

# Evaluation of pruning waste of *Mangifera indica* var Harumanis cultivated in greenhouse

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**Abstract.** *Mangifera indica* var Harumanis is one of the exotic mango cultivated in Perlis, Malaysia. Its economic importance increased in recent years due to the popularity attributed to its excellent taste, sweet and aromatic fragrance. Supply of Harumanis cannot meet market demand, mainly due to the difficulty of raising the crops and the short and uncertain harvesting seasons. The cultivation of Harumanis in greenhouse was found to be feasible to mitigate the short coming. However, the cultural practices of high density planting in greenhouse calls for regular pruning to meet the desired canopy. Regular strategic pruning produced pruning waste with potential economic value. This research was done to quantify the by-products produced by pruning from three ½ acre greenhouses, under the ecological and climatic of Perlis. The fresh biomass of waste collected during primary, secondary and tertiary pruning were determined. The pruning waste produced was 0.676kg per plant equivalent to 146.4kg per greenhouse during primary and secondary pruning. Estimation of fresh biomass waste produced during floral induction determined by regression was 816 kg per greenhouse with the expected total of 40.8 ton from 50 greenhouses. In view of the fact that the mango plant management practice was from the clean agricultural, the waste can be potentially utilized for green manufacturing. This was the first attempted to quantify pruning waste in mango cultivation before further utilization of pruning waste.

## 1 Introduction

Mango in general is a region based fruit origin, located only in the tropical and subtropical region [1]. It is a woody plant that can have lifespan of more than 100 years. There were more than a thousand mango varieties existed, mostly located in the Pacific region, namely India and Southeast Asian and substantial amount from Central America including Florida. Generally, mango is cultivated in the traditional open field production system. A few selected mango varieties, for instant Irwin, Alphonso, Tommy Atkins, Haden, Kensington, Fiji, Keitt and Fairchild were cultivated in greenhouse to ensure quality and to meet market demand. Annually, mango production occupy the fifth position among tropical fruits, it amount to 23.4 million MT globally [2].

Mango cultivation in greenhouse was pioneered by Japanese during 1980s, in Okinawa [3]. Since then, Japan had 200ha greenhouse mango cultivation, followed by Canary Island, Israel and Egypt [4,5]. Currently, there are four types of successful mango cultivated in greenhouse in Japan,

for instant Irwin, Sensation, Keitt and Haden. The mango production from greenhouse had increased annually. The reasons were greenhouse production system (GHPS) provide protection from undesired weather condition, insects and disease. The technique to promote pollination either by honeybee or regular fruit flies was sufficient for yield target. Other routine mango cultural practices include pruning, flower peduncle hanging, flower peduncle thinning, fruit thinning and hanging, netting and reflector setting, and harvesting. GHPS has successfully produced high quality mango that promote seasonal gift during summer and festival seasons.

The mango phenological development of plant growth consists of vegetative shoot development, reproductive (flowering) shoot development, and fruit growth and development [6]. It is acknowledged that each branch required at least two times of full cycles of vegetative shoot development (these episodes are called flushes, before the branch is ready for reproductive shoot development. Ramirez proposed that neither vegetative, generative nor fruit growth stages of mango are similar throughout mango varieties [6]. Each full cycle consists of several stages either

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leaf maturity, flower development or fruit growth stages. The vegetative shoot development is believed to be influenced by unknown substance, called vegetative promoter, while for reproductive stage it is called florigenic promoter. There were 8 vegetative stages existed, which are resting, vegetative bud break, vegetative bud elongation, early leaf elongation, elongating green leaf, limp red leaf, immature green leaf, and mature green leaf stages. This cycle of vegetative growth can be repeated at least twice per branch, with 8 weeks for complete stages development.

In high density planting of mango tree, pruning strategies throughout vegetative growth cycles become essential to ensure a well balance canopy with high productive terminal shoots. Conventionally, pruning in mango tree do not have specific rule. It is design based on current purpose of farmer, for example pruning in young mango tree is to shape initial canopy structure of the tree [7]. Davenport classified pruning into three types for commercialize mango tree practice, which are tip, formation and severe pruning [8]. Tip pruning is pruning at the terminal stem to promote new branching in mango tree. The nature of new branches very depended on position of pruning location at the terminal stem. The purposes of tip pruning in mango are to stimulate branching flushes into dense canopy structure, to promote synchronizing flush of vegetative growth of several new branches, and to restore productivity of pruned branches. Over the time, branches in mango tree canopy become overcrowded and unproductive. Thus formation pruning is necessary to restore the original number of stem at lower canopy. Once the tree canopy is beyond reach and unmanageable, severe pruning help to rejuvenate these large tree into smaller size with reasonable height and canopy management.

