American Journal of Plant Sciences, 2017, 8, 40-52
http://www.scirp.org/journal/ajps
ISSN Online: 2158-2750
ISSN Print: 2158-2742

Alternancy Study on Rambutan (*Nephelium lappaceum* L.) Tree in Mexico

Rubén Joo-Pérez[1], Carlos Hugo Avendaño-Arrazate[2*], Alfredo Sandoval-Esquivez[2], Saúl Espinoza-Zaragoza[3], Moisés Alonso-Báez[2], José Luís Moreno-Martínez[3], Rafael Ariza-Flores[4], Carlos Raúl Morales-Nieto[5]

[1]Faculty of Agricultural Sciences, Autonomous University of Chiapas, Huehuetan, Mexico
[2]National Forestry, Crops and Livestock Research Institute (INIFAP), Experimental Station Rosario Izapa, Tuxtla Chico, Mexico
[3]Autonomous University of Chiapas, Huehuetan, Mexico
[4]INIFAP, Experimental Station Iguala, Guerero, Mexico
[5]Autonomous University of Chihuahua, Chihuahua, Mexico
Email: *avendano.carlos@inifap.gob.mx

How to cite this paper: Joo-Pérez, R., Avendaño-Arrazate, C.H., Sandoval-Esquivez, A., Espinoza-Zaragoza, S., Alonso-Báez, M., Moreno-Martínez, J.L., Ariza-Flores, R. and Morales-Nieto, C.R. (2017) Alternancy Study on Rambutan (*Nephelium lappaceum* L.) Tree in Mexico. *American Journal of Plant Sciences*, **8**, 40-52.
http://dx.doi.org/10.4236/ajps.2017.81004

Received: November 19, 2016
Accepted: January 6, 2017
Published: January 9, 2017

Abstract

Rambutan growing in the state of Chiapas has brought about a demand for new plantations; however, this species has several biotic and abiotic factors that limit its production. These factors include phytosanitary problems, deficient agronomical handling, and production alternancy. Because of this, the objective of the present study was to evaluate the effect of the application of agronomical practices such as pruning, ringing, water stress, and their interaction on the rambutan alternancy. The experiment was carried out in the "La Chinita" commercial orchard located on KM. 4.5 the Huehuetan Station, municipality of Huehuetan, Chiapas, Mexico. We used 48 rambutan trees in production with an age of 14 years. Two production cycles were evaluated. The experiment was established under a divided plot experimental design in random complete blocks with a factorial arrangement and six replicates; each tree being a replicate. The study factors were: water stress, pruning, girdling, irrigation (control), and their combinations, resulting in eight treatments. The evaluation was done during flowering, fruit set, and harvest. In flowering, the treatments with permanent irrigation in both evaluated cycles (2010-2011 and 2011-2012) manifested a production alternancy behavior, with an average 36.4% flowering in the first evaluation cycle and increased to 82.1% in the second cycle. The treatments with water stress kept a proportional flowering during the first and second cycles of 97.9% and 95.3%, respectively. The water stress influenced the bunch weight (PR) variable fruit set with bigger fruits and higher bunch weight than the irrigated treatments. In production, pruning and girdling together with water deficit had no alternancy in both production cycles.

Keywords

Nephelium lappaceum L., Water Stress, Pruning, Girdling, Irrigation

1. Introduction

Rambutan is a fruit tree original from Malaysia, member of the Sapindaceae family. It is currently grown in some parts of India, Thailand, Indonesia, Costa Rica, Ecuador, Australia, Guatemala, and Mexico [1]. Given its acceptance in regional and national markets, rambutan is an economic option for the diversification of fruit crops in Chiapas, Mexico, mainly in the coffee growing zones located at an altitude between 100 and 1000 m [2], with the 28˚C temperatures, 4000 mm precipitation and 75% HR averages during the spring and summer. The growing interest in this crop has brought about an increase in new plantations in the Soconusco area in the Chiapas state. The yields reported by the SAGARPA [3] are of 9.81 $t \cdot ha^{-1}$; while the FAO [4] reports yields in Malaysia, where this crop has efficient agronomical handling of 15 $t \cdot ha^{-1}$. Despite the mentioned importance of rambutan growing in Mexico, there are several biotic and abiotic factors that limit its production. These factors are phytosanitary problems, little genetic diversity in the grown varieties, deficient agronomical handling, difficulty in vegetative propagation, and production alternancy [1].

Alternancy is a frequent phenomenon in woody fruit species. It is characterized for having high production yields in one year followed by low yields in the next year. Guardiola [5] mentions that this phenomenon has been mainly linked to genetic and physiological factors, among which stands out insufficient floral differentiation. In some fruit species, this behavior can be regulated with some agronomical practices like girdling, pruning, and water stress which are recommended to decrease alternancy in production [6].

The practice of girdling or striping the branches of trees interrupts phloem in the plant, which favors the accumulation of carbohydrates and decreases gibberellins in buds and leaves. This allows inducing the anticipated flowering and increases floral differentiation [7] [8]. Likewise, it causes an increase in fruit set and fruit size, partially corrects late ripening of the fruits and alternancy of the production in fruit crops like litchi and citrus fruits [9]. The pruning of terminal shoots in fruit trees is done to ensure balance in the distribution of sap, light penetration, and ventilation of neighboring branches. In mango and citrus fruit crops, however this has invigorating effects, allowing to increase the number of new terminal shoots, increase photosynthetic efficiency, and the optimum value of cytokinins-gibberellins to stimulate flowering every year [10] [11]. With regard to the practice of water stress in tropical fruit crops, it causes flower induction and increase in flowering, while at the same time helps seasonal regulation, intensity, duration, and distribution of the flowering and harvest [12]. In fruit crops like apples and peaches, this practice induces flower bud production since the trees have greater reserves in the flower differentiation stage than for vegetative growth of stem and roots. Moreover, depending on the intensity of the stress, there can be wilting of the leaves, decrease of the stoma activity, net CO_2 assimilation, and radical conductance [13]. Because of this, the objective of the present study was to evaluate the effect of the application of agronomical practices such as pruning, girdling, water stress, and their interaction on the rambutan alternancy.

