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Influence of Changing Rainfall Patterns on the Yield of Rambutan (*Nephelium lappaceum* L.) and Selection of Genotypes in Known Drought-tolerant Fruit Species for Climate Change Adaptation

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ABSTRACT

In fruit crop production, rainfall, water stress, temperature, and wind are key variables for success, and the present changes in rainfall patterns could affect the flowering and yield of the rambutan (*Nephelium lappaceum* L). Other fruit species like macopa (*Syzygium samarangense*), siniguelas (*Spondias purpurea*), and native santol or cotton fruit (*Sandoricum koetjape*) remain productive despite extreme climatic changes. This study assessed the influence of rainfall on rambutan yield and evaluated and selected tree genotypes of known drought-tolerant fruit species. Rambutan yield in a selected farm in Calauan, Laguna, Philippines, dropped remarkably from 152.2 kg/tree in 2008 to 8.6 kg/tree in 2009. This reduction could be attributed to the high rainfall in April 2009 at 334.4 mm, and possibly other environmental factors like temperature, relative humidity, solar radiation, and strong wind. Furthermore, wet months in 2009 also inhibited the flowering of rambutan. However, a low yield obtained in 2010 at 45.5 kg/tree could be partly attributed to the very low rainfall in May 2010 at only 9.1 mm. On the other hand, in relation to changing climate, selection of tree genotypes for use as varieties in known drought- and flood-tolerant fruit species based on important fruit qualities like sweetness, juiciness, and high edible portion was done. Among 103 macopa genotypes, Mc-13, 43, and 91 were selected and the best (i.e., Mc-13) had sweet (7.15 °Brix) and crispy fruits weighing 49.44 g, creamy white (RHCC 155 A), and had high edible portion (EP, 93.22%). Among 114 siniguelas genotypes, Sg-41,

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42 and 105 were selected and the best selection (i.e., Sg-41), had sweet (12.50 °Brix) and juicy fruit weighing 20.42 g, ruby red (RHCC 59 A), and had high EP (83.27%). Among 101 native santol genotypes, Sn-47, 59, and 74 were selected and the best selection (i.e., Sn-59) had relatively sweet (5.56 °Brix) and juicy fruits weighing 51.96 g, maize yellow (RHCC 21 B), and had high EP (82.20%). These selections are recommended for planting in marginal and drought-prone areas for climate change adaptation. In addition, they can fare better in flooded areas in the face of climate change since they are very hardy, and have woody and strong roots that can resist strong wind and increasing amount of rainfall brought about by climate change.

Keywords: Climate change, rainfall, macopa, native santol, rambutan, siniguelas

LAYMAN'S ABSTRACT

In fruit production, the rainfall, water stress, temperature, and wind are important variables for success. However, the changing rainfall patterns could affect the flowering and yield of rambutan. Other fruit species like macopa, siniguelas, and native santol remain productive despite extreme climatic changes. In relation to this, the influence of rainfall on rambutan yield and evaluation of genotypes of known drought-tolerant fruit species were conducted in this study. The rambutan yield in a farm in Calauan, Laguna, Philippines, decreased remarkably from 152.2 kg/tree in 2008 to 8.6 kg/tree in 2009. This could be due the high rainfall in April 2009 at 334.4 mm, and possibly other environmental factors like temperature, relative humidity, solar radiation, and strong wind. In addition, the low yield in 2010 at 45.5 kg/tree could be due to the very low rainfall in May 2010 at only 9.1 mm. In relation to climate change, selection of genotypes for future use as varieties in drought- and flood-tolerant fruit species based on sweetness, juiciness, and high edible portion was done. Among 103 macopa genotypes evaluated, three were selected (Mc-13, Mc-43, and Mc-91) and the best Mc-13, is sweet and crispy, weighs 49.44 g, creamy white and had high edible portion (EP). Among 114 siniguelas genotypes selected, Sg-41, Sg-42 and Sg-105 were selected, and the best selection Sg-41, is sweet, juicy, weighs 20.42 g, ruby red and had high EP. In addition, among 101 native santol genotypes evaluation, Sn-47, Sn-59, and Sn-74 were selected and the best selection Sn-59 is relatively sweet, juicy, weighs 51.96 g, maize yellow, and had high EP. These selections can be planted in marginal and drought-prone areas for climate change adaptation. Also they can fare better in flooded areas because they are very hardy, and have woody and strong roots that can resist strong wind and increasing amount of rainfall in the face of climate change.

INTRODUCTION

Climate change causes increases in the temperature of the earth, carbon dioxide concentration in the atmosphere, destruction of the ozone layer, and more intense hydrologic events causing flooding during typhoons (Lansigan 2009). This causes global warming that brings sea level rise, changes in hydrologic regimes, and more frequent and more intense extreme events like El Niño and La Niña. These adverse conditions brought about by climate change have pervasive effects on crop productivity and yield, poses a serious threat to the agricultural sector and consequently a threat to the country's food security (DA-BAR 2011).

