)	2.0 (0.176)	10.0
T_4	9.4 (9.260)	79.0 (1.101)	71.0 (0.899)	0.0	20.0 (0.431)	76.0 (1.016)	100.0	8.0 (0.286)	8.0 (0.286)	1.0 (0.162)	3.0 (0.186)	12.0
T_5	10.2 (-2.176)	72.0 (1.020)	69.0 (0.072)	0.0	31.0 (0.544)	71.0 (1.016)	100.0	8.0 (0.286)	9.0 (0.298)	3.0 (0.186)	5.0 (0.228)	17.0
T_6	10.0 (-2.202)	77.0 (1.074)	70.0 (0.854)	0.0	27.0 (0.523)	70.0 (1.016)	100.0	10.0 (0.312)	11.0 (0.340)	1.0 (0.162)	2.0 (0.176)	14.0
CD(0.05)	0.146	0.117	0.350		NS	NS		NS	0.088	NS	NS	

Fig.7. Effect of modified handling practices on postharvest losses in mango variety *Prior*



reused. (Kiss,1988; FAO,1989; Pruthi,1993).Chances of plastic containers serving as a carrier for inoculum of decay organisms are less since they can be cleaned before reuse.

4.7.2. Marketable fruits

The types of containers used for handling significantly influenced the recovery of marketable fruits at ripe stage. T2 (rectangular plastic container) gave the maximum of 89 per cent marketable fruits and was superior to all other treatments. The next best treatment was T3 (circular plastic container) with 85 per cent marketable fruits. T1(cardboard box) and T4 (bamboo basket) were on par and occupied the third position with 80 per cent and 79 per cent of ripe fruits being marketable. The gunny bag (T5) was the least suitable, giving an out turn of 72 per cent only. Thus it can be inferred that the rectangular plastic crates are most suitable for bulk handling of mangoes. Neelgreevam *et al*(1986) found that the losses during transport increase the cost upto 24.2 per cent. The extent of losses can be reduced by use of plastic crates for handling. Moulded plastic containers are strong, rigid, easily cleaned and can be made to stack and are reusable and therefore an economic packaging material (FAO,1989).

4.7.3. Ripening pattern

Ripening pattern of fruits were not influenced by the containers used for handling. Ripening was completed in eight days in all the treatments. (Table 8).

4.7.4. Spoilage of fruits

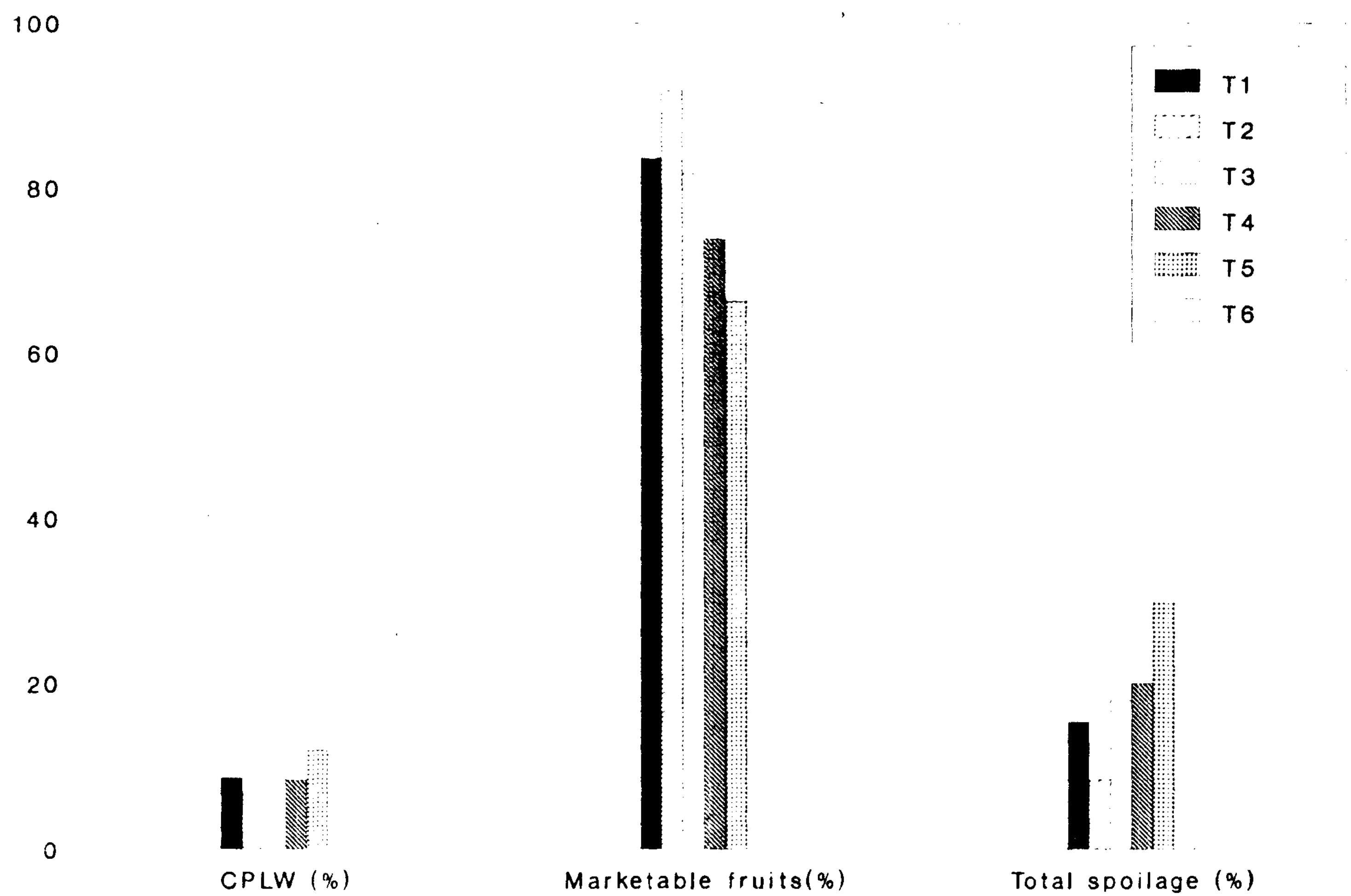
Data on the incidence of spoilage during storage after packing and transporting in the various containers revealed that the treatments were significantly different. Spoilage due to disease incidence was minimum where rectangular plastic crate (T2) was used (3 %). Extent of spoilage was seven per cent in circular plastic containers (T3) and eight per cent in bamboo baskets (T4). Maximum spoilage was observed when cardboard box and gunny bags were used (10 % in T5 and 11 % in T6). Spoilage due to discolouration and deformation were not influenced by treatments. Movement of the commodity for a short distance of 25 Km would not have resulted physical damage to cause deformation of fruits. Moreover there was no stacking of containers in the carriage as is normally done. The extent of spoilage observed in different treatments indicated that T2 (plastic crate) had minimum spoilage (5 %). Maximum spoilage of 17 per cent and 14 per cent were seen in treatments T6 and T5 (gunny bags) respectively.

