ACTA SCIENTIFIC AGRICULTURE (ISSN: 2581-365X)

Volume 3 Issue 4 April 2019

Research Article

Effect of Fruit Thinning and Defoliation on Yield and Quality of Papaya (*Carica papaya*) cv. Red Lady in Chitwan

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Received: October 17, 2018; **Publication:** March 14, 2019

Abstract

The effect of fruit thinning and defoliation on papaya cv. Red Lady was studied at commercial papaya orchard of Abloom Flora Farm, Chanauli, Chitwan from January to December, 2016. Factorial experiments were conducted in a randomized complete bock design (RCBD) with nine treatment combinations (control i.e. no thinning + no defoliation, no thinning + 33% defoliation, no thinning + 66% defoliation, hand thinning + no defoliation, hand thinning + 33% defoliation, hand thinning + 66% defoliation, chemical thinning by NAA 100 ppm + no defoliation, chemical thinning by NAA 100 ppm + 33% defoliation, chemical thinning by NAA 100 ppm + 66% defoliation) and 3 replications per treatment. The result showed that fruit set, fruit size, fruit weight, yield, physiological loss in weight percentage and firmness were found significantly higher with hand thinning. Chemical thinning resulted in significantly higher TSS, TSS/TA ratio along with slightly higher ascorbic acid content and lower TA. However, chemical thinning showed over thinning effect with higher abscission percentage and the lowest yield. Defoliation treatments did not result in significant improvement on yield and quality. The highest stem girth, leaf number, fruit diameter, yield and firmness were observed with 33% defoliation. The 66% defoliation treatment showed higher fruit drop and lower yield. These results suggest hand thinning and 33% defoliation practices improve the fruit yield and quality of papaya.

Keywords: *Carica papaya*; Hand Thinning; Chemical Thinning; Defoliation; Abscission; Quality

Introduction

Papaya (*Carica papaya* L.) is one of most important fruit crop, cultivated throughout the tropical and subtropical regions of the world, belonging to the Caricaceae family [1].

Papaya is one among the fruits, which has attained a great popularity in recent years, because of gynodioecious nature, easy cultivation, quick returns, adoptability to diverse soil and climatic conditions and attractive delicious wholesome fruits having multiple uses [2]. Major papaya cultivated districts are Siraha, Bara, Parsa, Dhanusha, Mahottari, Sarlahi, Rupandehi, Chitwan, Kailali, Dang, Nawalparasi and Dhading. The productive area covered by papaya in Nepal is 1,083 ha where production is 14,137 mt with the productivity of 13.05 mt/ha [3].

Papaya is regarded as a good source of vitamin A, ascorbic acid, beta-carotene, riboflavin, iron, calcium, thiamin, niacin, pantothenic acid, vitamin B-6 and vitamin K [4] which may prevent cancer, diabetes, jaundice and heart disease. It is also used in the pharmaceutical and cosmetic industries [5]. Production and quality of papaya are affected by climate, cultivar type and cultural practices [6]. Quality is the state of desired external features such as colour, shape, size and freedom from defects, and internal attributes like texture, sweetness, acidity, aroma, flavour, shelf life and nutritional value of a product. Researches of papaya were concentrated on the varietal trials and production aspects, but the study on quality improvement practices were low. Productivity and quality of papaya fruit is not satisfactory in Nepal. Little information is known about the influence of fruit thinning and defoliation in papaya.

Fruit thinning and defoliation practices could ensure better quality and yield of papaya. The effect of defoliation and fruit thinning on plant growth and development depends on the time and intensity of defoliation and fruit thinning [7,8]. Fruit thinning is the removal of fruitlets in heavy fruit set situations in plant aiming to increase fruit sizes, avoid branch breakdown, reduce harvesting

costs, and promote a balance between the vegetative and reproductive growth of plants [9]. It is Hundreds of year old work for manipulating the cropping and blooming of fruit plants like apple, pear and peach [10]. Defoliation is simply the removal of leaves for easing cultural practices and maintaining the physiological balance of plant. The availability of carbohydrate or assimilates exported from leaves to fruit determines papaya fruit production and sweetness. Partial defoliation (33% and 66%) of grape cv. Cabernet Sauvignon, was done to reduce vegetative growth and the source to sink ratio, to stimulate metabolic activity and to improve canopy microclimate, induced higher photosynthetic effectiveness of the remaining leaves as well as an increase in assimilate supply to the bunches [11]. According to Awada [12], it was found that defoliation increases papaya staminate flower number and decreases trunk growth and leaf dry weight (DW), whereas deflowering decreases staminate flower number and increases trunk growth and leaf DW [13]. Photosynthetic organs in the plant (mature leaves), are known as sources, while non-photosynthetic organs (fruits, roots and tubers) and immature leaves are known as sinks [14]. Source-sink balance is critical for papaya fruit set, development, and sugar accumulation [13]. Therefore, this study was carried out to study the effect of fruit thinning and defoliation on yield and yield attributing characters of papaya.