With several cycles of pruning process, enormous pruning waste will be generated. For instant, in Madrid alone pruning waste from 250000 trees were found to be more than 20,000 ton annually [9,10]. Disposal of pruning waste is an issue in modern farming and merit special attention. Various research for value added product and further application have been propose to utilize pruning waste, for example pruning waste as source of biomass for bio-fuel, compost and fertilizer, application in bio-sorption of toxic heavy metals such as lead (II), cadmium (II) and copper(II), and also as value added in animal feedstuff [10,11].

Since pruning waste of fruit farming mostly consisted of leaves, branches, and young shoots, thus high in fiber, active compound ingredients, and nutrients that are high in value should be capitalized. In pruning of young mango tree the main waste in pruning process are leaf at different maturity stage, young shoot, terminal shoot with early bud, and branches. Each of the wasted plant part has different potential value added revenue that can be generated into by-product as income for the mango farming community.

The aims of this research were to evaluate quantitatively the pruning waste at various stage of strategic pruning for Harumanis mango grown in the

greenhouse and to estimate pruning waste that will be generated during pruning for floral induction.

## 2 Methodology

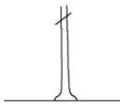
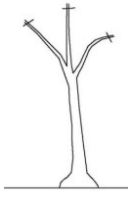
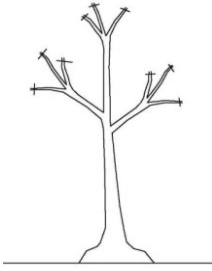
### 2.1 Study site

Evaluations were conducted at *Harumanis(HM)* commercial trials farm in the Institute Sustainable of Agrotechnology (InSAT), Universiti Malaysia Perlis (6°39'12.54"N 100°15'51.02"E) during January to December 2016. Three greenhouses planted with high density HM mango crop, were selected (out of total 50 mango cultivation greenhouses) for evaluation. The half-acre (GH), made of galvanized structure, with dimensions of 84x24.2m and 5m gutter height, and designed to withstand 80km/h wind load. The sides are covered with nylon net of 32 meshes; the roof is of 200micron plastic sheet with ultra-violet blocker. It is equipped with automatic micro-irrigation system designed to apply water as required by individual plants. The greenhouse is a tropical natural ventilated modular type, produce by CMF of France. Each GH can accommodate 216 HM plants and were planted in October to December of 2015, with the standard agronomic practice applied to ensure fertility and uniformity of the plants.

### 2.2 Pruning Waste Determination.

In high density HM mango planting system, strategic pruning is mandatory in order to achieve adequate number productive tertiary branches and later quaternary branches, while controlling the symmetric of canopy. Strategic pruning is a series of pruning at designated position at specific time and done simultaneously for all HM plants in the same greenhouse during the same day. For our in house strategic pruning routine, there were three main reasons involved, which were promoting productive branch at intended position, synchronizing plant/branch/vegetative growth and controlling size of canopy per plant. For example, primary pruning waste was by-product of pruning at main branch to promote primary branch. While secondary pruning waste was pruning at primary branch to promote secondary branch. For complete HM plant vegetative growth, minimum three stages of pruning routine is required, in order to produce tertiary branch. Pruning waste per pruning routine can be determined and quantified. Primary pruning waste is waste of pruning or pruning by-product collected during primary pruning, whilst secondary pruning waste at secondary pruning and tertiary pruning waste is at tertiary pruning routine, as described in Table 1.

**Table 1.** Illustration of the strategic pruning routine and the timing and waste collected for each respective strategic pruning routine.

Strategic Pruning	Primary	Secondary	Tertiary
Pruning Waste	Collection of by-product of primary pruning	Collection of by-product of secondary pruning	Collection of by-product of tertiary pruning
Evaluation			
Position of pruning	Pruning at main branch	Pruning at primary branch	Pruning at secondary branch
Illustration			
Height	45-80cm	80-120cm	100-150cm
Duration	3-4 months after planting	2-3 months after primary pruning	2-3 months after secondary pruning

All pruning waste were collected right after pruning session and quantified. There were two approached to evaluate the quantification of pruning waste of respective strategic pruning routine. At first, pruning waste of individual waste of HM mango plant were quantified from five replications per greenhouses. It was randomly sampled and applied for all three stages of strategic pruning routine. Secondly, all pruning waste collected once in the greenhouse were sampled. However, since pruning routine employed will include the end of branch, thus pruning waste was classified as consisted of young shoot, the different stages of HM leaf and the branches. Each vegetative growth stages of plant part were determined as BCCH scales [6]. Then biomass of each clustered of fresh plant part was determined on site by mass balance.