It can be concluded that the rectangular plastic crates are superior to all other containers used in the study with respect to the postharvest attributes like PLW, recovery of marketable fruits, incidence of spoilage etc. The only limitation for the use of plastic crates is the high initial cost and return of the empty containers to the production centre. These are in conformity with the observations by Kiss (1988); FAO (1989); Sethi and Maini (1989) and Pruthi (1993).

Table 9. Effect of modified handling practices on postharvest losses in mango var. *Muvandan*.

Container	Cumulative wt. loss at ripe stage(%)	Marketable fruits on number basis (5)	Ripening pattern (%)				Spoilage (%)				
			2 days	4 days	6 days	8 days	fruitfly	Diseases	Discolouration	Deformation	Total (excluding fruitfly infestation
T_1	8.6 (-2.364)	83.7 (1.157)	0.0 (0.159)	58.0 (0.872)	88.8 (1.227)	100.0	0.3 (0.151)	9.0 (0.294)	6.0 (0.233)	0.0 (0.159)	15.0
T_2	6.8 (-2.609)	91.9 (1.285)	4.0 (0.229)	61.0 (0.900)	100.0 (1.412)	100.0	0.0 (0.159)	8.4 (0.293)	0.0 (0.159)	0.0 (0.159)	8.4
T_3	8.5 (-2.372)	81.8 (1.132)	0.0 (0.159)	38.0 (0.658)	92.0 (1.286)	100.0	0.0 (0.159)	10.0 (0.309)	7.0 (0.270)	1.0 (0.165)	18.0
T_4	8.3 (-2.405)	73.9 (1.305)	0.0 (0.159)	33.0 (0.607)	87.0 (1.209)	100.0	0.0 (0.159)	11.0 (0.341)	6.0 (0.263)	3.0 (0.204)	20.0
T_5	12.0 (-1.997)	66.3 (0.952)	8.0 (0.278)	48.0 (0.769)	88.0 (1.219)	100.0	0.0 (0.159)	16.0 (0.411)	7.0 (0.270)	7.0 (0.270)	30.0
T_6	9.37 (-2.199)	73.3 (1.031)	16.0 (0.402)	81.0 (1.126)	98.0 (1.398)	100.0	0.0 (0.159)	12.0 (0.337)	5.0 (0.221)	5.0 (0.221)	22.0
CD(0.05)	0.146	0.058	0.117	0.117	0.0		NS	NS	NS	NS	

Fig.8. Effect of modified handling practices on postharvest losses in mango variety *Muvandan*



Variety *Muvandan*

The effect of different handling methods on the postharvest quality attributes like PLW, ripening pattern and spoilage were similar to that in variety *Prior* (Table 9, Figure 8). Use of plastic crate (T2) was superior to other treatments. In this case 91.9 per cent of the ripe fruits were marketable. As far as the ripening pattern was concerned, variety *Muvandan* started ripening earlier than *Prior* indicating that fruits could have been at an advanced stage of maturity as compared to *Prior*. However, all the fruits attained full ripeness by the eighth day as was observed in *Prior*. The ripening process was fastest in the T2.