2. Materials and Methods

The research was carried out in the "La Chinita" commercial orchard, located on km. 4.5 of the Huehuetan Station-Nueva Victoria highway, Huehuetan, Chiapas, Mexico, at 15˚00'33" North Latitude and 92˚26'17" West Longitude, an altitude of 19 m. The soil characteristics are: texture-sandy loam, with the organic matter content of 1.31%, pH 6.1, 37.2% porosity, 59.7% saturation, and field capacity of 37%. The climate is represented by the acronym Am (w') ig corresponding to the warm subhumid climate with summer rains, an annual mean precipitation of 2200 mm, an annual average isothermal temperature of 28.4˚C and an average annual relative humidity of 85%.

2.1. Plant Material

Forty eight producing rambutan trees "RJA Clone" and aged 14 years were selected, and the two annual production cycles were evaluated (2010-2011 and 2011-2012).

The experiment consisted of eight treatments (**Table 1**), derived from the combination of two study factors: soil moisture conditions in two levels and agronomical practices in four levels. In the field, these treatments were establishes under an experimental plot design divided into complete random blocks in the factorial arrangement with six replicates and each tree was a replicate. Soil moisture and agronomic practice levels were selected based on the physical characteristics of the soil, the utilizable moisture (UM; %) ranged between a field capacity (FC = 37%) and a permanent wilting point (PWP = 20%); but for the purposes of this research a temporal wilting point (TWP = 13%), lower than PWP, was selected.

Table 1. The trees in your combinations of practices on soil condition and handling were used during the cycle's research 2010-2011 and 2011-2012.

Soil condition	Handling practice	Simbology	Treatment
Irrigation	Pruning and girdling	I + P + G	1
	Pruning	I + P	2
	Girdling	I + G	3
	None	I	4
Water stress	Pruning and girdling	WS + P + G	5
	Pruning	WS + P	6
	Girdling	ES + G	7
	None	WS	8

In water stress and irrigation conditions, the agronomical practices of girdling, pruning and their combinations were performed as follows: the girdling was done through 3 mm-deep incisions around the three secondary branches of the trees; the pruning was done in roughly 30 cm long cuts in the penultimate vegetative growth, where it showed a light brown coloring; the water stress consisted in leaving 24 trees without irrigation until the soil moisture reached the temporary wilting percentage (TWP), equal to 13% usable moisture. Once the TWP was reached and was applied with the recuperation irrigation (RI). The water stress treatment was applied at end from the rainy season. With regard to the irrigation treatment, it consisted maintaining the usable moisture content of the soil above 50% during the production cycle. The value of temporal wilting point (TWP) was determined by soil samples that were obtained every seven days and when the average value of gravimetric moisture (%) between the depths studied (0 - 20 cm and 20 - 40 cm) reached the value of 13%, irrigation was applied to recover.

2.2. Variables Studied

Flowering variables. The 40 vegetative flows were tagged in every direction of the compass (North, South, East, and West) in each tree. These flows were evaluated for:

1) Flowering start date: when the inflorescences showed the first differentiated flower buds in each tree.

2) Flowering end date: were content the end of flowering and start of fruit set in the inflorescences.

Flowering percentage. It resulted from the quotient of dividing the number of inflorescences found by the total vegetative flows tagged in each tree (160 branches). The percentage was obtained through the following equation (**Figure 1**):

Fructification variables. Two inflorescences were selected from the 40 vegetative flows tagged in each direction. These were evaluated in:

1) *Fruit growth rate.* The increase in fruit size was recorded from fruit set to its physiological maturity. Data were taken every15 days. Measurements were done in centimeters from the base to the apex of the fruit using a digital Vernier scale.

2) *Aril thickness and skin thickness.* In each fruit was measured in millimeters using a digital Vernier scale.

Fruit shelf-life. The number of days that the fruits kept their color was recorded until they showed necrosis (black pigmentation).

Fruit diameter. The diameter of eight fruits per tree was recorded in centimeters using a digital Vernier scale.

Fruit weight. The individual weight of each ripe fruit was recorded using a

$$\text{Flowering } \% = \frac{\text{Number of inflorescences}}{\text{Total number of vegetative shoots}} \times 100$$

Figure 1. Equation used to obtain the flowering percentage.

triple bar scale.

Bunch weight. The weight of bunches was recorded in grams to all the ripe fruits using a tripla bar scale.

Harvest variables. It was realized from the 160 vegetative flows tagged in each replicate, the following were evaluated:

1) *Harvest start date.* The harvest start date was recorded when the first bunch was harvested from each tree, once it reached ripeness.

2) *Harvest end date.* The end of harvest was recorded when the last tagged bunch was harvested.

3) *Yield per tree.* The record was kept of the fruit kilograms per tree, registered according to the kilograms obtained in each harvest.

