CHAPTER 7
STUDY ON HARVESTING CONSIDERATIONS IN JATROPHA

Introduction

Previous study in Chapter 4 argue that main reason of poor harvesting in this crop is actually due to variability in the reproductive variables. After study the oil content (Chapter 5) and effect of postharvest handling (Chapter 6) to extractable oil yield, three harvestable groups of individual jatropha fruits has been recommended in this dissertation. Recommended harvestable fruit group one is dry fruit only because according to the results in previous study, the fresh kernels from this fruit has the highest extracted oil yield (Figure 16). Recommended harvestable fruit group two is a mixture of ripe, black and dry fruits. This group of fruits if dried prior to extraction showed similar extracted oil yield (Figure 20). Recommended harvestable fruit group three is a mixture of mature, ripe, black and dry fruits. This third recommendation was based on the previous study in Chapter 6. The mature green was included because the fruits, if ripe and senescent off the tree will give significantly higher extracted oil yield (Figure 23).

The harvestable fruit number three recommended has an advantage when compared with the other recommended harvestable fruit groups because harvesting physiological mature green fruits could increase harvestable fruit volume and directly decrease the number of harvesting visits required. However, the advantages of the harvestable fruit group number three are implied depending on the capability of harvesters to pick the right physiological mature green fruits in the field. Therefore, one the objectives in this chapter is to determine the individual fruits’ and bunches’ harvesting indicators. To indicate a specific big harvest in a year, the experiment was designed to monitor the trend of the harvestable groups throughout the year 2010. The character of fall fruit was also determined to indicate the effect of delay on harvesting on percentage of fall fruits. It was implied that harvesting in a jatropha plantation could be scheduled and thus directly reduce harvesting costs.
Materials and Methods

Source of jatropha fruits and trees

The sources of jatropha fruits and trees for this study were from the main sample source described in Chapter 3.

Test sample for study on individual fruit harvesting characters

Three individual fruits were harvested for characterization for this experiment. These included small sized immature young light green fruits, full sized mature dark green fruits and mature green with trace of yellow. Results from previous study on the fruit size (Table 2) were used when determining the normal size of mature fruits. Not less than a hundred fruits of each predetermined fruit group were harvested randomly from different trees in the plot and were left to ripen naturally without any ripening agent under room temperature (28.5±3°C). Ripening percentages were measured every 6, 12, 24, 36 and 114 hours after harvest.

Test samples for study on fruit bunches’ harvesting characteristics

Five fruit bunches’ characteristics were predetermined for the bunch harvest indicator study. For each bunch this included (1) 100% of fruits still mature green, (2) more than 80% of fruits still green, (3) 70 – 80% of fruits still green, (4) 50 - 70% of fruits still green and (5) less than 50% of fruits still green. Not less than a hundred fruits of each predetermined fruit bunch type were harvested randomly from different trees in the plot and were left to ripen naturally without any ripening agent under room temperature (28.5±3°C). Ripening percentages were measured every 6, 12, 24, 36 and 114 hours after harvest. Ripening percentages were measured as described in Chapter 3.
Test samples for study on fall fruit on the farm

Twenty five fruit bunches which had at least eight fruits per bunch and at least one fruit at yellow maturity stage. The samples were randomly selected in the pilot. The number of fall fruits was measured every three days for 60 days.

Test sample for study on oil extracted yield from non-fall fruits

During the dry season in the pilot plot, several levels of dry fruit bunches still attached to the parent plant from bottom to tip of any main branches were observed. These non-fall fruits were collected for oil extraction yield analysis according to their level of attachment on the branch. Five levels of bunch attachment were identified and the fruits collected for this study. Preparation of the samples prior to oil extraction analysis was based on previous study in Chapter 6.

Test sample for study on harvestable fruit production

Ten trees were randomly selected in the pilot project for this study. Total fruits according to maturity stage were measured every month throughout the year in 2010. The fruit maturity stages were the general five fruit maturity index as described in Chapter 3. The total fruits measured were then grouped into predetermined harvestable groups. The harvestable groups of fruits were only dry fruits (harvestable group one), dry and yellow fruits (harvestable group two) and dry, yellow and mature green fruits (harvestable group three).

Measurement of ripening percentages

The ripening percentage was measured according to the method described in Chapter 3.
Measurement of fall fruit percentages

The percentage of fall fruit was measured by dividing the total available fruits during observation day with total fruits number during first day of observation and then multiplied by hundred.