There was no significant difference among the treatments with respect to spoilage of fruits. However the minimum spoilage (8.4 %) was recorded in T2(rectangular plastic crate). Fruits in the gunny bags (T5 and T6) had high levels of spoilage. It can be stated that the use of gunny bags as container for mango can cause higher postharvest losses and should not be encouraged.

EXPERIMENT III

EFFECT OF POSTHARVEST TREATMENTS ON QUALITY AND POSTHARVEST LOSSES IN MANGO

Data on the effectS of various postharvest treatments on the PLW and spoilage in the five mango varieties are furnished in Table 10.

Table 10. Effect of different postharvest treatment on CPLW and spoilage

Variety/ treatment	Cumulative wt. loss (%)	No. of fruits spoiled at ripe stage (%)	Causes of spoilage (on no. basis)			
			Shrinkage	Doscolouration	Diseases	Fruitfly
Muvandan	14.48 (-1.779)	17.5 (0.414)	3.33 (0.164)	5.5 (0.218)	7.17 (0.238)	1.5 (0.112)
Olour	16.9 (-1.593)	15.5 (0.384)	1.0 (0.091)	2.33 (0.123)	1.67 (0.0107	8.83 (0.296)
Prior	14.82 (-1.750)	14.17 (0.379)	3.17 (0.169)	2.0 (0.133)	2.33 (0.123)	6.67 (0.255)
Neelum	17.22 (-1.571)	20.17 (0.439)	4.33 (0.173)	7.0 (0.260)	8.83 (0.277)	0.00
Bangalora	17.67 (-1.541)	31.67 (0.592)	3.83 (0.173)	3.33 (0.164)	7.17 (0.256)	17.33 (0.424)
CD (0.05)	0.499	0.064	NS	0.075	0.096	0.097
T_1	15.9 (-1.668)	18.1 (0.418)	1.8 (0.124)	4.0 (0.173)	4.8 (0.191)	7.5 (0.254)
T_2	15.35 (-1.711)	12.1 (0.321)	0.6 (0.075)	1.8 (0.124)	1.2 (0.100)	8.5 (0.284)
T_3	15.43 (-1.700)	8.3 (0.247)	0.6 (0.075)	0.6 (0.075)	0.6 (0.075)	6.5 (0.237)
T_4	16.36 (-1.637)	24.85 (0.495)	4.6 (0.212)	4.0 (0.187)	8.0 (0.243)	8.25 (0.266)
T_5	16.65 (-1.614)	27.6 (0.529)	5.4 (0.216)	6.0 (0.241)	7.2 (0.261)	9.0 (0.286)
T_6	17.52 (-1.504)	35.35 (0.639)	5.0 (0.223)	7.8 (0.277)	10.8 (0.330)	11.75 (0.305)
CD (0.05)	0.054	0.0702	0.104	0.082	0.105	NS

4.8.1. PLW

Results indicated that there was significant difference between varieties and treatments with respect to the cumulative PLW monitored till twenty per cent of the fruits were spoiled. Among the varieties, *Muvandan* registered the minimum of 14.48 per cent weight loss followed by *Prior* (14.82 %), *Olour* (16.90 %), *Neelum* (17.22 %)and *Bangalora* (17.67 %). As explained previously, the basic mechanism governing PLW could be dependent the varietal characters and therefore, the varietal differences are acceptable. Results indicated that ambient conditions favour loss of considerable quantities of moisture under tropical conditions during summer. The net effect is that the shelf life reduced. In this case also for a meaningful comparison of the PLW, the weight loss on a per day basis was examined. Minimum PLW on a per day basis was observed in *Neelum* (1.08 %) followed by *Bangalora* (1.10 %), *Prior* (1.40 %), *Olour* (1.41 %) and *Muvandan* had the maximum PLW of 1.81 per cent.

The effects of postharvest treatments on PLW were significant. Minimum PLW was recorded in T2 and T3(15.1% and 15.43 %) while control (T6) had 17.52 per cent.