In fruit crops production, the onset of rain, duration of the rainy period, water stress following the vegetative stage (e.g., flowering), occurrence of extreme events like strong wind, intense rainfall, and high temperature are the key variables for determining success. Some fruit species like rambutan, avocado, and sugar apple are affected by climate change because their flowering behavior changes and fruit yield decreases significantly either during El Niño or La Niña (Magdalita 2012).

The rambutan (*Nephelium lappaceum* L.) is a tropical fruit species that thrives best in humid and hot regions with rainfall that is evenly distributed throughout the year. It has fruited successfully in areas with pronounced dry season if irrigated during the reproductive period. It is unable to withstand cold temperature, and its growth is thus restricted to areas with an elevation below 700 m. The moisture content of the soil should always be maintained at a high level so that the best places to grow rambutan are those with evenly distributed rainfall or where the dry season is short (Coronel 1998). It also grows well from sea level to medium altitudes in places with a long rainy season (Coronel 2011). However, with the occurrence of changing rainfall patterns in places where the rambutan is well-adapted like in Calauan, Laguna, it has been observed that there were corresponding changes in the flowering and fruiting behavior. Hence, one of the objectives of this study is to find out if rainfall has an influence on flowering of rambutan in Calauan. This study used a government-owned orchard found in the area, wherein the researchers have an access to conduct the study and the only orchard with a complete data on rambutan yield for the last ten years, needed in studying climate change, hence, the reason for using only one experimental area using purposive sampling.

Before selections of these known drought-tolerant fruit species can be made available, they first need to be evaluated for fruit qualities. The native santol, *Sandoricum koetjape* (Burm. F. Merr.), is widely distributed in the Philippines and is esteemed by many people as a fresh fruit. It is a potential money earner for the country because it can be manufactured commercially into preserve, candies, chutney, jam, and jelly (Coronel 1998). At this time of drought and sometimes flooding, native santol can be tapped for planting since it is very hardy, vigorous, and has a very strong root system that can thrive successfully in dry and humid areas. Two varieties exist: the native santol and the big-fruited "Bangkok" santol. Because of so much interest in the "Bangkok" santol, the native santol has been neglected. However, efforts must be focused on the selection of native santol because of its very hardy nature that can stand either drought or flooded conditions aside from being a fresh fruit having sweet aril and pulp.

Macopa, *Syzygium samarangense* (Blume) Merr. & Perr., a very prolific tree and a popular symbol of "good luck," is being grown in many frontyards of Filipino homes. It is another attractive summer fresh fruit because of its crunchy and striking red, maroon, pink, white, or green color. The astringent bark is made into a mouthwash, the dried powder leaves are applied to cracked tongue, and the root is used as a diuretic. It grows well from sea level to 750 m elevation with well distributed rainfall, although it also grows successfully in both dry and humid areas (Coronel 1998). This makes the macopa another potential income earner despite extreme changes in weather conditions. Nevertheless, selection/s that are sweet, juicy, and small-seeded are still limited.

The siniguelas, *Spondias purpurea L.,* a very hardy and prolific tree is one of the most popular seasonal fruit during summer in the Philippines because of its attractive color, delicious taste, and wholesome and excellent flavor. The ripe fruit has a ready market, while the mature green fruit is made into pickles and used as the souring ingredient for cooking "sinigang." It grows equally well in both dry and wet places, but better quality fruits are apparently produced in places with long dry season. Siniguelas grows successfully in dry areas that are otherwise not suited to many fruits (Coronel 1998), thus making it another potential income generator. While the siniguelas is clonally propagated, selections of bud mutant with big fruits, sweet and small-seeded are wanted.

While the effect of rainfall on rambutan flowering is important to fruit production, similarly, the evaluation of known drought-tolerant fruit species like macopa, siniguelas, and native santol needs to be done since they are also important for fruit production in the face of climate change. Particularly, specific genotypes in each species with desirable fruit qualities are also of paramount importance in the future production of these lesser known fruits because they are drought-resistant, hence selections of these species were also identified in this study. They can be used and traded as alternative fruits during drought periods. Hence, this study was conducted to assess the influence of changing rainfall patterns on the yield of rambutan in Calauan, Laguna, and evaluate, select, and identify genotypes with good fruit qualities in known drought-tolerant fruit species including macopa, siniguelas, and native santol.

