ABSTRACT
Two experiments were conducted on mango in order to improve its quality during postharvest supply chain. In first experiment, effect of pre- and post-transport application of fungicide (Carbendazim @ 400g/100L) along with hot water treatment (48°C – 60min) on mango fruit cv. Sindhri was determined after 25 days of storage at 13°C±2°C and 85-90% RH. It was found that pre-transport application of fungicide do have significant effect on reducing postharvest diseases, skin injuries and blemishes as compared to postharvest treatments. And when pre-transport application of fungicide is accompanied with HWT (48°C – 60min.), it additionally reduced disease development (9.3%) during storage as compared to control (12.2%). Bio-chemical analysis revealed non-significant effects of treatment except total titrable acidity which was higher (0.23%) in fruit treated with fungicide and hot water treatment at post-transport stage, while in all other treatments, this parameter was statistically at par with each other. In second experiment, fruits were transported in various packaging material (wooden crates, corrugated cardboard boxes and plastic containers) and it was observed that fruits which were packed in wooden crates showed minimum broken pedicels (9.5%), while fruit packed in cardboard boxes showed least sapburn percentage (15.5%). It was also found that packaging material has significant effect on production of soft fruits. Minimum percentage of soft fruits was observed in cardboard packed fruits (20.8%), while maximum in fruits packed in wooden crates (37.4%).

KEYWORDS: Storage, ripening, anthracnose, stem-end rot, packaging material,

INTRODUCTION
Mango (Mangifera indica L.) is the second largest fruit being produced in Pakistan and has become an integral part of history and culture of this country (Asif et al., 2002). With over 1.3 million tons of annual production, Pakistan is world’s fifth largest producer of mango after India, China, Thailand, and Mexico (FAO, 2006). Mango is admired all over the world for its attractive colours, savouring smell, delightful taste and high nutritive value. A worldwide increase in the demand of fresh mango fruit has increased the prospect for the producing countries. Like other fresh commodities, the market potential of mango is also linked with its quality. Skin colour and appearance are the most important features to attract the consumers. Fruit free of wrinkles, blemishes and other skin disorders give pleasing appearance to the commodity. To achieve such produce, better post harvest management not only enhances its cosmetic look and fruit quality but also help to extend storage life of fruit to be exported to international markets (Anwar and Malik, 2007).
Fruit infection with disease inoculum starts right from the field which causes severe post harvest losses especially during extended storage. Anthracnose (Colletotrichum gloeosporioides and occasionally C. acutatum) (Simmonds, 1965) and stem-end rot (Lasiodiplodia theobromae) (Lim & Kho, 1985; Prakash & Srivastava, 1987) of mango fruit are two of the major post harvest diseases. Controls of post harvest diseases in mango is currently achieved by a combination of pre harvest and post harvest fungicide application, orchard hygiene and post harvest temperature management (Ledger, 2004; Prusky et al., 2004; McMillian, 1984). For post harvest disease control, Carbendazim (Methyl-2-ylcarbamate) is an approved fungicide in Australia and some other countries (Malik, 2005). Hot water treatment (HWT) is another effective non-chemical method to control post harvest diseases (Coates et al., 1993; Coates & Johnson, 1993; Spalding & Reeder, 1986), which is now-a-days becoming very important post harvest disinfections treatment for fruit flies, as entailed by importing countries like China (48°C – 60min). However, the efficacy of HWT on disease control, storage life and quality of commercial mango cultivars of Pakistan is yet to be tested. Packaging material also affects the cosmetic look and quality of fruit. In Pakistan, wooden crates are the conventional and most widely used packaging type. Corrugated cardboard boxes are preferred, if fruit are to be exported to international markets. In different packaging types, the extent of physical damage to fruit might be different which is yet to be explored with respect to logistic chain of Pakistan.

Keeping the above points, two experiments were conducted to determine the effect of fungicide application on mangoes in the way that whether it is better to apply fungicide at pre-transport or post-transport stage and what would be combined effects of fungicide application and HWT on fruits’ physical and bio-chemical features. Moreover, extent of physical damage caused by packaging material during transport was also determined.