Treatments T1, T2 and T3 seemed to have some influence on decreasing the PLW where as T4 and T5 did not show any such influence. The indication that treatments with water has some effect on the reduction of moisture loss gives scope for detailed studies using cold water, extended treatment time etc. Chauhan *et al(1987)* reported that mango fruits dipped in hot or cold water were the best as there was minimum weight loss and decay loss. A number of researchers have studied the effect of postharvest treatments on PLW and have attributed this to changes in the ripening pattern and effect of fungicides or waxes used in the treatments (Lakshminarayana,1974; Sharma and Ray, 1987; Chauhan *et al* ,1987; Sethi and Maini,1989).

4.8.2. fruits spoiled at ripe stage

The varieties significantly differed with respect to extent of spoilage at full ripe stage. Variety *Prior* recorded minimum spoilage of 14.17 per cent followed by *Olour*(15.50 %), *Muvandan* (17.5 %),*Neelum* (20.17 %) and *Bangalora* (31.67 %). The fruit characteristics which resulted in higher spoilage in *Neelum* and *Bangalora* have to be examined in detail.

Among the postharvest treatments, T3 was significantly superior to all other treatments. Effective control or elimination of inoculum of pathogenic fungi by the use of fungicides could have been responsible for this. T2 (treatment with warm water at 52 °C) also was an effective treatment for spoilage reduction (10.42 per cent). The beneficial effect of warm water in reduction of spoilage in mango has been reported by various workers.(Fawcett,1922; Chang,1975; Spalding and Reeder,1978; Sampaio *et al*,1979; Srivastava,1984; Kalra and Tandon,1984).

Treatment with water at normal temperature also was effective for reducing the microbial spoilage. This might be due to removal of microbial load on the surface of the fruits resulting in a lower level of microbial spoilage. However, the

T4 (dipping in 6 % solution of Borax) and T5 (dipping in water containing bleaching powder 0.1 %) recorded spoilage levels higher than that of T1 and were not effective. Maximum spoilage of 35.8 per cent was recorded in control.

4.8.3. Shrinkage of fruits

The fruits judged as spoiled were grouped into four categories based on shrinkage, discoloration, diseases and fruitfly infection. Shrinkage is a physical phenomenon due to postharvest effects resulting in the shrivelled appearance of the fruit skin making it unmarketable. In the present study varieties were not significantly different with respect to the shrinkage. However, the postharvest treatments influenced this attribute. Shrinkage was minimum in T2 and T3 (0.6 %). When treated with water at room temperature 1.8 per cent of the fruits showed shrinkage symptoms, while it was 4.6 per cent, 5.4 per cent and 5.0 per cent respectively in T4, T5 and T6. This indicated that treating with water cold or warm, had a beneficial effect by reducing shrinkage. The osmotic effect might have permitted entry of water molecules into the outer cell layers of the fruit skin allowing it to remain intact for a longer period under storage. T4 and T5 did not show beneficial effect in reducing shrinkage.

4.8.4. Discolouration

Varieties ~~were~~ significantly differed with respect to discolouration during postharvest storage. (Table 10).Each variety has its characteristic fruit colour depending on the pigmentation. The development of pigments could be influenced by the treatments resulting in discolouration. The data revealed that discolouration was minimum in *Prior* (2 %) and maximum in *Neelum* (7.0 %). *Olour* registered 2.33 per cent discoloured fruits while in *Bangalora* it was 3.33 per cent and in *Muvandan* 5.5 per cent.

The postharvest treatments had a significant effect on the discolouration in ripe fruits.(Plate 12 to 16). The minimum number of discoloured fruits (0.6 %) were found in the T3 (warm water + Bavistin 0.1 per cent) and it was superior to all other treatments. This could be due to the antimicrobial action of carbendazim preventing microbial activity. T2 (soaking in warm water) was the second best treatment with only 1.8 per cent of discoloured fruits. The washing and soaking with warm water would also have reduced the microbial load resulting in lesser discolouration. The treatment with water at room temperature (T1) and water containing six per cent Borax (T4) recorded four per cent discoloured fruits. T5 (water containing bleaching powder) registered six per cent discolouration. The percentage of discolouration in control (T6) was 7.8 per cent. Thus T1, T4 and T5 were not very effective in reducing discolouration of mangoes during ripening process as compared to T3 and T2. Treating harvested fruits with warm water (52 ^{o}C) containing carbendazim (0.05 %) could be considered for improving the colour of fruits if the levels of chemical residues present are within the safe limits. Otherwise, hot water treatment offers good scope for the control of postharvest discolouration in mango. Similar findings were reported by Sampaio *et al* (1979) and Kalra and Tandon(1983).