MATERIALS AND METHODS

The annual yield of rambutan for a 12-year period was obtained from a selected orchard located in Lamot II, Calauan, Laguna, Philippines. The site is a government-owned orchard, fenced, and planted to several species of fruit crops including rambutan, lanzones, caimito, pomelo, banana, macopa, and other fruit crops. A propagation nursery is also located in the site. The area is flat, rainfed, and has clay loam soil. The orchard is presently being managed by the nursery chief, Mario Tenorio. The total rambutan yield was taken from 2001 to 2012 fruiting trees growing in a portion of a 15-ha orchard planted to different fruit crops. The number of rambutan trees growing in the orchard on a year basis from 2001 to 2012, respectively is as follows: 300, 310, 353, 266, 310, 296, 164, 134, 134, 154, 242, and 143. In addition, the annual rainfall accumulation from 2001 to 2012 was obtained from the University of the Philippines Los Baños National Agrometeorological Station in Los Baños, Laguna. Since this is the only weather station available in the area, it was used and assumed that there are small differences in the climatic pattern between the two municipalities (PAGASA 2012). Calauan is very close to Los Baños, Laguna, which is only about 10 km away via the national highway going to San Pablo City. The rambutan yield data from 2001 to 2012 were used for correlation analysis with the rainfall data using Pearson r correlation (Gomez and Gomez 1984).

In addition, drought-tolerant fruit crop species including macopa, siniguelas, and native santol, were identified based on literature (Coronel 1998). While excessive moisture from high rainfall during La Niña is a known effect of climate change, the other scenario being experienced is the occurrence of very low soil moisture during El Niño. Because of this, an investigation on the utilization of drought-tolerant species becomes a truly important component study. More than 100 trees of each species growing in different places primarily in Laguna, Batangas, and Cavite were selected and used as sources of ripe fruits for evaluation of selected fruit characters.

Selection of trees and collection of fruits for macopa, siniguelas, and native santol was conducted from March to June 2012. The places and owners of the tree/s where the fruit samples of the different trees of macopa, siniguelas and native santol were collected were indicated in Tables 1, 2, and 3.

Table 1. Different macopa genotypes or trees where fruit samples were obtained, the location, and the owner of the tree

Tree Genotypes	Location	Owner of the Tree
Mc-01 & Mc-02	Sta. Maria, Talisay, Batangas	Bobet Luna
Mc-03 to Mc-06	Caloocan, Talisay, Batangas	Lucita Ramos, Cynthia Carandang & Archie Trinidad
Mc-07	Ambulong, Talisay, Batangas	Gigit Panganiban
Mc-08 to Mc-10	Santor, Tanauan City, Batangas	Pastor Landicho & Ethel Vivas
Mc-11	Darasa, Tanauan City, Batangas	Rose Pecho
Mc-12	Luta Sur, Malvar, Batangas	Evelyn Viaje Ledesma
Mc-13	Inisluban, Lipa City, Batangas	Aristides Lindog
Mc-14 & Mc-15	Tangway, Lipa City	Tangway Elem. School
Mc-16	San Felix, Sto. Tomas, Batangas	Orlando Maloles
Mc-17	Talahiban, Sta. Cruz, Bay, Laguna	Dominador Hernandez
Mc-18	Masaya, Bay, Laguna	Cleotilde Caldo
Mc-19 to Mc-22	Lamot II, Calauan, Laguna	Sta. Cruz Nursery c/o Mr. Tenorio
Mc-23	Orchard, College of Agriculture, College, Laguna	UPLB
Mc-24	BPI, San Andres Bukid, Manila	BPI, Manila
Mc-25	Imus, Cavite	Dr. Emer S. Borromeo
Mc-26	Ambulong, Talisay, Batangas	Adel Rapadas
Mc-27 to Mc-29	Santor, Tanauan City, Batangas	Fely Macadilo & Ricky Cariño
Mc-30	Balayhangin, Calauan, Laguna	Guillermo del Valle
Mc-31 to Mc-33 & Mc-35	Lamot II, Calauan, Laguna	Sta. Cruz Nursery c/o Mr. Tenorio
Mc-34	Calamba City, Laguna (beside National Road in Licheria)	Calamba City Council
Mc-36	Balayhangin, Calauan, Laguna	Corazon Melba Borton
Mc-37 & Mc-38	Tanauan City, Batangas	Norma Perez & Lilibeth Dayta
Mc-39	Talaga, Tanauan City, Batangas	Dominga Robles
Mc-40 & Mc-41	Sto. Cristo, San Jose, Batangas (T#1&3)	Sto. Cristo Brgy. Council
Mc-42	Darasa, Tanauan City, Batangas	Dolor Magsino
Mc-43 to Mc-46	Sto. Cristo, San Jose, Batangas	Clara Mendoza, Conchita Atienza, Pablo Mendoza & Cleofe Mendoza
Mc-47	Maraouy, Lipa City, Batangas	Aristides Lindog
Mc-48	351 Vallejo St., Sta. Rosa, Laguna	Mercy Alvarez
Mc-49 to Mc-53	IPB Fruit & Ornamentals Section	CSC & IPB, UPLB, CA
Mc-54	Social Garden, UPLB	UPLB
Mc-55	Raymundo Subdivision, Los Baños, Laguna	Laila Perez

Table 1. Different macopa genotypes or trees where fruit samples were obtained, the location, and the owner of the tree (Cont'd.)