Soil moisture. The soil moisture was monitored every other day in 10 places for the irrigation and water stress treatments at different depths from: 0 to 20 cm and 20 to 40 cm of high; at the end of the water stress treatment, monitoring was done every seven days. The soil moisture percentage was determined through the ecuation following (**Figure 2**).

Temperature and precipitation: daily temperature was recorded at 5 a.m. and precipitation was registered with a data logger (WS-2080).

The statistical analysis. The corresponding, the variation of effects treatment were evaluated to variance factorial analysis. When a significant difference was found, a Tukey ($p \leq 0.05$) mean comparison test was done.

3. Results and Discussion

From the temperature and precipitation records in the study site, it was observed that flowering induction of rambutan was influenced by exogenous factors, since all the treatments showed floral differentiation in the vegetative shoots. The factors that possibly allowed floral induction were: low temperatures between 17 and 20˚C, in the mornings (5:00 h A.M.) during November and February; and the loss of soil moisture during the dry season from November to April (**Figure 3**). The temperature in second cycle of evaluation was low from November to February, which allowed the flowering induction of the crop (**Figure 4**).

According to the data obtained from the monitoring of soil moistures under water stress conditions, the temporary wilting percentage (TWP) was reached 60 days after irrigation was suspended, with a percentage of usable moisture of 13%. Moreover, it was observed that the start of flowering (SF) and start of harvest was homogeneous in the treatments with water stress (WS), water stress and pruning (WS + P), water stress and girdling (WS + G), and water stress with pruning and girdling (WS + P + G); while at the end of the harvest (EH), the same treatments showed a longer harvest period than did the treatments with permanent irrigation (**Figure 5**).

$$\text{Moisture}\,\% = \frac{\text{Moist weight} - \text{Dry weight}}{\text{Dry weight}} \times 100$$

Figure 2. Equation used to obtain the soil moisture.

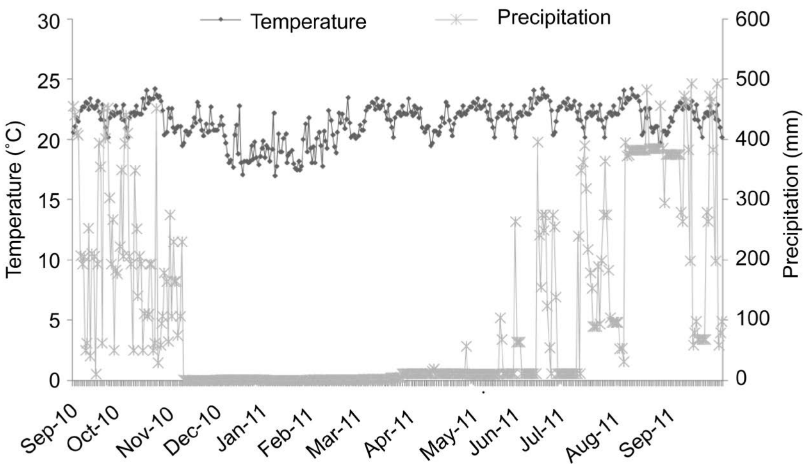

Figure 3. The temperature and precipitation histogram's from September 2010 to September 2011 in the "La Chinita" orchard, Huehuetan, Chiapas, Mexico.

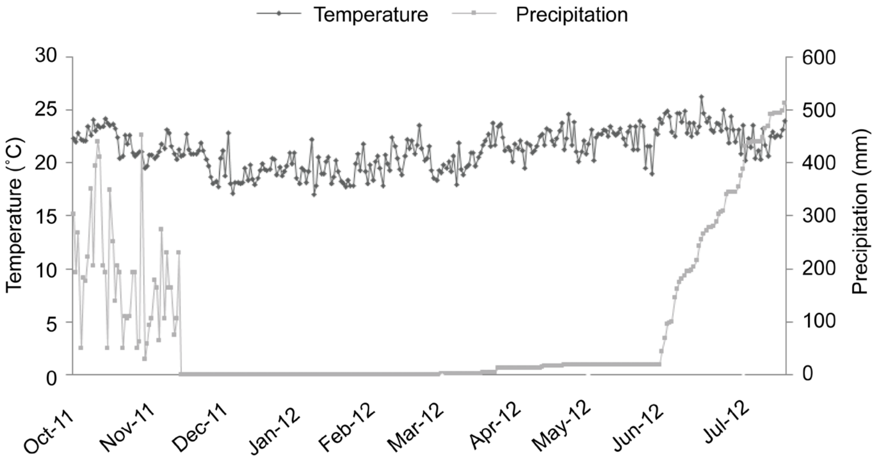

Figure 4. The temperature and precipitation histogram's of from October 2011 to July 2012 in the "La Chinita" orchard, Huehuetan, Chiapas, Mexico.

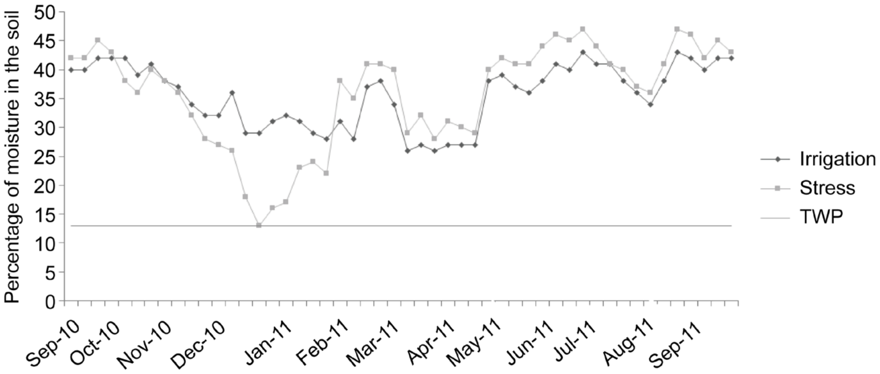

Figure 5. The rambutan floral biology and production behavior in the response to agronomical practice's (2010-2011). TWP: temporary wilting percentage.