Measurement of CJO content

The CJO content was analyzed chemically according to the method described in Chapter 3 and the CJO percentage calculated according to the calculation described in Chapter 3.

Experimental design and statistical analysis

Experimental design of all four studies in this chapter is indicated from explanation of each test sample in study. Randomized complete design was the experimental design for all experiments with each having two sources of variance while there was only one source of variance in the study on harvestable fruit production. Data collected was analyzed using one way ANOVA and the differences between means were calculated from the error bar at 5%.

Results and Discussion

Harvesting indicator for individual jatropha fruits

The results showed that the harvested mature green with trace of yellow fruits have higher ripening percentage compared to harvested mature green and immature fruits after 24 hours of storage (Table 5). The ripening percentage in the harvested mature green with trace of yellow fruit was 91% compared to only 5 and 25% from harvested immature and mature green fruits respectively. The harvested mature green with trace of yellow fruit also showed 100% senescence after final day of
observation. The senescence percentage from harvested immature and mature green fruits during the final days of observation was only 10 and 65% respectively. These results indicate harvested mature green with trace of yellow fruit as the best individual fruit harvesting indicator.

Percentage of unripe fruits from harvested immature green fruits were still more than 80% during the final days in storage compared to less than 40% among the harvested mature green fruits. These results could indicate a difficulty in differentiating between immature and mature fruits with the naked eyes during harvesting. This problem has been projected earlier while analyzing previous data on fruit color in Chapter 5. The previous data showed that the difference in color hue angle value between immature and mature fruits was not significantly different. The previous data was also showed that other physical characters observed in the study, such as size, firmness and fresh weight were also not significantly different between harvested immature green and mature green fruits.

<table>
<thead>
<tr>
<th>Ripening Storage (hours)</th>
<th>Immature</th>
<th>Mature Green</th>
<th>Trace of Yellow</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unripe (%)</td>
<td>Ripe (%)</td>
<td>Senescent (%)</td>
</tr>
<tr>
<td></td>
<td>Unripe (%)</td>
<td>Ripe (%)</td>
<td>Senescent (%)</td>
</tr>
<tr>
<td></td>
<td>Unripe (%)</td>
<td>Ripe (%)</td>
<td>Senescent (%)</td>
</tr>
<tr>
<td>0</td>
<td>100a</td>
<td>0c</td>
<td>0b</td>
</tr>
<tr>
<td>6</td>
<td>100a</td>
<td>0c</td>
<td>0b</td>
</tr>
<tr>
<td>24</td>
<td>95a</td>
<td>5b</td>
<td>0b</td>
</tr>
<tr>
<td>36</td>
<td>90ab</td>
<td>10a</td>
<td>0b</td>
</tr>
<tr>
<td>114</td>
<td>85a</td>
<td>5a</td>
<td>10a</td>
</tr>
</tbody>
</table>

* = significant at p<0.05
y = different letters within a row denote significant difference by using DMRT at p<0.05

High percentage of unripe fruits among the harvested immature fruits was expected because it has been long known that harvested fruits which have not reached development and maturation stage as yet will not ripen off the tree (Wills et al. 1989). The research team confirmed that development and maturation of fruit was completed only when attached to the plant, but ripening and senescence may proceed on or off
the plant. The percentages of ripe and senescent fruits among the mature fruits were considerably higher as compared to the immature fruit. This indicates potential to improve the percentage through several ripening enhancers. However, there is limited information related to such treatment in the reference list on jatropha.

**Harvesting indicator for jatropha fruit bunches**

The results showed that increasing number of ripe individual fruits per bunch will hasten the ripening and senescence process (Table 6). Harvested bunch with 100% green character showed high percentage of unripe fruits at the final day of storage. The other harvested bunches’ characters had no unripe fruits after three or four days of storage. These results indicate maximum 80% green fruits per bunch as the best bunch harvesting indicator for jatropha. The 80% green fruits per bunch are equal to minimum 10 to 20% of ripe yellow fruits per bunch. So if there are one or two individual ripe yellow fruits per bunch from ten fruits per bunch, this bunch is recommended to be harvested. As the numbers of fruits per bunch are not uniform, (Figure 18) interpretation on the percentage should be modified accordingly.