Tree Genotypes	Location	Owner of the Tree
Mc-56 & Mc-57	Falklands, CSC & IPB (T#1&2)	UPLB
Mc-58 & Mc-59	Magnetic Hill, Los Baños, Laguna (Non-seeded variety)	Danilo Ubaldo
Mc-60 to Mc-62	San Antonio, Pila, Laguna	Gil Garcia, Jose Lat & Carmelita Hernandez
Mc-63	Timugan, Los Baños, Laguna	Mrs. Umali
Mc-64	Masiit, Calauan, Laguna	Mercy Dreje
Mc-65 to Mc-67	Imok, Calauan, Laguna	Alberto Peñaranda & Rosalinda Alcantara
Mc-68	Balayhangin, Calauan, Laguna	Aurora San Gabriel
Mc-69	Pansol, Calamba City, Laguna	Johnny Amparo
Mc-70	Pulo, Indang, Cavite	Delma Guevarra
Mc-71 & Mc-72	Bagong Pook, San Jose, Batangas	Lina Harina & Yoyong Harina
Mc-73	Banay-Banay II, San Jose, Batangas	Aquilino Lizardo
Mc-74	Pulo, Indang, Cavite	Analie R. Mateo
Mc-75	Sungay East, Tagaytay City	Loraine Cumabig
Mc-76 & Mc-77	Carasuchi, Indang, Cavite	Felix Feraer & Ester Rosela
Mc-78	Mendez, Cavite	Asuncion Encarnacion
Mc-79 & Mc-80	San Vicente, San Pablo City	Amada Ibarra & Glicerio Perinog
Mc-81 & Mc-83	San Mateo, San Pablo City	Cristina Reyes & Dennis Amante
Mc-82	San Antonio, Quezon	Averina Vicedo
Mc-84	San Francisso, San Pablo City	Hick Cayton
Mc-85	Santa Maria, San Pablo City	Maita Fajardo
Mc-86 to Mc-88	Mahanadyong, Taysan, Batangas (T#1,3&4)	Amada Ibarra
Mc-89	Bagong Kalsada, Calamba City, Laguna	Rodolfo Jimenez
Mc-90 to Mc-93	Magnetic Hill, Los Baños, Laguna (T#1-4)	Emma Leonzon
Mc-94	Maahas, Los Baños, Laguna	Miguel Lauang
Mc-95 & Mc-96	San Juan, San Pablo City	Billy Matandig & Concepcion Federizo Cortez
Mc-97 & Mc-98	Padre Garcia, Batangas (T#1&2)	Paolo Sison
Mc-99	Sto. Domingo, Bay, Laguna	Mr. Ordobesa
Mc-100	CSC & IPB Compound	UPLB
Mc-101 & Mc-102	San Isidro, Batangas City	Efren Forto
Mc-103	San Pablo Nayon, Sto. Tomas, Batangas	Celia Mansit

Table 2. The different siniguelas genotypes or trees where fruit samples were obtained, their location, and the owner of the tree

Tree Genotypes	Location	Owner of the Tree
Sg-01 to Sg-09	Bagong Pook, San Jose, Batangas (T#14, 5, 10, 9, 15, 7, 1, 11 & 8)	Rodel de la Peña & Lina Harina
Sg-10	Sitio Paligawan, Taysan, Batangas	Lydia Lontoc
Sg-11 & Sg-12	Paligawan, Taysan, Batangas (T#1 & 2)	Eleuterio Ramirez
Sg-13	Taysan, Batangas	Nicanor Tolentino
Sg-14	Sitio Paligawan, Taysan, Batangas (T#3)	Eleuterio Ramirez
Sg-15 to Sg-17, Sn-21, Sg-26 & Sg-31	Sto. Niño, Taysan, Batangas (T#1, 2, 3, 4, 5, 6)	Ciriaco, Lontoc & Lydia Lontoc
Sg-18 & Sg-19	Taysan, Batangas (T#1 & 2)	Art Cayap
Sg-20 & Sg-25	Pansol, Padre Garcia, Batangas	Ernesto Padilla
Sg-22, Sg 28, Sg-32 & Sg-33	Mahanadyong, Taysan, Batangas	Manny Ona, Buddy Cariño & Nicanor Tolentino
Sg-23	Paligawan, Taysan, Batangas (T#4)	Eleuterio Ramirez
Sg-24	National Highway, San Antonio, Quezon	Municipality of San Antonio
Sg-27	Paligawan, Taysan, Batangas (T#5)	Eleuterio Ramirez
Sg-29	Mataas na Lupa, Taysan, Batangas	Anadeto Evangelo
Sg-30	Namuco Rosario, Batangas	Lorna Mendoza
Sg-34	Mataas na Lugar, Taysan, Batangas	Violeta Untalan
Sg-35, Sg-36, Sg-41 to Sg 45	Bacao, Taysan, Batangas (T#6, 7, 8, 55, 69, 70, 71 & 95)	Benjamin Africa & Martin Atcheco
Sg-37 & Sg-38	Malapad na Parang, Lobo, Batangas	Gabriel Biacaro & Marcelino Manalo
Sg-39 & Sg-40	Pinya, Taysan, Batangas	Adelaida Magtibay & Alejandra Plata
Sg-46, Sg-48 & Sg-49	Lobo II, Batangas (T# 9, 10 & 14)	Apolinario Catipon, Benjamin Africa & Gabriel Binuro
Sg-47	Bacao, Taysan, Batangas (T# 9)	Benjamin Africa
Sg-50 & Sg-51	Pinatubo, Taysan, Batangas	Adelaida Magtibay
Sg-52 & Sg-53	Sto. Niño, Taysan, Batangas (T# 69 & 70)	Cristina Macatangay
Sg-54 to Sg-87	Highway, Taysan, Batangas (T#13, 16, 19, 51, 66, 25, 20, 22, 24, 27, 30, 31, 32, 33, 34, 36, 39, 40, 41, 26, 43, 46, 48, 52, 54, 56, 58, 59, 60, 63, 64, 65, 68, 69)	Remedios Azoilo, Martin Ateneco, Roger Azoilo, Rodrigo Azoilo & Apolonio Catipon
Sg-88 to Sg-106	Seaside, Lobo, Batangas (T# 12, 16, 17, 18, 23, 28, 29, 42, 44, 47, 49, 50, 53, 57, 67, 71, 75, 91)	Reynaldo Hernandez, Remedios Azoilo, Martin Atcheco & Renato Catipon
Sg-107 to Sg-114	San Miguel, Lobo, Batangas (T# 81, 84, 85, 88, 89, 91, 98)	Gina Adoyo & Apolonio Macatangay