**MATERIALS AND METHODS**

Research experiments were conducted during 2005. Two experiments were conducted separately but for both the experiments, mango fruits were sourced from a commercial orchard located in Kot Addu, Punjab, Pakistan (70°58'E & 30°28'N; 433m Altitude). Methodology of each experiment is given as under:

In first experiment, mature green mango fruit cv. Sindhri, with approximate total soluble solids (TSS) of 7.0°Brix, were harvested (15 th July 2005) along with 4-5cm stalks and transported carefully from the field to the packing shed in plastic containers. Fruits with injuries, disease/insect damage and those that had soft nose were removed. Pedicels were cut back and fruits were graded according to size. Fruits were randomly divided into five experimental lots. Fungicide (Carbendazim 50%WP, Shandong Huayang Pesticide Chemical, China) was applied @ 40g/100L both at pre-transport or post-transport stage followed by hot water treatment (48°C – 60min.). Fruit were packed in corrugated cardboard boxes and transported to Karachi (33 hours) in a non-refrigerated truck. Post-transport fungicide and hot water treatment facility was availed from Quest Pack Pakistan Pvt Ltd, Karachi. Before processing, fruit were again checked for quality and uniformity, and those with damage were removed. Fungicide and hot water treatments (HWT) were applied the other two fruit lots. During HWT, fruit core temperature was measured using digital thermometer with an electronic probe. In this way, following treatments were designed,

- **T₀**: Wash only (no treatment)
- **T₁**: Pre-transport fungicide + Wash only
- **T₂**: Pre-transport fungicide + HWT (48°C – 60min.)
- **T₃**: Post-transport fungicide + Wash only
- **T₄**: Post-transport fungicide + HWT (48°C – 60min.)

After processing, fruit were again packed in corrugated cardboard boxes and stored (13°C±2°C & 85-90% RH) at MDS commercial storage facility. After 25 days, fruit were removed and transported by air from Karachi to Faisalabad, for quality evaluation at the Institute of Horticultural Sciences, University of Agriculture, Faisalabad. Fruit were ripened at 24°C±2°C and 23±2% RH. Some observations on fruit quality were also made during storage.
To record ripening rate, fruit softening was observed using a subjective assessment of whether the mango yielded to thumb pressure (1: very hard to 5: over ripe). Eating soft fruit were given 4 scores. Peel colour development was assessed using rating scale of 1 to 5 (where 1 – fully green & 5 – fully yellow). Fresh fruit weight loss (FWL) was measured simultaneously, while data on diseased fruit was recorded on percent basis. Organoleptic properties (aroma, flavour, pulp, taste & texture) were observed using Hedonic scale method of Peryam and Pilgrim (1957). Fruit were presented to a 10 member taste panel. The panelists assessed fruit samples and rated for general acceptability (1: dislike extremely to 9: like extremely). During laboratory tests, total titratable acidity (TTA) was determined by method given by Hortwitz (1960). The method described by Ruck (1969) was used for estimation of ascorbic acid contents. TSS was measured by digital refractometer (Atago Co. Ltd., RX-5000, Japan). To estimate the sugars, the method of Lane and Eyon (1923) as described by Hortwitz (1960) was used. Total carotenoids were measured using spectrophotometer (6405 UV/VIS, Jenway Ltd., Essex, England) at absorbance frequency of 436nm (Lalel et al., 2003).

In second experiment, mature green fruit cv. Samar Bahisht Chaunsa were harvested (5th August 2005) with 4-5cm stalks at approximate TSS of 9.5°Brix. As in first experiment, fruits were graded in the same way but 3 inch pedicel was left with the fruit to determine packaging effect during transit. Fruit was randomly divided and packed as follow:

- T1: Card board boxes
- T2: Wooden crates
- T3: Open Top Plastic container (Loose packaging)

Transportation method was used same as mentioned in first experiment. Data regarding physical damage to fruit was recorded immediately after the fruit reached its destination at Karachi, Pakistan. Complete randomized design (CRD) was used in both experiments. The experimental data were subjected to analysis of variance (ANOVA) using Genstat Release 8.2 (Lawes Agricultural trust, Rothmsted Experimental Station, UK). Within the analysis of variance, the effects of different treatments was assessed. Least significant differences (Fisher’s protected LSD) was calculated following significant F test (p=0.05). All assumptions of analysis were checked to ensure validity.