Plate 13. Effect of various postharvest treatments on variety *Olour*

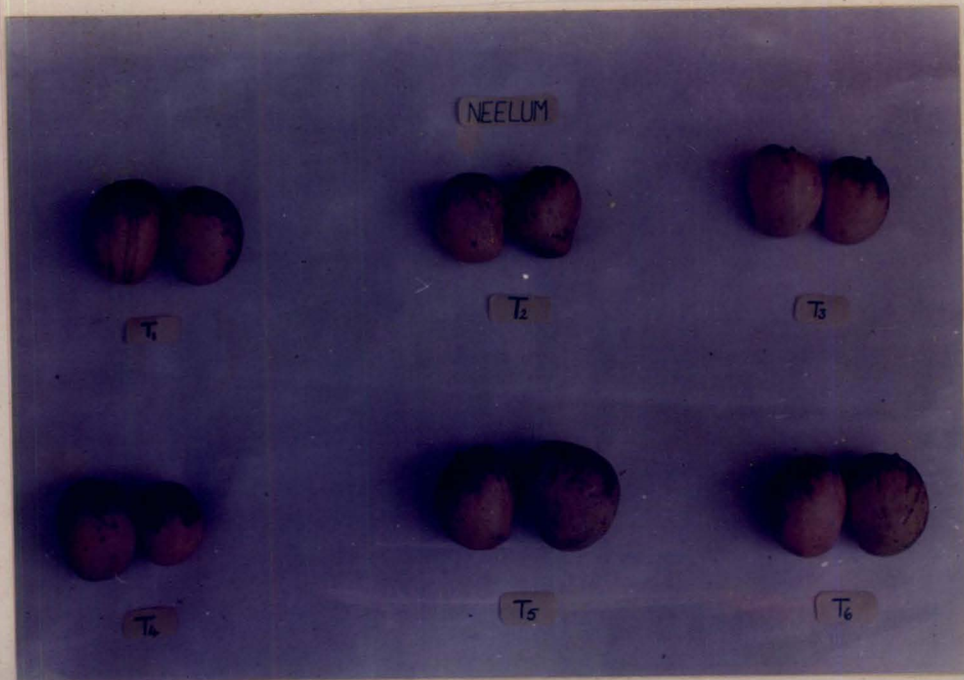
Plate 14. Effect of various postharvest treatments on variety *Prior*


OLOUR
T6
T4
T5
T1
T2


PRIOR
T1
T2
T3
T4
T5
T6

Plate 15. Effect of various postharvest treatments on variety *Neelum*

Plate 16. Effect of various postharvest treatments on variety *Bangalora*


NEELUM
T1
T2
T3
T4
T5
T6


T1
T2
T3
T4
T5
T6
BANGALORA

4.8.5. Disease incidence

Based on laboratory investigations, the following fungi were isolated and identified from mangoes kept for ripening.

1. *Colletotrichum gloeosporioides*

2. *Aspergillus niger*

3. *Botryodiplodia theobromae*

4. *Aspergillus flavus*

5. *Aspergillus aculeatus*

6. *Rhizopus oryzae*

7. *Corticium rolfsii*

8. *Pencillium sp.*

The organisms responsible for disease incidence in mango have been studied by several workers. (Palejwala and Modi,1985; Cheriyan,1987; Johnson *et al*,1989).

Varieties differed significantly with respect to incidence of diseases.(Table 10). Varieties *Olour* and *Prior* had less spoilage as was observed under expeqriment II compared to other varieties. Desirable attributes, if any, present in these varieties are to be investigated.

Among the postharvest treatments, T3 (combination of warm water and carbendazim (0.05 %) recorded disease incidence to 0.6 per cent followed by T2 (hot water treatment at 52 °C)in which it was 1.2 per cent. The other treatments like T1 (water at normal temperature), T4 (water containing 6 % Borax), T5 (water containing 0.1 % bleaching powder) and T6 (control) recorded rates of disease incidence ranging from 4.8 to 10.8 per cent

Bleaching powder or Borax treatment was not effective in controlling the postharvest diseases in mangoes. Fungicidal properties of Borax is used in citrus fruits to inhibit mould (Grayson,1978). The disease incidence of 4.8 per cent under treatment with water at room temperature in comparison with 10.8 per cent incidence in control indicated that a simple washing is effective for reducing postharvest diseases.

4.8.6. Spoilage due to fruitfly

There was significant difference among varieties with respect to spoilage due to fruitfly attack.(Table 10). Variety *Neelum* was relatively free from fruitfly infestation. Variety *Muvandan* also recorded low levels of spoilage due to fruitfly infestation. Texture and composition of fruits could be factors which influence fruitfly infestation. A thick skin may make the oviposition difficult. The skin thickness of the five varieties used for the study are presented in Table 3. The skin thickness of *Bangalora, Prior* and *Olour* were 0.34, 0.54 and 0.65 mm respectively and these varieties recorded higher incidence of fruitfly attack (17.33, 8.83 and 6.67 % respectively). *Muvandan* and *Neelum* had thicker skin and had lower infestation by fruitflies.

Postharvest treatments did not show any effect on the damage due to fruitflies. The infestation takes place from the field and the treatments given after harvest could not have influenced the subsequent phases.