In the treatments with permanent irrigation, the moisture percentage recorded was greater than 25% during the dry season; also, the start of flowering occurred 15 days before the treatments with water stress. Nevertheless, the start of harvest in the treatments with irrigation and pruning (I + P) was 10 days later than the treatments with only permanent irrigation (PI), irrigation and girdling (I + G), and irrigation with pruning and girdling (I + P + G). But at the end of harvest (EH), the treatment with irrigation, pruning and girdling (I + P + G) showed a more precocious harvest period (**Figure 5**).

In the second evaluation cycle, soil moisture for the conditions of water stress, the temporary wilting percentage (TWP) was reached 58 days after irrigation was suspended, where the percentage of usable moisture was 13%, similar to the first cycle of evaluation. In this cycle of evaluation, the start of flowering was homogeneous; however, when compared against the second cycle, there was a shorter harvest time. In the treatments with permanent irrigation, the moisture percentage was kept above 25% during the dry season. In this case, the flowering start time was in the months of December and January; however, the time necessary to start harvest was longer given that fruit development was slower (**Figure 6**).

The variance analysis showed significant differences for all the variables ($P \leq 0.05$), except for the skin thickness variable. During to the cycles evaluated, the relevant effects were in four of the main variables: flowering percentage, fruit diameter and weight, and bunch weight. The treatment with water stress had effects on yield components like flowering percentage, number of fruits in the inflorescence, fruit diameter, aril thickness, fruit weight, bunch weight, and kilograms per tree in both harvest cycles. The treatments with pruning and girdling showed effect on flowering percentage, fruit diameter, shelf-life, and kilograms per tree variables. The treatments interactions showed significant differences ($P \leq 0.05$) in fruit diameter, aril thickness, fruit weight, bunch weight, and post-harvest shelf-life variables (**Table 2**).

In the mean comparison, the variables in both evaluation cycles showed significant differences ($P \leq 0.05$) in the rambutan production. The trees with permanent irrigation (PI), flowering percentages of 52% were obtained, as well as fruits with 3.6 cm diameter, 0.6 cm thick arils, individual fruit weight of 31 g and a yield of 178 kg for tree. The trees with water stress were the flowering

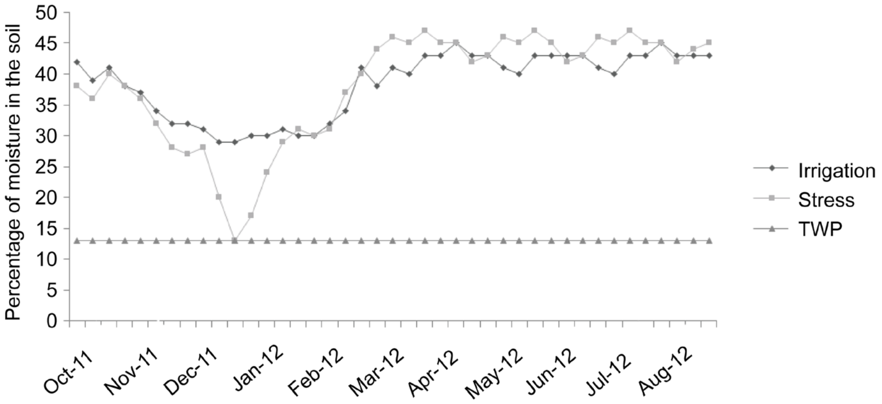

Figure 6. The rambutan floral biology and production behavior in the response to agronomical practice's (2011-2012). TWP: temporary wilting percentage.

Table 2. The mean squares of the variance analysis of the treatments for the flowering, fructification, and production variables (2010-2011).

VS	FP	NF	FD	AT	ST	FW	BW	SL	KPT
Y	4.32**	3.45	1.30**	0.01	0.01	681.06**	173655.09**	0.16	161.4
WS	9.28**	24652.86**	2.80**	0.24**	0.01	1284.07**	38760.84**	2.66*	336.4**
P	0.11	33.37	0.06	0.02	0.01	11.83	14479.59	2.66*	393.9
G	0.25*	2053.50	0.26*	0.01	0.01	0.27	16406.51	6.00**	311.4*
Y + WS	4.95**	16737.60**	2.28**	0.57**	0.01	1004.27**	221088.01**	1.04	524.0*
Y + P	0.01	1330.57	0.01	0.01	0.01	1.79	688.01	0.04	73.1
Y + G	0.01	828.38	0.07	0.01	0.01	3.26	19.26	0.04	114.1
WS + P	0.12	261.36	0.02	0.01	0.01	0.27	11115.51	5.04**	112.8
WS + G	0.04	80.30	0.22*	0.08*	0.01	40.95*	17631.26	2.04*	104.7
P + G	0.18	106.68	0.05	0.03	0.01	4.99	19181.76*	2.04*	114.1
Y + WS + P	0.01	502.34	0.08	0.05*	0.01	0.78	1298.01	0.16	37.6
Y + WS + G	0.04	829.55	0.02	0.03*	0.01	0.01	4523.76	0.16	596.9
Y + P + G	0.01	893.04	0.01	0.01	0.01	7.87	0.01	0.01	213.9
Y + WS + P + G	0.12	777.77	0.18	0.02	0.01	11.35	98.02	2.10*	366.2