RESULTS AND DISCUSSION

Experiment 1: Effect of pre- and Post-transport fungicide and hot water treatment on mango fruit quality

After 25 day of storage, when fruit were placed for ripening, it took 5 days for all treatments to reach eatable ripening stage with respect of development in fruit peel colour and softness. So, non-significant difference was observed among treatment regarding fruit peel colour and softness development. Data on stem-end rot showed significant differences among treatments. Fruit applied with fungicide along with hot water treatment at pre-transport stage (T2) produced least number of stem-end rot (1.9%), whereas, highest percentage of such fruit was recorded in untread fruits (wash only) i.e. 12.5%. These results are in line with earlier findings of Muller and Burt (1989) who controlled stem-end rot in harvested mango fruit upto 4 weeks of storage at 13°C after fungicidal dipping of 0.025% Prochloraz or 0.05% Benomyl. Post-transport treatment of fruit with fungicide and HWT (T4), though reduced the infection percentage (3.9%), but could not prove to be as much effective as T2. This could be due to the reason that in T2, fungicide was applied before transport which effectively killed the inoculum sourced from the field. Moreover, as organisms infect the fruit through skin injuries, causing stem-end and lateral rots (Snowdon, 1990; Johnson & Coates, 1993), such application method also reduces pathogen invasion chances through skin injuries developed during transport after fruit abrasion with packaging material and fruit itself.

There was no significant difference in FWL among treatments. Bio-chemical parameters were found to be non-significant except TTA. Highest TTA (0.23%) was found in T3 whereas, all other treatments including control gave values statistically at par with each other (Table 1). No significant differences among different treatments were found regarding organoleptic characteristics (Table 2).
Experiment 2: Effect of Packaging on mango fruit during transit
Data regarding percentage of fruits with physically pressure, broken pedicels, sapburn and softness showed significant results (Figure 2). Fruits which were packed in cardboard boxes (T₁) and open plastic containers (T₃) showed no physical pressure effect while fruits in wooden crates showed significantly higher percentage (8.53%) compared with other two. This was due to forcefully compact packing of fruit in wooden crates. Such practice is common in Pakistan which should be avoided, if wooden crate is to be used.

The highest percentage of fruits with broken pedicels was found in fruit packed in plastic containers (T₂, 26.7%). Fruits which were packed in wooden crates (T₁) showed minimum percentage (9.5%) while fruits packed in cardboard showed medium level of pedicel breakage (15%). Minimum percentage of fruit injured with sap exudation was found in cardboard packaging (15.5%), while statistically significant sapburn was found in plastic containers (T₃, 75%). Fruits packed in wooden crates (T₁) showed medium percentage of such fruits (32.9%). Soft fruits were separated from the different packings and percentage was calculate. It was found that packaging material has significant effect on production of soft fruits. Minimum percentage of soft fruits was observed in cardboard box packed fruits (T₁, 20.8%) while maximum in fruits packed in wooden crates (T₂, 37.4%).

CONCLUSION
It is important to consider using pre-transport application of fungicides to reduce postharvest incidence of mango fruit diseases, especially in areas where disease prevalence in orchard is high. For mango transport, cardboard box packaging proved to be better over other packaging material in terms of reducing injuries however, the quality (strength) of cardboard boxes must be of main consideration.

Acknowledgements
Pakistan Horticulture Development & Export Board (PHDEB) funded and supported this research project, which is acknowledged thankfully.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Peel Colour Score</th>
<th>Fruit Softness Score</th>
<th>FWL (%)</th>
<th>TSS (°Brix)</th>
<th>TTA (%)</th>
<th>Ascorbic Acid (mg/100ml)</th>
<th>Total Carotenoids (µg/g)</th>
<th>Sugars (%)</th>
<th>RS</th>
<th>NR</th>
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<tbody>
<tr>
<td>T₀</td>
<td>3.34</td>
<td>3.34</td>
<td>8.23</td>
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<td>70.56</td>
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<tr>
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</table>

TS: Total sugars; RS: Reducing sugars; NR: Non-reducing sugars

Table-2: Effect pre- and post-transport application of fungicide and hot water treatment on organoleptic rating of mango fruit

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Pulp Colour</th>
<th>Taste</th>
<th>Flavor</th>
<th>Texture</th>
<th>Aroma</th>
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<tr>
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<td>6.49</td>
<td>6.11</td>
<td>6.11</td>
<td>6.07</td>
</tr>
<tr>
<td>LSD (p&gt;0.05)</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>
Figure 1: Fruit infected with stem-end rot after 25 days of storage.

Figure 2: Effect of packaging material on physical characteristics of fruit during transit.

REFERENCES