Table 11. Effect of postharvest treatments on the ripening pattern (percentage of fruits ripened at different intervals)

Variety	Days of storage				
	2	4	6	8	10
Muvandan	20.5	83.3 (1.214)	100.0	100.0	100.0
Olour	0.0	16.17 (0.413)	57.17 (0.971)	96.0 (1.405)	100.0
Prior	0.0	37.17 (0.651)	59.33 (0.882)	100.0	100.0
Neelum	0.0	0.0	40.83 (0.692)	67.5 (0.967)	100.0
Bangalora	0.0	16.83 (0.411)	46.75 (0.756)	77.33 (1.109)	100.0
CD (0.05)		0.181*	NS	0.149*	
T_1	5.6	37.0 (0.640)	50.0 (0.787)	81.67 (1.152)	100.0
T_2	2.1	47.5 (0.800)	56.5 (0.852)	85.67 (1.235)	100.0
T_3	6.1	48.75 (0.824)	64.25 (0.939)	92.0 (1.367)	100.0
T_4	1.1	28.88 (0.547)	51.63 (0.809)	70.3 (1.013)	100.0
T_5	3.2	33.88 (0.609)	51.5 (0.810)	78.33 (1.151)	100.0
T_6	2.1	34.25 (0.613)	47.25 (0.757)	73.67 (1.045)	100.0
CD (0.05)		0.222*	NS	0.211*	

Figures in parenthesis indicate transformed values was significantly different with T2 (warm water) and T3(warm water + Bavistin 0.1%) showing higher rate of ripening (47.50 % and 48.57 % respectively) as compared to 28.88 per cent in T4 (Borax 6 %),33.88 per cent in T5 (0.1 per cent bleaching powder), 34.25 per cent in T6 (control) and 37.00 per cent in T1 (water at room temperature). Various workers had reported the beneficial effects of warm water soaking in the advanced and uniform ripening behaviour of mangoes. (Lakshminarayana et al, 1974; Kalra and Tandon,1984). Similar trend in ripening pattern was seen after eight days of storage also. Enhancing the ripening process could be of advantage to reduce handling in processing units. This would also result in lesser PLW and spoilage. The warm water treatment could have accelerated the biochemical processes leading to ripening of fruits.

All the fruits reached the ripe stage on the tenth day. Beyond the tenth day, shrivelling and spoilage increased and the proportion of marketable fruits decreased. The data thus indicated the crucial nature of the postharvest phase necessitating utilization of the fruits within a short span of time, once the fruits started ripening. The postharvest management for extention of shelf life in mango should primarily aimed at delaying the onset of climacteric process, rather than controlling the climacteric process in ripening initiated fruits. The climacteric process is an irreversible one and once initiated it is difficult to control (Wills *et al,1989)*.

4.8.8. Effect of postharvest treatments on colour of ripened fruits

Attractive yellow or orange colour make fruit display in the market more appealing. Therefore, development of attractive colour at ripening is an important factor in the marketing of fresh fruits. Assessment of the efficacy of postharvest treatment on colour development at ripe stage in the different varieties was done using a scoring test (Ranganna,1986) and the results of the same are presented in Table 12. Warm water treatments (T2 and T3) showed a better rating for colour development than the other four treatments. The beneficial effect of warm water treatment on better colour development in mango had been reported by several workers (Lakshminarayana *et al*, 1974; Kalra and Tandon, 1983).

4.9. Residues of fungicide in treated fruits

Postharvest treatment of mangoes with hot water at 52 °C containing Carbendazim 0.05 per cent was found to be effective in reducing postharvest diseases. The fungicidal residues in the treated fruits could be a limitation in adopting this method. The data on analysis of Carbendazim residues are shown in Table 13.

The treated fruits had high levels of Carbendazim residues at the ripe stage. The residue levels ranged between 120.7 ppm to 191.0 ppm when fruits were analysed along with the skin. In the fruit flesh the residue levels ranged between 90.8 to 156.9 ppm. Chauhan and Joshi (1990) had reported that Carbendazim left residues in the pulp when used for postharvest treatment in mango. Sharma *et al* (1991) had also found that the residue levels

Table 12. Effect of postharvest treatments on colour of fruits

Variety	Score					
	T_1	T_2	T_3	T_4	T_5	T_6
Muvandan	72	86	88	72	74	68
Olour	74	86	86	76	74	70
Prior	74	88	88	78	78	72
Neelum	72	86	88	78	76	66
Bangalora	78	88	90	78	74	68

Colour score - Numerical scoring Test.