Table 3. The different native santol genotypes or trees where fruit samples were obtained, their location, and the owner of the tree

Tree Genotypes	Location	Owner of the Tree
Sn-01	Barangay Uno, Tanauan, Batangas	Angelito Javier
Sn-02 & Sn-03	Santor, Tanauan, Batangas (T# 1&2)	Myrna Bathan
Sn-04 & Sn-05	Janopol Occidental, Tanauan, Batangas (T# 1&2)	Karen Flores
Sn-06 & Sn-07	De Leon's Nursery, Talisay, Batangas (T# 1&2)	Asuncion Carandang
Sn-08 to Sn-11	Janopol, Tanauan, Batangas (T#1-4)	Johsua Landicho & Mauro Landicho
Sn-12 to Sn-16	Bitin, Bay, Laguna (T# 1-5)	Eric Bautista
Sn-17	Makban Geothermal, Bay, Laguna	Cesar Alcantara
Sn-18 to Sn-25	Puypuy, Bay, Laguna (T# 1-9)	Romel Punzalan & Alex Vermi
Sn-26 to Sn-33	Riverside, Puypuy, Bay, Laguna (T#1-8)	Raymundo Salvador & Barak Virgilio
Sn-34 to Sn-39	Roadside, Puypuy, Bay, Laguna (T# 1-6)	Fe Batino, Efren Pura, Jehova Witnesses Church & Sofia Paril
Sn-40	Furniture Shop, Puypuy, Bay, Laguna	Jerry Peñaranda
Sn-41 & Sn-42	Calauan, Laguna (T# 1&2)	Councilor Gulay
Sn-43 to Sn-50	San Juan, Kalayaan, Laguna (T# 1-8)	Gregorio Macanilo, Pingot Lagumloay, May Gonzales & Wenceslao Macalintal
Sn-51 to Sn-55	Pagsanjan, Laguna (T# 1-5)	Iglesia Ni Kristo Church, Teresita Nadal, Weny Macalintal & Joseph Quizon
Sn-56	Gatid, Sta. Cruz, Laguna	Susan Maro
Sn-57 & Sn-58	Kalayaan, Laguna (T# 2&3)	Ariel Wenceslao
Sn-59 to Sn-76	Labuin, Sta. Cruz, Laguna (T#1-18)	Lotlot Banoknok, Iglesia Ni Kristo Church & Irene Baltazar
Sn-77 to Sn-84, Sn-88 & Sn-89, Sn-91, Sn-93, Sn-95 to Sn-99	UPLB Compound, College, Laguna (T# 1-17)	UPLB
Sn-85 to Sn-87, Sn-90, Sn-92, Sn-94, Sn-96, Sn-101	Jamboree, Los Baños, Laguna (T# 1, 3, 5-10)	Boy Scouts of the Philippines
Sn-95	UPCO (T# 1)	UPLB
Sn-100	Inclineville, UPCO	UPLB