**2.3 Biomass Determination**

Biomass of pruning waste was determined at the same day of pruning waste collection [12]. Fresh sample of pruning waste were placed in oven for overnight at 70°C. Daily measurement of dried weight was done until the weight of dried samples was constant. The procedures were done in triplicate for each of greenhouse. It was done for all primary, secondary and tertiary pruning waste collection respectively.

**2.4 Regression Analysis**

The pruning waste collections were carried out from strategic pruning during vegetative growth of HM

mango plant in the greenhouse. It involved three stages, which were primary, secondary and tertiary stages of pruning waste collection respectively. While, quaternary pruning waste referred as pruning waste from strategic pruning routine for floral induction, which will be practiced annually, after harvest. The estimation of quaternary pruning waste was determined by extrapolated biomass of fresh weight of pruning waste collected respectively. The plot was developed by Microsoft excel, with three possible regression namely linear, quadratic and exponential regression equation. All waste was determined by average of triplicate and with standard deviation. Variable of the graph was determined by r<sup>2</sup> value.

**3 Result & Discussion**

Complete cycle of strategic pruning for HM plant vegetative growth required at least three pruning routine, thus produced primary, secondary and tertiary pruning wastes. The fresh biomass collections of respective pruning waste of different stages were quantified by sampling from plants replicates and greenhouse (GH) as shown as Table 2. While for Table 3, showed all pruning waste were clustered by stages of vegetative shoot stages [6]. HM Early Bud was young branch that possessed vegetative bud break (VBB) that has the potential use as scion wood for vegetative propagation. HM young shoot was young branch that consisted of vegetative bud at elongation stage (VBE), early leaf elongation stage (ELE), elongating green leaf stage (EGL) and limp red leaf stages (LRL). HM green leaf consisted

of only immature green and matured dark green leaves. HM Young Branch was young green branch that was leftover from the remaining waste.

**Table 2.** The amount of fresh pruning waste (kg) from respective strategic pruning routine.

Strategic Pruning Routine	kg Fresh Biomass/plant ( <i>n</i> =15)	Estimated Biomass per GH		
		kg Fresh Biomass/GH	kg Dry matter/GH	STDev
Primary	0.073±0.003	15.55	5.57	0.19
Secondary	0.200±0.004	44.64	15.9	0.52
Tertiary	0.403±0.008	86.17	30.8	0.61
<b>Total</b>	<b>0.676</b>	<b>146.36</b>	<b>52.27</b>	

**Table 3.** The distribution of different parts of pruning waste (kg) from three Greenhouses.

Pruning Waste	HM Early Bud (number)	HM Young Shoot	kg Fresh Biomass/GH		
			HM Green Leaf	HM Young Branch	Total
Primary	29±1.9	2.06±0.18	8.57±0.21	4.93±0.22	15.55
Secondary	108±2.9	3.79±0.26	28.75±1.20	12.11±0.10	44.64
Tertiary	167±3.7	10.54±0.35	52.91±0.87	22.73±0.62	86.17
<b>Total (kg)</b>	<b>304</b>				<b>146.36</b>

It was observed, pruning waste generated at the end of a branch produced less than one feet of young branch with different vegetative growth stages. Generally, the primary waste consisted of only one young branch waste per plant. Whilst secondary waste produced three less than one feet young branch waste. While third waste produced nine young branch waste. The stages of young branch of waste collected very dependent on plant growth. Total fresh biomass of pruning waste per plant quantified was generally less than one kilogram of waste. However, total waste collected per greenhouse amount to 146kg, which is a very significant amount of waste. Base on the regression correlation the waste produced per GH, can be for casted to be consisted for of approximately less than one feet of 216 young branches from primary waste, while secondary consisted of 648 young branches waste, and 1944 young branches from tertiary wastes. The waste biomass consisted of 15.55kg (10%) from primary waste, 44.64kg (30.5%) from secondary waste, and 86.17kg (58.9%) from tertiary waste.

The estimated waste generated from 50 GH was expected be 7.3 tons; which consisted of varied stages of vegetative shoot. From the clustered sampling, biomass of the major waste produced from

HM green leaf was 90.23kg (61.65%) per GH from complete cycle of strategic pruning routine. Whilst, HM young branch produced was 39.77kg (27.2%) and HM young shoot produced was 16.39kg (11.2%). While, the number of HM early bud waste produced was 29 (13.4%), 108 (16.7%), and 167 (8.59%) respectively from the three stages of pruning.