VS = Variation source, Y = years, WS = Water stress, P = Pruning, G = Girdling, Y + WS = Years and Water stress, Y + P = Years and Pruning, Y + G = Years and Girdling, WS + P = Water stress and Pruning, WS + G = Water stress and Girdling, P + A = Pruning and Girdling, C + E + P = Years with Water stress and Pruning, C + E + A = Years with Water stress and girdling, Y + P + G = Years with Pruning and Girdling, Y + WS + P + G = Years with Water stress, Pruning, and Girdling, * = Significant alpha = 0.05 and ** = Highly significant alpha = 0.01; FP = Flowering percentage, NF = Number of fruits, FD = Fruit diameter, AT = Aril thickness (mm), ST = Skin thickness (mm), FW = Fruit weight (g), BW = Bunch weight (g), SL = Shelf-life (days), KPT = Kilograms per tree (kg).

percentage reached 96.8%, fruits with 3.9 cm diameter, 0.7 cm thick arils, individual fruit weight of 38.3 g and a yield of 296 kg for tree. In "Fortune" mandarin trees, Dell'Amico *et al.* [14] observed that plants subjected to water stress increased 21.35% more fruits per plant than the plants managed with sufficient irrigation; however, in other studies with citrus fruits, it has been observed that limited irrigation conditions are responsible for a greater number of smaller fruits given their lower average weight and lower final diameter [15]. The trees with girdling, the variables no showed effect, although there was an effect on flower percentage, fruit diameter, shelf-life, and kilograms per tree. In the first cycle of evaluation, the expressed variables were: fruit diameter, fruit weight, and bunch weight. In the second cycle of evaluation, the variable that showed significant difference ($P \leq 0.05$) was flowering percentage (**Table 3**). In works with apples, similar behaviors were observed, agreeing with previous evaluation from other authors. Thus, it is important to cut down the number of fruits in commercial production of apple, mostly to obtain greater girths and avoid alternancy in cultivars with genetic problems. Late water deficit does not affect fruit quality. The production, fruit weight, and production efficiency are in function the fruit loads. The applied water deficit affects tree growth, but favors flowering density [16].

In the global analysis of the two production cycles, the trees had an effect on

Table 3. The mean comparison to the water stress treatment to evaluated variables during 2010-2011 and 2011-2012 cycle's.

STRESS	FP	NF	FD	AT	ST	FW	BW	SL	KPT
WS	**96.80 a**	233.30 b	**3.95 a**	**0.74 a**	0.33 a	**38.38 a**	209.05 b	3.18 b	**296854 a**
I	52.00 b	**265.35 a**	3.61 b	0.64 b	0.31 a	31.07 b	**249.69 a**	**3.52 a**	178458 b
P	68.20 a	248.74 a	3.75 a	0.67 a	0.32 a	35.08 a	241.88 a	**3.52 a**	244063 a
WP	73.00 a	249.92 a	3.80 a	0.71 a	0.32 a	34.37 a	217.31 a	3.18 b	231250 a
G	66.80 b	244.70 a	3.73 b	0.68 a	0.32 a	34.78 a	216.52 a	3.10 b	219646 b
WG	**74.80 a**	253.95 a	**3.83 a**	0.70 a	0.32 a	34.67 a	242.67 a	**3.60 a**	**255667 a**
Y1	56.90 b	249.14 a	**3.90 a**	0.69 a	0.32 a	**37.39 a**	**272.13 a**	3.31 a	250625 a
Y2	**87.40 a**	249.52 a	3.66 b	0.69 a	0.32 a	32.06 b	187.06 b	3.39 a	224688 a

Same letter in a column shows no significant statistical difference alpha = 0.05, WS = Water stress, IR = Irrigation, P = Pruning, WP = Without pruning, G = Girdling, WG = Without girdling; Y1 = 1st year, Y2 = 2nd year, FP = Flowering percentage, NF = Number of fruits, FD = Fruit diameter, AT = Aril thickness (mm), ST = Skin thickness (mm), FW = Fruit weight (g), BW = Bunch weight (g), SL = Shelf-life (days), KPT = Kilograms per tree (kg).

the phenomenon of production alternancy were those kept though management the water deficits. The trees have the stress and pruning and girdling, stress and pruning, stress and girdling, and water stress no showed effect on the flowering percentage, fruit weight, and kilograms per tree. With regard the trees were haven constant irrigation combined with pruning and girdling, pruning, girdling, and irrigation, the same variables mentioned shown significant effects (Table 4).

3.1. Flowering Variables

The flowering percentages in the treatments with permanent irrigations in both evaluated cycles showed a behavior according to the phenomenon of alternancy in production, in the first cycle was an average flowering of 36.4% and in the second cycle, it increased to 82.1%. With regard to the trees with water stress were the flowering percentages similar at 97.9% and 95.3% in the first and second cycles, respectively (Figure 7). According to Martinez *et al.* [17] high and low harvests are the consequence of a serious nutritional imbalance, where the nitrogen content accumulated as a nitrate in the leaves and roots limits floral differentiation [6]. On the other hand, Guardiola [5] points out that alterations in hormone balances can to be because the fruits modified hormone concentrations in the plant for the gibberellin synthesis, hindering floral differentiation of the following harvest. In lemon, flowering was very weak (<10 flowers per tree) in the absence of water stress and was only heavy (>35 flowers per tree) after stressed were rewatered [18]. In litchi, high day temperatures in the shoot and high root temperatures promoted vegetative growth and reduced or eliminated flowering [19]. This author suggests that day shoot temperatures and root temperatures interact to control the level of flowering in litchi. Water stress appears to act by synchronizing vegetative dormancy in the branches before exposure to low temperatures. In coffee, temperatures of 33˚/28˚C during summer will ensure maximum vegetative growth and potential number of flowering nodes. Temperatures of 23˚/18˚C during winter will ensure healthy and synchronized

Table 4. The variance analysis of comparison's mean of at the nine variables to evaluate the eight treatments in both productive cycles (2010-2011 and 2011-2012).