Recommendation of bunch harvesting indicator in this study was not in agreement with any previous bunch harvesting recommendation. Priyanto (2007) recommended harvesting bunches when 75% of the fruits are ripe. Nurchholis and Sumarsih (2007) suggested when 60-70% was ripe while Hambali et al. (2008) recommended harvesting when 50% are ripe. The suggested bunch harvesting indicator in this study implies increased harvesting volume in a single harvesting visit and directly decreases the number of harvesting visits required.

Potential to harvest bunches with 100% green fruits were shown in this experiment. The balance of 35% unripe fruits at the final day of observation could be ripened by extending the ripening storage duration. The ripening percentages could also be higher if a ripening enhancer is introduced. As there is no information related to the effect of ripening treatments on this crop, future experiments are suggested. The harvesting volume per harvesting visit will be higher if the 100% mature green
fruit bunches are to be harvested. The effects of several ripening enhancers are reported in Chapter 8 in this dissertation.

Table 6 A change in percentage of ripe, unripe and senescent fruits from harvested five different fruit bunch characters during storage.

<table>
<thead>
<tr>
<th>Fruits bunches characters</th>
<th>Maturity Stages</th>
<th>Storage Duration (days)</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>100% Green</td>
<td>Unripe (%)</td>
<td>100a</td>
<td>92a</td>
</tr>
<tr>
<td></td>
<td>Ripe (%)</td>
<td>0e</td>
<td>8d</td>
</tr>
<tr>
<td></td>
<td>Senescent (%)</td>
<td>0d</td>
<td>0d</td>
</tr>
<tr>
<td>&gt;80% Green</td>
<td>Unripe (%)</td>
<td>84a</td>
<td>32b</td>
</tr>
<tr>
<td></td>
<td>Ripe (%)</td>
<td>16d</td>
<td>68b</td>
</tr>
<tr>
<td></td>
<td>Senescent (%)</td>
<td>0e</td>
<td>0e</td>
</tr>
<tr>
<td>70-80% Green</td>
<td>Unripe (%)</td>
<td>70a</td>
<td>16b</td>
</tr>
<tr>
<td></td>
<td>Ripe (%)</td>
<td>30d</td>
<td>79ab</td>
</tr>
<tr>
<td></td>
<td>Senescent (%)</td>
<td>0f</td>
<td>4e</td>
</tr>
<tr>
<td>50-70% Green</td>
<td>Unripe (%)</td>
<td>56a</td>
<td>16b</td>
</tr>
<tr>
<td></td>
<td>Ripe (%)</td>
<td>44d</td>
<td>75ab</td>
</tr>
<tr>
<td></td>
<td>Senescent (%)</td>
<td>0f</td>
<td>9e</td>
</tr>
<tr>
<td>&lt;50% Green</td>
<td>Unripe (%)</td>
<td>43a</td>
<td>8b</td>
</tr>
<tr>
<td></td>
<td>Ripe (%)</td>
<td>57c</td>
<td>90a</td>
</tr>
<tr>
<td></td>
<td>Senescent (%)</td>
<td>0e</td>
<td>2d</td>
</tr>
</tbody>
</table>

* = significant at p<0.05  
γ = different letters within a row denote significant difference by using DMRT at p<0.05

Harvestable fruit production throughout the year

Jatropha planted in the pilot project was fruiting throughout the year in 2010 (Figure 26). Irrespective of harvestable fruit group, the results showed three maximum and minimum harvestable fruits per year. The maximum was in March, August and December while the minimum was in January, May and October. High percentage of fruits from harvestable group C was expected because it included the mature green fruits. There were no mature green fruits in harvestable group A and B. Low percentage of fruits in the harvestable group A was due to only harvesting dry fruits. Results of this study confirm a suggestion by Carels (2009) to have three harvesting times in a year for jatropha. The researcher implied that because flowering
and fruiting in jatropha occurred four times a year the harvesting should be done three times a year.

The percentage of harvestable fruits in this study should be converted to real production and this can be done by adopting the fruit production data shown in Figure 7. The fruit production data showed that the peak of fruit production is in June and July (Figure 7). By adopting the information from this harvestable group data, peak production is indicated to be in July. The amount of fruits was similar in June and July but due to the high number of immature fruits in June and low such numbers in July, thus peak harvesting is confirmed to be in July. The percentage of immature fruits in June and July was 50 and 20% respectively. Lowest immature fruit
percentage was actually in August but because the total fruit in that month was significantly lower compared with that in July, thus August was not the month with high volume of harvestable fruits.