Twenty to thirty fruit samples were gathered from each tree and taken to the laboratory for analysis. In all three fruit species, fruit weight, fruit length, fruit width, total soluble solids, and percent edible portion were evaluated. Fruit weight (g) was determined using a triple beam balance, while fruit length (cm) and width (cm) were measured using a vernier caliper. A hand-held refractometer was used to measure the total soluble solids (TSS, °Brix), while the edible portion (%) was determined by dividing the edible portion by the total fruit weight and the quotient was multiplied by 100. The colors of the skin and flesh were characterized based on the Colour Chart of the Royal Horticultural Society (RHS) of London (RHS 2007). Based on the evaluation of fruit qualities, the best three genotypes were selected and identified.The selection of the best genotypes of macopa, siniguelas, and native santol was based on the standard or criteria focusing on fruit qualities and found on the "Guidelines for Evaluation, Selection, and Registration of New Fruit Crop Varieties" developed by the Fruit Crops Technical Working Group (FCTWG) of the National Seed Industry Council (FCTWG-NSIC 2009).

In selecting the three best macopa genotypes, the criteria set by the FCTWG-NSIC (2009) must be satsified. According to these criteria, the whole fruit is large (> 50 g); the shape is widely obovoid; the skin or peel color at maturity is either pink, maroon, or red; and the texture is smooth and shiny. The flesh color is creamy white; texture is crispy, smooth, and firm; flesh aroma is mild; flavor is sweet to sub-acid (> 15°Brix) and juicy; while the seed is small (≤ 1 g) and the fruit is either seedless or has one seed only.

In the case of the native santol, the following selection criteria were used: the fruit is either large (>100 g), medium (80-100 g), or small (<80 g); the fruit shape is spheroid; the skin color is yellow to yellow orange; and the skin texture is smooth. Pulp is either thick (> 6 mm) or intermediate (4-6 mm); texture is fine and smooth and pulp flavor is sub-acid; the flavor of the aril is sub-acid to sweet (>18°Brix); color is cottony white, juicy, thick (> 5 mm); and has none to scanty fibers. The seed is small (<2.5 g) and the percent edible portion is high (> 40%).

On the other hand, in selecting the best three genotypes of siniguelas, the following criteria were used: the whole fruit is big (> 15 g), the shape is oblong, the skin or peel color at maturity is dark brown, and the texture is smooth and shiny. In addition, the flesh color is yellow orange, texture is smooth and firm, no fibers, flavor is sweet to sub-acid (> 10°Brix) and juicy, while the seed is small (≤ 3 g).

The mean, range standard deviation, and Shannon-Weaver diversity index (H') were taken for all fruit characters evaluated. The Shannon-Weaver diversity index was used to estimate phenotypic diversity and guide to selecting the best genotypes. It was computed for the different characters using the method of Tolbert and others (1979) given below.

$$H' = -\sum pi(\log 2 pi)/\text{Log}2n$$

where pi = frequency of each descriptor state, n = the number of states per descriptor.

The formula gives H' within 0-1.0 and the value nearest to 1.0 is most diverse. For the Shannon-Weaver diversity index, a value of 0.80-1.0 is arbitrarily considered high to indicate a wide variability, while a value of 0.20-0.79 is considered low, indicating narrow variability.

RESULTS AND DISCUSSION

Effect of Rainfall on Rambutan in Calauan, Laguna

Rambutan thrives well in tropical and humid regions with high rainfall over a fairly long season. The dry season should not last much over three months. It can live from sea-level to 500 m or even up to 600 m. It is also very sensitive to water stress, but it cannot withstand poor drainage condition. In Southeast Asia, rambutan flowers normally appear shortly after the dry season when the climate is highly influenced by monsoon. In the Philippines, rambutan flowering occurs from late March to early May and the fruits mature from July to October or occasionally to November (Morton 1987).

A dry month is defined as one with a total rainfall of less than 50 mm (PAGASA 2010). As shown in Figure 1, the climate of Los Baños and of nearby municipalities have two distinct seasons similar to a Type I climate (i.e., dry from January to April and wet during the rest of the year) (PAGASA 2010). Majority of rambutan production in the Philippines are found in areas with distinct wet and dry seasons (Type I and Type III) including Laguna. It has also fruited successfully in areas with a pronounced dry season (Coronel 1998).