TRAT	FP	NF	FD	AT	ST	FW	BW	SL	KPT
Y1 (T5)	97.38 b	244.40 bc	3.91 ab	0.58 d	0.31 a	**37.65 a**	177.50 cd	3.00 b	308.33 abc
Y1 (T6)	96.83 b	253.23 bc	3.95 ab	0.78 abc	0.35 a	**38.70 a**	274.66 abcd	3.00 b	260.83 abcde
Y1 (T7)	97.68 b	240.81 bc	3.93 ab	0.64 cd	0.33 a	**36.40 a**	164.50 d	3.00 b	258.33 abcde
Y1 (T8)	100.00 b	246.83 bc	3.86 abc	0.66 bcd	0.31 a	**38.51 a**	199.50 bcd	3.16 b	318.33 ab
Y2 (T5)	92.80 b	216.50 c	3.91 ab	0.76 abc	0.31 a	**39.58 a**	204.83 bcd	3.16 b	311.83 ab
Y2 (T6)	100.00 b	223.33 bc	3.98 ab	0.83 ab	0.33 a	**39.23 a**	273.16 abcd	3.33 b	288.66 abcd
Y2 (T7)	87.70 b	216.66 c	4.03 ab	0.83 ab	0.35 a	**37.51 a**	184.66 cd	3.16 b	278.66 abcde
Y2 (T8)	100.00 b	224.66 bc	4.03 ab	**0.85 a**	0.33 a	**39.50 a**	197.16 cd	3.66 ab	**349.83 a**
Y1 (T1)	**33.60 a**	252.78 bc	3.81 abc	0.70 abcd	0.33 a	**38.33 a**	343.16 ab	3.16 b	220.00 abcde
Y1 (T2)	**35.58 a**	258.68 abc	3.81 abc	0.63 cd	0.33 a	**35.75 a**	**353.00 a**	**4.66 a**	250.00 abcde
Y1 (T3)	**31.73 a**	251.81 bc	3.83 abc	0.83 ab	0.30 a	**36.66 a**	**352.83 a**	3.16 b	130.00 cde
Y1 (T4)	**44.86 a**	244.56 bc	**4.06 a**	0.73 abcd	0.28 a	**37.13 a**	311.83 abc	3.33 b	259.16 abcde
Y2 (T1)	74.80 b	267.00 abc	3.26 d	0.56 d	0.31 a	25.88 b	133.16 d	3.16 b	107.66 e
Y2 (T2)	75.58 b	274.00 ab	3.40 cd	0.56 d	0.30 a	25.51 b	175.50 cd	4.66 a	205.16 abcde
Y2 (T3)	78.32 b	267.66 abc	3.13 c	0.56 d	0.33 a	26.23 b	171.51 cd	3.00 b	142.33 bcde
Y2 (T4)	95.23 b	**306.33 a**	3.56 bcd	0.56 d	0.31 a	23.06 b	156.50 d	3.00 b	113.33 de

TRAT = Treatments, Y1 = 1st year, Y2 = 2nd Year, FP = Flowering percentage, NF = Number of fruits, FD = Fruit diameter, AT = Aril thickness (mm), ST = Skin thickness (mm), FW = Fruit weight (g), BW = Bunch weight (g), SL = Shelf-life (days), KPT = Kilograms per tree (kg).

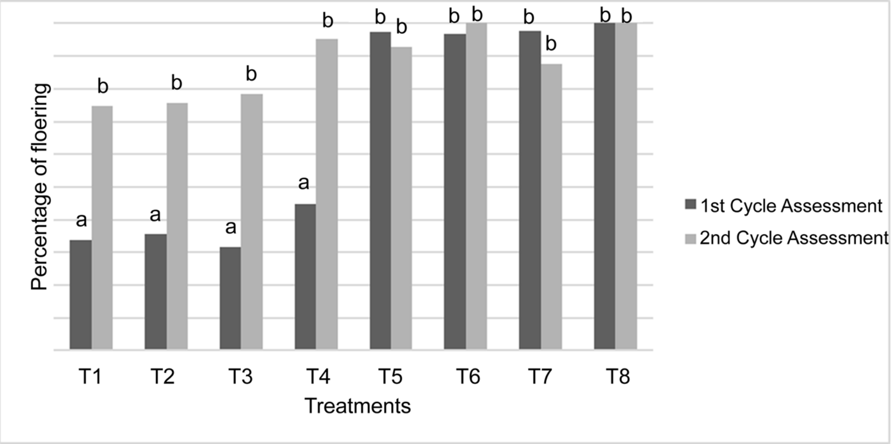

Figure 7. The flowering percentages according to treatments with regard to the 160 vegetative flows selected from each tree during 2010-2011 and 2011-2012. T1 = Irrigation + Pruning + girdling; T2 = Irrigation + Pruning, T3 = Irrigation + Girdling, T4 = Irrigation, T5 = Water stress + Pruning + girdling, T6 = Water stress + Pruning, T7 = Water stress + Girdling, T8 = Water stress. Same letter in a bars shows no significant statistical difference alpha = 0.05.

floral bud development and maximize the number of inflorescences per node [20].