Materials and Methods

Site selection

This study was conducted at commercial Papaya farm (Abloom flora farm) of Chanauli, Chitwan, Nepal during January to December in 2016. It was situated at 27° 37' 3" North latitude and 84° 17' 43" East longitudes and at an elevation of 175 meters from the sea level. The climate of the site is tropical between the temperatures 9-37^{0}C with 2500 mm of annual mean precipitation. The soil was sandy loam with a pH of 5.6. The postharvest quality analysis of fruit was done in the post-harvest laboratory of Agriculture and Forestry University (AFU) during October to December, 2016.

Selection of the cultivar

Experiment was carried out using a high yielding, gynodioecious and early maturing variety 'Red Lady' of Taiwanese origin. Healthy, disease free and uniform seedlings of 45 days were transplanted in a regular rows, with a 2×2 m frame and 1.8 m plant to plant distance and subjected to uniform cultural practices before and during the field trial.

Experimental design

Factorial experiment in randomized complete block design (RCBD) with three replication was used with three replications and nine treatments were laid out. The first factor is fruit thinning, which include control (not treated), hand thinning (retaining one fruit per node), and chemical thinning (using 100 ppm of NAA). The second factor is defoliation, which include control (not treated), 33%defoliation (33% leaves are removed using secateurs), and 66% defoliation (66% leaves are removed with secateurs).

Treatment Combinations

Treatments No. (T)	Treatment Detail
1	Control (no thinning + no defoliation) (T_0D_0)
2	No thinning + 33% defoliation (T_0D_{33})
3	No thinning + 66%defoliation (T_0D_{66})
4	Hand thinning + No defoliation (T_hD_0)
5	Hand thinning + 33% defoliation (T_hD_{33})
6	Hand thinning + 66% defoliation (T_hD_{66})
7	Chemical thinning + no defoliation (T_cD_0)
8	Chemical thinning + 33% defoliation (T_cD_{33})
9	Chemical thinning + 66% defoliation (T_cD_{66})

Table a

Treatments application

Treatments were applied on May 20th, 130 days after transplanting (DAT). Chemical thinning was done two times by spraying 100 ppm NAA to run-off condition with the electric sprayer on May 20 and June 5th, 2016. Hand thinning was applied weekly after May 20th (130 DAT) for two months. Defoliation was done single time (in which 33% and 66% leaves were removed out of total leaves) on May 20th, 2016.

Physical characteristics of papaya

Flower and fruit drop (%)

Total number of abscised flower buds and fruits of size less than 3 cm were counted. And abortion percentage was calculated as,

$$\text{Fruit drop percentage} = \frac{\text{Total number of aborted flower and fruitlets}}{\text{Total number of flower emerged}} \times 100$$

Yield per plant (kg)

It was calculated by total number of fruit set multiplied by average weight of fruit for each treatment and expressed in kilogram per plant.

Fruit weight (g)

Seed weight (g)

Fruit length (cm)

Fruit width (cm)

Fruit Firmness (kg cm^{-2})

Firmness was measured with Effigi Penetrometer (FT - 327, Italy). A slice of peel was removed on soft and firm sides of the fruit and 11 mm tip plunger was inserted into a depth of 7.9 mm until the reading was taken.

Physiological loss in weight (%)

It was done by taking initial weight on the day of harvest followed by taking weight on each alternate day during the storage period.

Percentage physiological loss in weight (%) =

$$\frac{\text{Initial weight-Final Weight}}{\text{Initial weight}} \times 100$$

Chemical characteristics of papaya

Total soluble solids (°Brix)

The TSS content of the fruits was analyzed by homogenizing in a blender and measured with a hand Refractometer (ERMA Inc., Tokyo, Japan) using juice extracted directly from the pulp and expressed as °Brix.