Obviously, low percentage of immature fruits could not indicate optimum harvesting volume and this indicated that mechanical harvesting could become more challenging. Reduction in total fruits from July to September was observed due to natural occurrence of fall fruits. Thus it indicates the importance of understanding the occurrence and to recommend minimum delay in harvesting to reduce loss of fruits due to fall fruits. The following subsection in this chapter is the result of observation of the occurrence.

*all fruits during delay in harvesting*

The results showed a logarithmic trend (R²=0.94) in fall fruits with delay in harvesting (Figure 27). Delay of 1, 2, 3 and 4 weeks will cause about 38, 45, 55 and 70% of fall fruits respectively. After two months delay in harvesting, about 95% of fruits fall and this is the plateau of the occurrence. Results of this study highlighted the importance of reducing delay in harvesting. This result was also not agreement with the three harvesting times per year recommended by Carels (2009) for this crop.

Fall fruits which normally occur during senescence phase indicate the limit of minimum delay in harvesting for this crop. Study in Chapter 4 showed that number of days required to reach wet black senescence from fruit set was 34 days on average (Table 1). However, only about 6 days on average was recorded to reach wet black senescence from mature green stage. Thus this study indicates that first harvest after first flowering should be done after 34 days and about 6 days is suggested as the interval harvesting visit time after first flowering to avoid falling fruits. Maximum and minimum days required by fruit at mature green maturity stage to reach black senescent maturity stage was 9 and 3 days respectively (Table 1).
Figure 2.7 Percentage of *J. curcas* L. Luanti accession fall fruits during delay in harvesting (day). Different legends indicate the different observed bunches and solid lines indicate the average logarithmic trend ($R^2 = 0.9416$).

As increase in the percentage of fall fruits increased with delay in harvesting and most of the occurrences were during the wet black senescence stage, the findings from this study are not in agreement with the recommendation of harvesting at dry senescence stage (Appendix 9). This study implies that if the senesced fruits did not fall for a period of time then the harvesting visit could be delayed for that period of time. This approach is suggested as an important selection character to reduce harvesting problems in this crop. However, there is limited information on this characteristic in literature and thus future research is suggested.

The percentage of fall fruit in this study was seen to be very much affected by the agro-climate especially rainfall and wind. All organisms will eventually die
Environmental and other factors that accelerate senescence and abscission (e.g. mineral deficiency, drought, low light and lack of pollination) have been well documented (Keys 1991). During the dry season at the plot, up to five levels of dry fruit bunches were still attached on the same branch. However, only one, two or three levels of dry fruits bunch were still attached on the same branch during normal or rainy season. The related important question on this character will be the extracted oil yields from different levels of dry fruit bunch development in the same tree. The following subsection in this chapter discusses the extracted oil yield. Realistically, occurrence of fall fruit is a natural process. This is called abscission and it is seen as an effort by the jatropha tree to remove senescent fruits.

**Extracted oil yield from non-fall fruits**

Interestingly, the extracted oil yield from the different fruits bunches from the same branch were significantly different (Figure 28). The extracted oil yield (chemical extraction), was significantly high in fruit bunch number two from bottom, at about 60% compared to only about 55% from the other bunches. The highest oil yield observed in this case is identical to similar extraction of those ripened off the tree. This result indicates the benefit of harvesting during the dry season.

High extracted oil yield in this sample was expected because the collection of samples for this experiment was during the dry season. High extracted oil yield was also reported by Santoso (2008) during the dry season compared to during the wet season. No reason was found in the present literature on why high oil content does during dry season. The reason could be due to changes on the oil body during dry season. The oil body which is mostly coated with a protein derivative such as olesin could be in inactive condition so that oil becomes easily released during extraction.

On the other hand, extracted oil yield from this study showed the benefit of having multiple dry fruit bunches that were still attached on the tree. However, due to the
occurrence of fall fruits this multiple dry fruit bunches are observed to be in low numbers in the field.

![Figure 28](image-url) Percentage of extracted oil yield (w.b) from different fruit bunches from the same branch. Horizontal bars indicated error bars of measurements at 5%.