3.2. Fructification Variables

Constant irrigation showed a negative effect on fructification. For example, the fruits did not keep a stable weight during the two observation cycles (**Figure 8**), which undoubtedly such behavior shows clear evidence of the phenomenon of alternancy in rambutan. In this sense, Guardiola [5] mentioned that the relationship existing between flowering and fructification is established in two ways: the level of flowering that determines fruit filling is to the series of mechanisms that vary according to the crop, and together with this, the fruit causes an inhibition of the vegetative development and floral induction. Nevertheless, the fruits of trees with water stress maintained the weight stability. To this regard, Parra *et al.* [16] indicate that handling of the water stress no has direct effect on fruit size, since nutrient storage and biochemical, physiological, anatomical, and morphological mechanisms, that are found in the roots and stems are translocate upon demand, and allow the plant's organs in leaves and fruits, to remain firm and therefore, the physiological processes that allow to maintain the quality and yield fruits can be carried out [21].

3.3. Production Variables

The trees haven with pruning, girdling, water stress, and permanent irrigation had significant effects on production, especially in the trees haven with water stress, since these latter no showed alternancy in rambutan production during the cycles of evaluation (**Figure 9**). Goldschmidt and Monselise [22] mention that the gibberellic acid effect inhibiting on flowering is the responsible for increasing or decreasing the floral differentiation. Given the roots synthesize gibberellins, water stress would be decreasing synthesis and transportation of

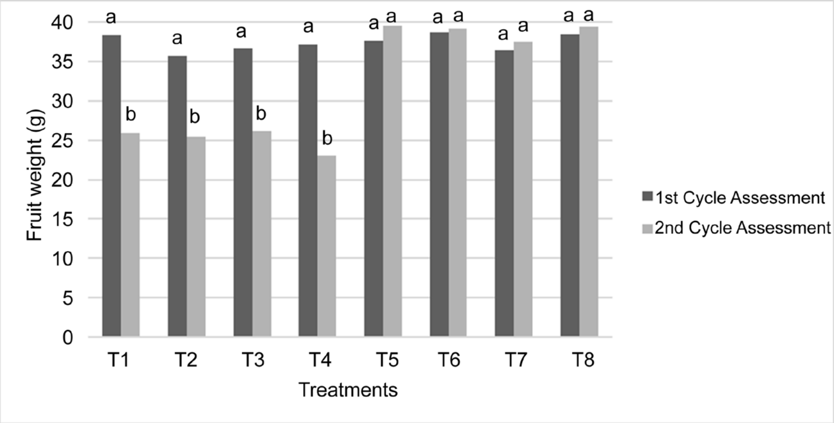

Figure 8. The rambutan fruit weight (g) of each treatment during 2010-2011 and 2011-2012 cycle's. T1 = Irrigation + Pruning + girdling; T2 = Irrigation + Pruning, T3 = Irrigation + Girdling, T4 = Irrigation, T5 = Water stress + Pruning + girdling, T6 = Water stress + Pruning, T7 = Water stress + Girdling, T8 = Water stress. Same letter in a bars shows no significant statistical difference alpha = 0.05.

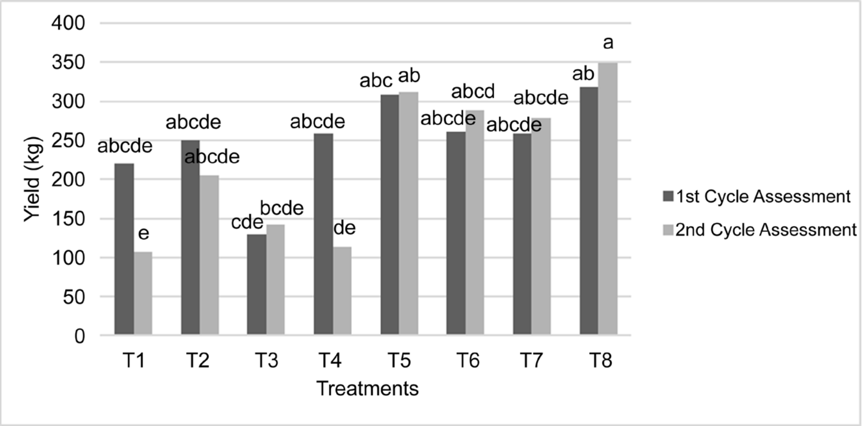

Figure 9. The rambutan yield of each treatment during 2010-2011 and 2011-2012 cycle's. T1 = Irrigation + Pruning + girdling; T2 = Irrigation + Pruning, T3 = Irrigation + Girdling, T4 = Irrigation, T5 = Water stress + Pruning + girdling, T6 = Water stress + Pruning, T7 = Water stress + Girdling, T8 = Water stress. Same letter in a column shows no significant statistical difference alpha = 0.05.

gibberellins to the canopy, thus allowing floral induction through their decrease or absence, and at the same time an increase in the cytokinins [8]. However, tree rehydration is necessary through rain or irrigation, to allow the development of the flowers from generative buds already formed [12] [23].

4. Conclusions

According to the results of this study, agronomical management like pruning, girdling, and water stress has effects on the yield components in rambutan fruit crops. Thus, the impact of the alternancy phenomenon on the yield components of fruit crop can be decreased through some for the studied agronomical practices.