Figure 2 shows the annual rambutan yield from 2001 to 2012 in Calauan and the amount of rainfall for April 2001 to 2012. The yield of rambutan remarkably dropped from 152.2 kg/tree in 2008 to 8.6 kg/tree in 2009. Analysis of monthly rainfall data from 2001 to 2012 revealed that the flowering of rambutan could have been affected by the abnormally high rainfall at 334.4 mm observed for the month of April 2009 due to the La Niña phenomenon. Furthermore, other environmental factors including temperature, relative humidity, solar radiation, and wind contributed to the decrease in rambutan yield. In this month, a moderate negative correlation (r=-0.64) between rambutan yield with rainfall was detected (Table 5). This negative correlation suggests that while there is an increase in the amount of rainfall, there is a corresponding decrease in the amount of yield of rambutan. The month of April is usually considered a dry month with a normal rainfall of 41.6 mm from 1971 to 2000 (Figure 2). However, in this case, the reverse happened where there is high rainfall in April (Figure 2). In addition, the yield also decreased from 152 kg/tree in 2008 to 9 kg/tree in 2009 (Table 5). In relation to this, there is a moderate negative correlation (r=-0.51) between yield and amount of rainfall (Table 5). This negative moderate correlation also partially implies that while the amount of rainfall is increased, the yield of rambutan decreased. This is shown in the data where in March 2009 the amount of rainfall increased to 127.3 mm (Table 4) when, in fact, March should be a dry month instead, which is a typical effect of climate change. In addition, other weather factors like temperature, relative humidity, and solar radiation may also have affected flowering of rambutan. Corollary to this, it has been reported that excessive rainfall before the expected flowering of rambutan is detrimental since it promotes vegetative growth rather than flowering (Tindall and others 1994).

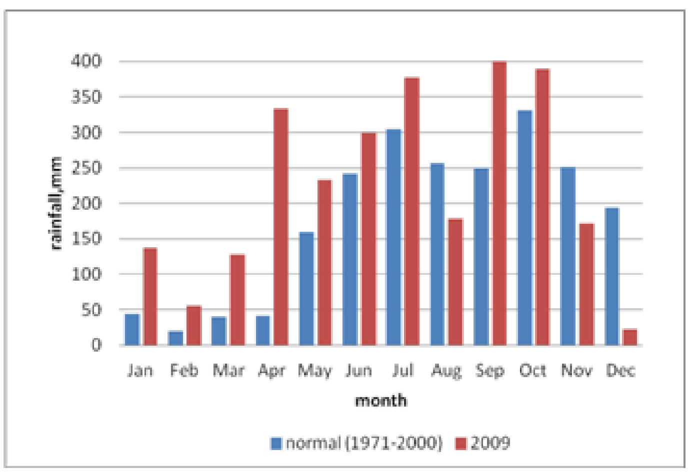

Figure 1. Normal rainfall (mm) from 1971 to 2000 and monthly rainfall in 2009 at the University of the Philippines Los Baños National Agromet Station, College, Laguna, Philippines. Normal rainfall is the average of the rainfall values over a thirty-year period and rainfall may very often be either well-above or well-below the seasonal average or normal (Williams 2008). Each bar corresponds for the month from 1971 to 2000 and for 2009.

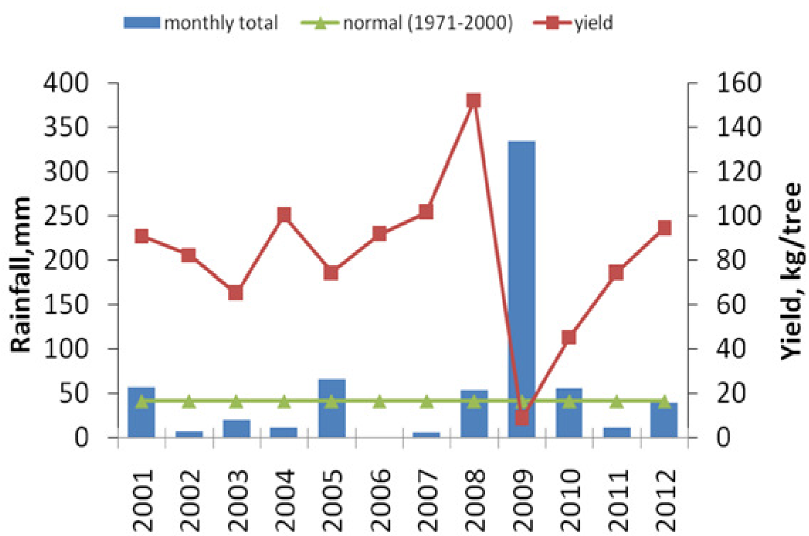

Figure 2. Amount of rainfall (mm) for April 2001 to 2012 and the annual rambutan yield in Calauan, Laguna, Philippines. Each bar represents the amount of rainfall for April of each year.

Table 4. Amount of monthly rainfall (mm) from 2001 to 2012 showing the critical amount during dry (*) and wet (**) months prior to and at the start of flowering of rambutan