The mechanism of abscission-disperse in *J. curcas* L. fruit and seed implied that it does not follow the normal seed dispersal method of other legume crops. The separation between fruit and seed was seen to be not completed and this implies that there is potential to use this character as selection criteria of jatropha accession. In general, the occurrence was reported to be a species-dependent mechanism (Addicott 1982). Jatropha accession without this character will give the benefit of low risk of seed loss during delay in harvesting. However, there is limited information on the character in jatropha cited in the literature list.

**Extracted oil yield from fall fruits**

Extracted oil yield for fall fruits was significantly lower compared with the off-tree senescence and on-tree dry fruits (Figure 29). Extracted oil yield from fall fruits was only about 40% compared to about 50% and 60% from off-tree senescence and on-tree dry fruits respectively. This result indicates the disadvantage of fall fruits and why they should be avoided. Reduction in extracted oil yield was expected as the
Fall seeds are preparing for germination. The oil might be converted to chemicals required for the germination processes (Kornberg and Beevers (1957)).

![Diagram](image-url)

**Figure 29** The percentages of extracted oil yield (w.b) from different harvested fruit conditions (off-tree senescence (n=3), on-tree dry (n=5) and fall fruits (n=2)). Verticals bars indicate the error bar of measurements at 5%.

Low extracted oil yield from fall fruit in this study could also be due to the variation in samples. Most of the collected seed might already have fallen for a certain period of time and the fruits might be from wet black senescence or from dry senescent fruit. There may be different extracted oil yields according to prolonged duration of fall, variation of sample conditions and environmental conditions enhancing the occurrence. For example, results from a previous experiment in this chapter showed variations in the extracted oil yield from different dry samples from the same branch. This indicates the requirement for future research to identify the rate of oil content reduction during wide post falling occurrences. The information is important to provide an alternative to solve the problem related to the unavoidable fall fruits in this crop. If the rate of reduction is low than harvesting visits could be
reduced. Calculation of harvesting costs between reductions in oil content should compare picking costs for economic viability decision making.

Hand picking of fall fruit and seed as harvesting approaches for this crop was proposed when the basic mechanical harvester are not available (Henning 2003). The approach is by hitting the dry fruit with a stick. The picker then has to collect the fall fruits. The report implied that the best way to harvest jatropha fruits is by using a long wooden stick with a circular comb with a cotton bag at one end. With this tool the dry fruits can be picked from the trees, the fruits fall into the bag and do not have to be collected on the ground. However, the picking cost for jatropha is high and thus several mechanical harvesting techniques have been reported. Placing a net under the fruit tree is commonly used for many fruits such as olive, mango and durian. Many shake-and-catch systems for processing apples have been evaluated (Markwardt et al. 1969). Besides manual shaking, chemical desiccation was reported as an alternative harvesting method in rapeseed (Pouzet, 1995) and cuphea (Johnson et al. 2005). According to Bowerman (1984) it can be a way of limiting seed loss and improving seed quality. A Jatropha harvester called OxboKorvan 900 which is based on blueberry harvesting technology could be the only jatropha mechanical harvester available but no scientific data has been reported on its efficiency. Thus, future research on harvesting technology for this crop is needed.

**Conclusion**

The study has identified individual and fruit bunch harvesting indicators for jatropha. Individual fruit character of mature green with trace of yellow was recommended as the individual harvesting indicator. Fruit bunch harvesting indicator was those bunches that has maximum 80% of fruits that were still green in color while the others were advancing in maturity as either yellow ripe or senescent. The trend of harvestable fruit production throughout the year confirms three big harvesting times in a year. Those are in in March, August and December. However,
the data on fall fruit during delay in harvesting suggests that the harvesting times should be repeated within 6 and 17 days to avoid fall fruits. Increase in fall fruits percentage was a function of time and was best described as a logarithmic trend ($R^2=0.94$). The fall trend showed a plateau after about two months of observation indicating occurrences of multiple dry fruit bunches in the same branch. The occurrence was easily observed during the dry season. The extracted oil yield from up to five different levels of dry fruit bunches from the same branch was found to be almost uniform at about 55% except for the samples from the second from bottom of the branch which has about 60% yield. However, the extracted oil yield from fall fruits was found to be significantly low at only about 40%. The disadvantage of fall fruit in this study suggests that the harvesting visits could be prolonged if 100% mature green fruits can ripen off the tree. Thus, the following chapter in this dissertation will discuss the potential of several ripening enhancers for harvested mature green jatropha fruits.