The pruning and girdling practices in rambutan were very unstable when paired with constant irrigation, but when interacting with water stress they showed the effects favorable in yield. Furthermore, the water stress is a practice suggesting that for the rambutan fruit crops, it gives the benefits in the fruit quality, uniformity of flowering differentiation, yield, and the decrease in alternancy.

References

[1] FHIA (2002) Rambutan Production in Honduras. La lima, Cortés, Honduras.

[2] Fraire, V.G. (1999) The Rambutan. Technical Report of the Experimental Station Rosario Izapa CIRPS-INIFAP-SAGDR.

[3] SAGARPA (2009) Statistical Yearbooks of Agricultural Production in Mexico D.F. http://www.sagarpa.gob.mx

[4] FAO (1994) The Cultivation of Rambutan. Italy, Rome.

[5] Guardiola, J.L. (1992) Curd and Fruit Growth. *Levante Agrícola*, **31**, 229-242.

[6] Agustí, M. (2003) Citricultura. 2nd Edition, Editions Mundi Prensa. Spain.

[7] FAO (1987) The Litchi and Its Cultivation, Italy, Rome.

[8] Gaete, M.M. (2007) Evaluation of Different Scratch Dates for Control of Flowering in Clementines (*Citrus clementina* Blanco) cv. Clemenules. Quillota, Chile.

[9] Goren, R. and Monselise, S.P. (1971) Effects of Ringing on Yields of Low-Bearing Orange Trees (*Citrus sinensis* (L.) Osbeck). *Journal of Horticultural Science*, **46**, 435-441. https://doi.org/10.1080/00221589.1971.11514422

[10] Vázquez-Valdivia, V., Pérez-Barraza, M.H., Osuna-García, J.A. and Urías-López, M.A. (2009) Pruning Intensity on Vigor, Fruit Yield and Weight, Mango "Ataulfo". *Revista Chapingo Serie Horticultura*, **15**, 127-132. https://doi.org/10.5154/r.rchsh.2009.15.017

[11] Gil, P.M., Sergent, E. and Leal, F. (1998) Effect of Pruning on Reproductive and Quality Variables on Mango. *Biagro*, **10**, 18-23.

[12] Davenport, T.L. (1990) Citrus Flowering. *Horticultural Reviews*, **12**, 349-395.

[13] Davies, F.S. and Albrigo, L.G. (1994) Citrus. CAB International, Wallingford, 254.

[14] Dell'Amico, R.J.M., Domingo, R.M., Pérez, P.A., García, M., Peñalver, M., Villanueva, F. and Puerto, P. (2012) Effect of Water Stress on the Final Development of Mandarin Fruit "Fortune". *Cultivos Tropicales*, **33**, 63-68.

[15] Treeby, M.T., Henriod, R.E., Bevington, K.B., Milne, D.J. and Storey, R. (2007) Irrigation Management and Rootstock Effects on Navel Orange [*Citrus sinensis* (L.) Osbeck] Fruit Quality. *Agricultural Water Management*, **91**,24-32. https://doi.org/10.1016/j.agwat.2007.04.002

[16] Parra-Quezada, R.A., Robison, T.L., Osborne, J. and Parra-Bujanda, L.B. (2008) Effect of Fruit Loading and Water Deficit on Apple Quality and Production. *Revista Chapingo Serie Horticultura*, **14**, 49-54.

[17] Martínez, A.F., Mesejo, C.J.M., Almela, V. and Agustí, M. (2004) Restrictions on the Exogenous Control of Flowering in Citrus, *Acta Horticulturae*, **632**, 91-98. https://doi.org/10.17660/ActaHortic.2004.632.11

[18] Chaikiattiyosa, S., Menzel, C.M. and Rasmussen, T.S. (1994) Floral Induction in Tropical Fruit Trees: Effects of Temperature and Water Supply. *Journal of Horticultural Science*, **69**, 397-415. https://doi.org/10.1080/14620316.1994.11516469

[19] Menzel, C.M., Rasmussen, T.S. and Simpson, D.R. (1989) Effects of Temperature and Leaf Water Stress on Growth and Flowering of Litch (*Litchi chinensis* Sonn.) *Journal of Horticultural Science*, **64**, 739-752. https://doi.org/10.1080/14620316.1989.11516017

[20] Drinnana, J.E. and Menzelb, C.M. (1995) Temperature Effects Vegetative Growth and Flowering of Coffee (*Coffea arabica* L.). *Journal of Horticultural Science*, **70**, 25-34. https://doi.org/10.1080/14620316.1995.11515269

[21] Naor, A., Klein, I., Hupert, H., Grinblat, Y., Peres, M. and Kaufman, A. (1999) Water Stress and Crop Level Interaction in Relation to Nectarine Yield, Fruit Size Distribution, and Water Potentials. *Journal of the American Society for Horticultural Science*, **124**, 189-193.

[22] Goldschmidt, E.E. and Monselise S.P. (1972) A Role for Carbohydrate Levels in the Control of Flowering in Citrus. *Scientia Horticulture*, **26**, 159-166. https://doi.org/10.1016/0304-4238(85)90008-1

[23] Nir, I., Goren, R. and Leshem, B. (1972) Effects of Water Stress, Gibberellic Acid, and 2-Chloroethyl Trimethylammonium Chloride (CCC) of Flower Differentiation in "Eureka" Lemon Trees. *Journal American Society Horticultural Science*, **97**, 774-778.