Titratable Acidity (%)

It was determined from 10 ml fruit juice diluted in 50 ml distilled water, titrated with 0.1 N NaOH using phenolpthalein indicator (2-3 drops), and calculated as percent citric acid. Percent titrable acidity was calculated by using the following formula as suggested by Saini., *et al*. [15]:

TA (%) =

$$\frac{\text{Volume of NaOH used (ml)} \times \text{Normality of NaOH} \times 0.064^{*}}{\text{Volume of juice titrated}} \times 100$$

*Acid milliequivalents (mEq) factor for citric acid

TSS/TA ratio

It was obtained by the ratio of TSS to TA.

Vitamin C (Ascorbic acid) content

The ascorbic acid of the ripe fruit was measured by volumetric method as per the reference from Sadasivsm and Manickam [16]. It was measured at the beginning of experimental set-up, and at designated interval till the termination of storage. Following formula was used to calculate the ascorbic acid content.

$$\text{Amount of ascorbic acid } \left(\frac{\text{mg}}{100\text{ml}}\text{sample}\right) =$$

$$\frac{0.5 \text{ mg} \times V_2 \times 100 \times 100}{V_1 \times 5\text{ml} \times \text{Wt. of sample}}$$

Where, V1= amount of dye consumed during the titration
V2 = amount of dye consumed when the supernatant was titrated with 4% oxalic acid.

Statistical method

Factorial randomized complete block design (RCBD) was used with three replication and nine treatments. Experimental data were analyzed using MSTAT-C and GenStat Software of 15th edition and treatment means were separated using Duncan's Multiple Range Test (DMRT) at 5% level of significance. Analysis of variance (ANOVA) was used to test differences among the two factors [17]. Correlation coefficient was studied among various traits to determine the effect of treatments applied.

Result and Discussion

Effect of fruit thinning and defoliation on fruit drop and fruit yield

It was observed that chemical thinning significantly increased the percent of fruit drop among all of the thinning treatment (Figure 1). Hand thinning treatment exhibit lower fruit drop which was statistically at par with no thinning treatment. These results are in accordance with Zhou., *et al*. [13], Sharma, Singh and Singh [18] and Nartvaranant [19] who reported higher number of fruit set due to the hand thinning treatment in papaya, peach and pummelo respectively. Zhou., *et al*. [13] reported that flower abscission increased nine fold in 'Sunset' papaya subjected to 75% defoliation which might be due to the less photoassimilates available in the absence of source. Similarly, in 2003 Jemric, Pavicic, Blaskovic, Krapac, and Pavicic found that chemical thinning with NAA had lower crop density than hand thinned trees due to the strong thinning property, epinasty effect on papaya [20] and toxic effects [21] of NAA. Results of fruit drop are in contrast with Sharma [22] who reported fruit drop was highest in control and lowest in NAA 60 ppm treatment followed by hand thinning on plum cv. Satluj Purple, which might be due to the strong physiology of tree plant and lower concentration of NAA favored fruit retention mechanism.

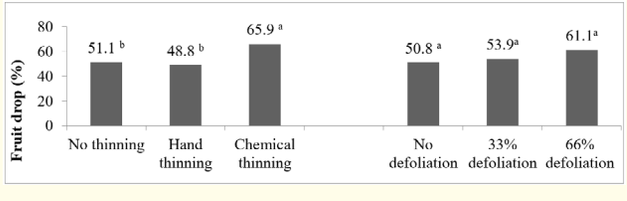

Figure 1: Effect of fruit thinning and defoliation on fruit drop of papaya (*Carica papaya*) cv. Red Lady in Chitwan, Nepal, 2016.

The highest yield (56.4 kg) was observed with hand thinning which is at par with control (51.1 kg). The lowest yield (33.2 kg) was found with chemical thinning (Figure 2). The results obtained on yield are in line with Fischer., *et al.* [23] who found highest increase in yield due to hand thinning than in control which might be due to availability of photo-assimilates in apple. Sharma., *et al.* [18] reported that fruit yield was significantly higher in control as compared to chemical thinning (NAA treated plants) might be due to the toxic effect of higher [21,24,25].

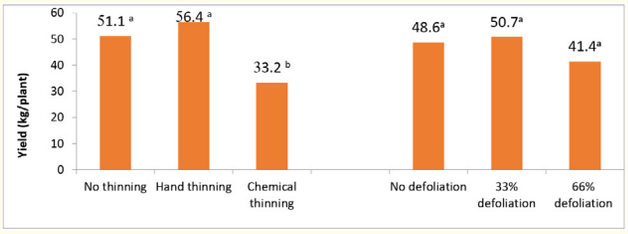

Figure 2: Effect of fruit thinning and defoliation on fruit yield of papaya (*Carica papaya*) cv. Red Lady at Chitwan, Nepal, 2016.