Score	Quality description
90	Excellent
80	Good
70	Fair
60	Poor

(Source: Ranganna, 1986)

Table 13. Residues of Carbendazim estimated in treated fruits at ripe stage

variety	residues in fruit pulp along with skin (ppm)	Residue in fruit pulp after removal of skin (ppm)	percentage reduction in residues with removal of skin
Muvandan	141.13	99.30	29.64
Olour	130.40	56.50	56.67
Prior	120.70	101.20	16.16
Neelum	191.00	156.90	17.85
Bangalora	131.70	90.80	31.06

varied with the concentration of fungicide and duration of treatment. The Acceptable Daily Intake (ADI) for the chemical is 0.125 ppm. The present study indicated that the treated fruits have Carbendazim residues much higher than the permittable levels (18.75 ppm in food stuffs).Further studies are required to examine whether lower concentrations of the fungicide for postharvest treatment will be effective for reducing losses at the same time leaving residues within the permitted levels.

Summary

SUMMARY

The present investigations on Harvest and postharvest losses in mango (*Mangifera indica* L.) and its management were conducted in the Department of Processing Technology, College of Horticulture, Vellanikkara, Thrissur, Kerala from February 1994 to July 1995.

In this study an effort was made to find out extent of losses of mangoes during harvest and handling and ways for reducing such losses. Evaluation of modified harvesting and handling techniques and effecf of some postharvest treatments comprised the experimental strategy. Three experiments included in the present study were the following.

1. Quantification of harvest and handling losses and evaluation of modified harvesting practices for loss reduction in mango.
2. Effect of modified handling practices on postharvest losses in mango.
3. Effect of postharvest treatments on quality and postharvest losses in mango.

Five mango varieties , viz; *Prior, Neelum, Bangalora, Olour* and *Muvandan* available at the Instructional Farm, Vellanikkara and in the orchard of College of Horticulture were used for the study.

The harvested fruits were separated into specific gravity groups, viz; < 1.00, 1.00 to 1.05 and > 1.05. Majority of fruits fell into the specific gravity group of 1.00 to 1.05.

The fruit weight among five varieties ranged from 177 g (*Muvandan*) to 439 g (*Bangalora*). The fruit length ranged from 7.6 cm (*Prior*) to 13.3 cm (*Bangalora*). Maximum fruit diameter was recorded in *Olour* (9.2 cm) while that was minimum for Prior (5.7 cm). Maximum fruit circumference was for *Bangalora* (26 cm) while *Muvandan* recorded a minimum of 20.6 cm. Shape index was maximum for *Bangalora* (2.11) while it was the least in *Muvandan* (1.16). *Neelum* had the thickest skin (0.94 mm) while, it was minimum for *Bangalora* (0.34 mm). Flesh firmness ranged from 0.58 Kg/cm^2 in *Bangalora* to 0.73 Kg/cm^2 in *Neelum* at the ripe stage. Specific gravity of fruits showed a decreasing trend during ripening.

Total sugar content varied between 14.4 per cent (*Neelum*) and 9.5 per cent (*Muvandan* and *Bangalora*). *Neelum* recorded highest reducing sugar and non-reducing sugar content(3.3 % and 11.1 % respectively).

TSS ranged between 19 degree brix in *Neelum* and 13 degree brix in *Muvandan*. Acidity was highest in *Muvandan* (0.24 %) and lowest in *Prior* (0.11 %).

Three mango harvesters were designed and fabricated. KAU mango harvester III was found superior to the traditional harvester in terms of harvesting efficiency, and retention of pedicel. The extent of spoilage of fruits was less when this harvester was used. KAU mango harvester III recorded an increased harvesting efficiency of 14.45 per cent on number of fruits basis and 13.70 per cent on weight of fruit basis compared to the traditional harvester.

It was found that while using the KAU mango harvester III only 1.74 per cent fruits dropped as against 2.48 per cent in the case of traditional harvester. The KAU mango harvester III caused injuries to 1.34 per cent of the fruits harvested while it was 2.18 per cent when the traditional harvester was used. The KAU mango harvester III retained pedicel with a mean length of 1.66 cm in 69.7 per cent fruits harvested. 1.22 cm long pedicel retained in 59.7 per cent of harvested fruits when traditional harvester was used.

Physiological weight loss ranged from 8.95 to 14.20 per cent in the different varieties. Minimum PLW on per day basis was recorded by *Bangalora* (0.74 %) and maximum by *Muvandan* (1.92 %). The recovery of marketable fruits ranged from 68.0 per cent in *Bangalora* to 75.75 per cent in *Neelum*. The percentage of fruits that exhibited the symptoms of spoilage before reaching optimum ripening varied from 3.75 per cent in *Neelum* to 20 per cent in *Prior*. Padding given for collection baskets did not influence postharvest characters.

Among the different types of containers used, packing density was maximum when cardboard box was used (0.55 %) followed by rectangular plastic crates (0.49 %).

Studies on the effect of containers and transportation on postharvest losses of mango showed that handling of mangoes in rectangular plastic crate was superior in terms of number of marketable fruits (89 %), minimum PLW (8.6 %) and less disease incidence (3 %). As far as the spoilage due to fruitfly, discolouration and deformation were concerned, there was no significant difference among treatments. Two varieties, *Prior* and *Muvandan* showed similar trends in all attributes studied except in ripening pattern. The ripening process was faster in *Muvandan* compared to *Prior*.