Despite of the large amount of waste produced during vegetative growth of HM mango plant, it happened only at the very first year of cultivation. However, strategic quaternary pruning will be carried out to design the total number of productive shoot prior to floral induction to promote uniform flowering or during post harvest period. The yearly quaternary pruning will produce quaternary pruning waste. Several regression equations were developed in order to predict yearly quaternary pruning waste, namely linear, quadratic and exponential equations, as shown in Table 4 and Table 5. The value of biomass obtained was determine base on regression equation with time of pruning in weeks (*w*) was after planting the *x*-axis. FBs indicated fresh biomass produced from pruning routine of respective plants and GH, as presented in Table 4. While FB indicated fresh biomass produced from pruning routine of clustered waste respectively, as shown in Table 5.

**Table 4.** Regression equations to predict fresh biomass (FB) obtained from pruning waste of respective strategic pruning routine weeks after planting.

Regression Analysis		R <sup>2</sup>
per plant	FB = 0.011x – 0.063	0.987
	FB = 0.001w <sup>2</sup> + 0.003w + 0.015	0.999
	FB = 0.04e <sup>0.058w</sup>	0.984
per GH	FB = 2.439w – 13	0.993
	FB = 0.023w <sup>2</sup> + 1.22w – 0.749	0.999
	FB = 8.805e <sup>0.058w</sup>	0.976

**Table 5.** Regression equation to predict fresh biomass of clustered plant part from pruning waste of strategic pruning routine.

Regression Analysis		R <sup>2</sup>
HM Young shoot	FB = 0.294w – 1.995	0.907
	FB = 0.011w <sup>2</sup> – 0.281w + 3.79	0.999
	FB = 1.038e <sup>0.056w</sup>	0.984
HM Green Leaf	FB = 1.529w – 8.681	0.999
	FB = 0.005w <sup>2</sup> + 1.23w – 5.676	0.999
	FB = 4.83e <sup>0.062w</sup>	0.957
HM Young Branch	FB = 0.614w – 2.324	0.991
	FB = 0.006w <sup>2</sup> + 0.27w + 1.136	0.999
	FB = 2.92e <sup>0.052w</sup>	0.985
HM Early bud	FB = 4.748w – 18.97	0.989
	FB = -0.058w <sup>2</sup> + 7.765w – 49.28	0.999
	FB = 17.62e <sup>0.06w</sup>	0.911

Based on regression equation, projected quaternary pruning if performed at 107 weeks after planting, approximately at end of 2017, then the pruning waste generated was expected to be 1.1kg per plant, 0.4kg per plant, and 19.8kg per plant estimate linear, quadratic, exponential equations, respectively. Similarly, pruning waste of GH generated will be 248kg per GH, 393kg and 43.65tons per GH. Even though the regression equations are statically, rational, however, the growth of young age of HM mango plant would high likely follow exponential equation, later slow down to the expected sigmoid curve. The projected quaternary pruning waste was best estimated by assuming the average value of pruning waste generated based on all three regression equations. Thus quaternary waste can be expected to be about 7kg per plant, while equivalent estimated waste per GH was 1.7 tons. In addition, the average of estimated clustered fresh biomass waste produced consisted of 190kg of HM young shoot, 1337kg of HM green leaf, 308kg of HM young branch and 3808 count of HM early bud. It can be expected that total waste of fresh biomass from 50 greenhouses, can be predicted to be in the region of approximately 85 tons per year. This is significant large of amount of waste produced compared to waste of other commercial fruit production from open farming. The waste from HM farming by GHPS amount to 7kg/tree of fresh biomass compared to other commercial fruit farming, such as 2.34kg/tree of apple, 2.45kg/tree of pear and 7.23kg/tree of peach [11].

In order to produce high quality of HM mango all year round, the waste produced is inevitable. Nevertheless, it can be utilized and formed into new discovery. For example, in the case of mango leaf, there were extensive studies of it benefits and practices. Mango leaf can be extracted and had varied of medicinal applications [13]. It can also be used as supplement of animal feedstuff, compost, one of material in silver-nanoparticle synthesis, and bio-sorbent of toxic elements [9,14–16].

### 4 Conclusion

Although there were many studies of biomass quantification of pruning waste, this was the first attempted to evaluate quantitatively the by-product of pruning of HM mango cultivated in greenhouse. To ensure high productivity and quality, pruning is mandatory, and the waste produce can be scheduled for processing into value added products. The quantification of the value of pruning waste will help in the design of green manufacturing to increase the efficiency of product utilization. The mango leaves as pruning by-product of mango cultivation, are known to have lots of benefits, it can be exploited and thus expected to contribute to the income of HM mango cultivation in greenhouse, and concomitantly, benefited by mango community as whole.

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