Effect of fruit thinning and defoliation on physical characteristics of papaya

Highly significant differences on fruit weight and fruit length of papaya due to fruit thinning were stated (Table 1). The highest fruit weight (1631 g) and fruit length (28.61 cm) was seen by hand thinning. Lowest fruit weight (999 g) and fruit length (24.01 cm) was with chemical thinning, which was statistically at par with control thinning. Fruit width was also found significantly different among fruit thinning practices with highest (39.38 cm) in hand thinning treatment. Among defoliation there was no significant difference in fruit breadth.

The results of present study were in accordance with Clingeleffer and Petrie [26] in grapes, Link [27] in apple and Park., *et al.* [28] in persimmon, who reported from the study on fruit thinning that higher fruit weight was found at harvest. Similarly, Burge., *et al.* [29], Sharma., *et al.* [18], and Nartvaranant [19], reported that fruit thinning increased size of fruit due to the more availability of assimilates and higher leaf to fruit ratio.

The highest seed weight (83.6 g) was observed with hand thinning and lowest seed weight was found with chemical thinning (39.8 g) practice. Pathirana., *et al.* [30] found in tomato that seed vigour and seed weight was higher due to fruit thinning and canopy management then control. Lower seed weight in fruit subjected to chemical thinning by NAA is due to the parthenocarpic effect, which is supported by Nawaz., *et al.* [31] in mandarin.

	Physical parameters			
Treatment	Breadth (cm)	Length (cm)	Fruit weight (g)	Seed wt. (g)
Fruit thinning (T)				
No thinning	35.99 ^{b}	27.34 ^{a}	1217 ^{b}	62 ^{ab}
Hand thinning	39.38 ^{a}	28.61 ^{a}	1631 ^{a}	83.6 ^{a}
Chemical Thinning	37.93 ^{ab}	24.01 ^{b}	999 ^{b}	39.8 ^{b}
F-test	*	**	**	*
Defoliation (D)				
No defoliation	37.54	27.06	1333	64.9
33% defoliation	38.29	26.07	1301	62.4
66% defoliation	38.06	26.83	1212	58.2
F-test	Ns	Ns	Ns	Ns
SEm (±)	1.181	0.923	80	9.83
LSD (0.05)	3.541	2.769	239.9	29.46
CV%	9.3	10.4	18.7	47.7
Grand Mean	37.97	26.65	1282	61.8
T x D	Ns	Ns	Ns	Ns

Table 1: Effect of fruit thinning and defoliation on physical characteristics of papaya (*Carica papaya*) cv. Red Lady at Chitwan, Nepal, 2016.

Ns,* and ** indicate non-significant and significant at P<0.05 and P<0.01, respectively. Means followed by different letters within the same column are significantly different at 5% by DMRT.

Highly significant differences were seen among the fruit thinning practices on PLW % (Table 2). Highest PLW % (10.7) was noticed with chemical thinning which was significantly different from hand and no thinning practices. These results are similar with Shivakumar [32], who reported that presence of vital nutrients and some unidentified metabolites like GA3 might have acted as ripening retardants leading to reduced respiration, transpiration and weight loss with extended shelf life. Defoliation practices showed no significant difference among each other. Similarly, no significant results were seen between the interaction of fruit thinning and defoliation.

All three thinning practices showed significantly different fruit firmness (Table 2). Maximum firmness (1.9 kg cm^{-2}) was observed with hand thinning followed by no thinning (1.5 kg cm^{-2}) and minimum (1.1 kg cm^{-2}) was observed on chemical thinning. Saini, Singh, Dhaliwal, and Chanana [33] observed similar results viz. fruit firmness was reduced by chemical thinning which might be due to higher accumulation of nitrogen in the fruit resulting in fruit softening through activation of cell wall softening enzymes. On the other hand, different defoliation practices and interaction between fruit thinning and defoliation did not show significant difference among each other.