Among various postharvest treatments, soaking fruits in warm water (52 °C) containing carbendazim 0.05 per cent showed minimum PLW (15.1 %) compared to 17.5 per cent in control. *Muvandan* and *Olour* showed higher mean PLW. The variety *Prior* recorded minimum spoilage of 14.17 per cent while it was maximum in *Bangalora* (31.6 %). Postharvest spoilage was minimum in fruits soaked in warm water (52 °C) containing Carbendazim (0.05 %). It was maximum in control (35.8 %).

Shrinkage was minimum when warm water treatments were used (0.6 %) compared to control (5.0 %). Postharvest treatments had a significant effect on discolouration of fruits during postharvest storage. Discolouration was minimum in *Prior* (2.0 %) and maximum in *Neelum* (7.0 %). The minimum number of discoloured fruits (0.6 %) were found in T3 (warm water at 52 °C + 0.05 % Carbendazim).

Disease incidence was minimum when hot water containing

Carbendazim was used for postharvest treatment (0.6 %). Important causal organisms identified were *Colletotrichum gloeosporioides*, *Aspergillus niger*, *Aspergillus flavus*, *Aspergillus aculeatus*, *Botryodiplodia theobromae*, *Rhizopus sp* and *Penicillium sp*.

Postharvest treatments did not show any effect on spoilage due to fruitfly. Variety *Neelum* was relatively free from fruitfly infestation. It was maximum in *Bangalora* (17.3 %).

Rate of ripening was faster when warm water treatments were used. Warm water treatments (T2 and T3) also showed a better colour development. Treatment with Carbendazim left high levels of residues in the fruit pulp.

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HARVEST AND POSTHARVEST LOSSES IN MANGO (*Mangifera indica* L.) AND ITS MANAGEMENT

BY

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ABSTRACT OF A THESIS

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ABSTRACT

The present investigations on Harvest and postharvest losses in mango (*Mangifera indica* L.) and its management were conducted in the Department of Processing Technology, College of Horticulture, Vellanikkara, Thrissur, Kerala.

Five mango varieties, viz; *Prior, Neelum, Bangalora, Olour* and *Muvandan* were used for the study. Harvested fruits having a specific gravity between 1.00 and 1.05 were used. The fruit weight ranged from 177 g (*Muvandan*) to 439 g (*Bangalora*). The fruit length and circumference was maximum for *Bangalora*(13.3 cm and 26 cm respectively). Shape index was maximum for *Bangalora* (2.11) while it was minimum in *Muvandan* (1.16) . *Neelum* had the thickest skin (0.94 mm). *Bangalora* had the thinnest skin (0.34 mm). Flesh firmness ranged from 0.58 Kg/cm^2 in *Bangalora* to 0.73 Kg/cm^2 in *Neelum* at the ripe stage. Total sugar content varied between 14.4 per cent (*Neelum*) and 9.5 per cent (*Muvandan* and *Bangalora*). *Neelum* recorded highest reducing and non-reducing sugar content (3.3 % and 11.1 % respectively). Total soluble solids ranged between 19 degree brix in *Neelum* and 13 degree brix in *Muvandan*. Acidity was the highest in *Muvandan* (0.24 %) and the lowest in *Prior* (0.11 %).

Among different mango harvesters designed and fabricated, KAU mango harvester III Was found superior to the traditional harvester, in terms of harvesting efficiency, retention of pedicel and collection of fruits in the net. The extent of spoilage of fruits was less when this harvester was used. The

recovery of marketable fruits ranged from 68.0 per cent in *Bangalora* to 75.75 per cent in *Neelum*. Padding given for collection baskets did not influence postharvest characters.

Among the different types of containers used, packing density was maximum when cardboard box was used, followed by rectangular plastic crate. Studies on the effect of containers and transportation on postharvest losses of mango showed that handling of mangoes in rectangular plastic crate was superior in terms of number of marketable fruits (89.0 %), minimum Physiological loss in weight (8.6 %) and less disease incidence (3.0 %).

Among various postharvest treatments, dipping of fruits in warm water (52 °C) containing Carbendazim 0.05 per cent showed minimum PLW, less spoilage in terms of shrinkage, discolouration and disease incidence. Important causal organisms identified were *Colletotrichum gloeosporioides, Aspergillus niger, Aspergillus flavus, Aspergillus aculeatus, Botryodiplodia theobromae, Rhizopus sp* and *Penicillium sp*. Postharvest treatments did not show any effect on spoilage due to fruitflies. Rate of ripening was faster when warm water treatments were used. Warm water treatments gave a better colour for the fruit. Treatment with Carbendazim left high levels of residues in the fruit pulp.