	Shelf life	
	PLW %	**Firmness (kg cm^{-2})**
Fruit thinning (T)		
No thinning	8.17 ^{b}	1.5 ^{b}
Hand thinning	7.51 ^{b}	1.911 ^{a}
Chemical thinning	10.73 ^{a}	1.13 c
F-test	**	**
Defoliation (D)		
No defoliation	8.68 ^{ab}	1.48 ^{a}
33% defoliation	9.7 ^{b}	1.7 ^{a}
66% defoliation	8.03 ^{a}	1.35 ^{a}
F-test	*	Ns
SEm (±)	0.44	0.12
LSD (0.05)	1.34	0.36
CV%	15.3	24.2
Grand Mean	8.8	1.51
T x D	Ns	Ns

Table 2: Effect of fruit thinning and defoliation on Physiological Loss in weight (PLW) and firmness of papaya (*Carica papaya*) cv. Red Lady at Chitwan, Nepal, 2016.

Ns,* and ** indicate non-significant and significant at P<0.05 and P<0.01, respectively. Means followed by different letters within the same column are significantly different at 5% by DMRT.

Effect of fruit thinning and defoliation on chemical characteristics of papaya

Highest TSS (10.07 0Brix) was observed with chemical thinning which was at par with hand thinning (9.49 0Brix), and lowest TSS (9.01 0Brix) was noticed with no thinning which was also at par with hand thinning (9.49 0Brix). These results are supported by Jemric., *et al*. [34] in apple found highest TSS through fruit thinning, which might be due to the reason that thinning promotes greater supply of carbohydrates (sucrose, glucose and fructose) to remaining fruits. While, Coombe and McCarthy [35] reported higher TSS might be due to increase in sugars due to the transpiration. The TSS content of fruits due to defoliation practices were not found significantly different among each other. (Table 3)

The results obtained from this study are supported by Khan., *et al*. [36] who found non-significantly different TA at different levels of defoliation and fruit thinning. The TSS/TA content of fruits due to fruit thinning was observed significantly different. The results of this study showed some contradiction with Chahill, Grewal and Dhatt [37] who reported that TSS/TA ratio was found to be higher in hand thinning as compared to chemically thinning practices [38-45].

	Chemical parameters			
Treatment	TSS (^{0}Brix)	TA (%)	TSS/TA	AAscorbic acid (mg 100g^{-1})
Fruit thinning (T)				
No thinning	9.01 ^{b}	0.14^{a}	63 ^{b}	62.6 ^{a}
Hand thinning	9.49 ^{ab}	0.13 ^{a}	73.2 ^{ab}	69.3 ^{a}
Chemical Thinning	10.07 ^{a}	0.12 ^{a}	87.9 ^{a}	73.5 ^{a}
F-test	*	Ns	*	Ns
Defoliation (D)				
No defoliation	9.69 ^{a}	0.12 ^{a}	82.5 ^{a}	71.8 ^{a}
33% defoliation	9.6 ^{a}	0.13 ^{a}	76.3 ^{a}	68.6 ^{a}
66% defoliation	9.28 ^{a}	0.15 ^{a}	65.4 ^{a}	64.9 ^{a}
F-test	Ns	Ns	Ns	Ns
SEm (±)	0.24	0.007	5.77	3.34
LSD (0.05)	0.73	0.02	17.31	10.33
CV%	7.7	17.4	23.2	15.1
Grand Mean	9.52	0.13	74.7	68.5
T x D	Ns	Ns	Ns	Ns

Table 3: Effect of fruit thinning and defoliation on chemical characteristics of papaya (*Carica papaya*) cv. Red Lady at Chitwan, Nepal, 2016.

Ns,* and ** indicate non-significant and significant at P<0.05 and P<0.01, respectively. Means followed by different letters within the same column are significantly different at 5% by DMRT.

Conclusion

Chemical thinning increased abscission of flower and fruitlet by 22 and 20 percent than hand thinning and no thinning practices respectively. While abscission increased by 20 percent in 66% defoliation than control. In hand thinning practice, fruit weight and seed weight were increased by 39 percent and 52 percent respectively and it also improved shelf life of papaya than chemical thinning practice. While fruit weight increased by 9 percent in no defoliation than 66% defoliation practice. Hand thinning practice increased 41 percent yield than chemical thinning while 33% defoliation increased 18 percent yield than 66% defoliation.

Acknowledgements

Author is thankful to Department of Horticulture, Directorate of Research and Extension, Agriculture and Forestry University (AFU), Rampur, Chitwan and Abloom Flora Farm, Chanauli Chaitwan for providing experimental site. Highly acknowledged toward 'Participatory Biodiversity and Climate Change Assessment for Integrated Pest Management in the Chitwan-Annapurna Landscape' project of Nepal, funded by USAID, for providing research grant for this thesis research.

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Volume 3 Issue 4 April 2019