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001	7.1*	132.9**	43.6*	57.9**	191.0**	243.6**	252.7**	278.8**	127.5**	168.6**	261.0**	187.4**
2002	16.4*	11.8*	16.1*	6.8*	131.6**	88.6**	621.6**	214.7**	166.0**	188.9**	173.8**	80.9**
2003	7.8*	3.2*	14.5*	19.9*	350.4**	131.1**	356.0**	180.1**	189.5**	87.4**	226.2**	27.2*
2004	19.0*	51.2**	4.3*	11*	128.9**	249.0**	409.2**	236.5**	114.4**	152.1**	342.6**	60.1**
2005	16.6*	17.4*	45.0*	65.5**	61.20**	79.5**	110.8**	192.3**	298.3**	242.4**	118.6**	397.0**
2006	140.5**	39.6*	54.6	0.7*	143.8**	243.7**	285.9**	208.8**	637.1**	80.6**	198.5**	265.3**
2007	38.1*	15.0*	47.7*	6.4*	69.5**	75.4**	228.3**	469.1**	161.0**	226.6**	451.1**	199.2**
2008	164.5**	62.5**	4.7*	54.1**	211.8**	319.3**	165.9**	238.8**	149.6**	174.9**	162.1**	184.0**
2009	136.6**	56.4**	127.3**	334.4**	233.2**	299.7**	377.0**	178.1**	502.9**	389.4**	171.2**	23.4*
2010	15.3*	3.0*	26.2*	56.2**	9.1*	171.2**	762.5**	211.3**	124.3**	368.7**	159.8**	170.0**
2011	49.7*	6.1*	67.9**	11.4*	143.2**	476.1**	302.6**	294.4**	242.4**	275.6**	290.6**	254.1**
2012	81.6**	86.5**	116.4**	40.0*	178.5**	72.3**	464.4**	486.1**	136.5**	337.2**	76.7**	340.0**

* Dry month
** Wet month

Table 5. The yield of rambutan in Calauan, Laguna from 2001 to 2012 and the monthly rainfall from January to December (2001-2012). The correlation of yield and rainfall is also shown.

Year	Yield (kg/ tree)	Monthly rainfall (mm)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
2001	91	7.1	132.9	43.6	57.5	191	243.6	252.7	278.8	127.5	168.6	261	187.4
2002	82	16.4	11.8	16.1	6.8	131.6	88.6	621.6	214.7	166	188.9	173.8	80.9
2003	65	7.8	3.2	14.5	19.9	350.4	131.1	356	180.1	189.5	87.4	226.2	27.2
2004	100	19	51.2	4.3	11	128.9	249	409.2	236.5	114.4	152.1	342.6	60.1
2005	75	16.6	17.4	45	65.5	61.2	79.5	110.8	192.3	298.3	242.4	118.6	397
2006	92	140.5	39.6	54.6	0.7	143.8	243.7	285.9	208.8	637.1	80.6	198.5	265.3
2007	102	38.1	15	47.7	6.4	63.5	75.4	228.3	469.1	161	226.8	451.1	199.2
2008	152	164.5	62.5	4.7	54.1	211.8	319.3	165.9	238.8	149.6	174.9	162.1	184
2009	9	136.6	56.4	127.3	334.4	233.2	299.7	377	178.1	502.9	389.4	171.2	23.4
2010	45	15.3	3	26.2	56.2	9.1	171.2	762.5	211.3	124.3	368.7	159.8	170
2011	74	49.7	6.1	67.9	11.4	143.2	476.1	302.6	294.4	242.4	275.6	290.6	254.1
2012	94	81.6	86.5	116.4	40	178.5	72.3	464.4	486.1	136.5	337.2	76.7	68.1
Mean		57.8	40.5	47.4	55.3	153.9	204.1	361.4	265.8	237.5	224.4	219.3	159.7
	r	0.18	0.26	-0.51	-0.64	-0.02	-0.01	-0.41	0.35	-0.37	-0.54	0.18	0.24

r= Pearson r value or correlation coefficient
0-0.3 (0 to -0.30) = little correlation
0.31-0.5 (-0.31 to -0.5) = low correlation
0.51-0.7 (-0.51 to -0.7) = moderate correlation
0.91-1.0 (-0.91 to -1.0) = very high correlation
0.71-0.9 (-0.71 to -0.9) = high correlation

Furthermore, wet months were observed during 2009 and this further inhibited the flowering of rambutan trees (Table 4). According to Kawabata and others (2007), excessive rainfall during the expected flowering season is detrimental to rambutan flowering and enhances vegetative growth. Instead, in order for rambutan to flower, it should be naturally induced by water stress for 2 to 4 weeks period with a temperature greater than 22°C (Nakasone and Paull 1998; Salakpetch 2005; Tindall and others 1994). However, for 2009, there was a high amount of rainfall for March (127.3 mm) and April (334.4 mm) which coincided with the flowering season of rambutan. This could be one of the factors that induced vegetative growth of the trees instead of being reproductive.

In addition, a lower yield of rambutan was also observed in 2010 at 45.5 kg/tree (Figure 2). This could be partly explained by the abnormally reduced rainfall at 9.1 mm for the month of May 2010 (Table 4). The month of May is considered a wet month with a normal rainfall of 159.7 mm from 1971 to 2000 (Figure 3). However, an extended water stress period in March and May (Table 4) could have inhibited the flower initiation and flower bud growth, hence a low yield. In addition, high solar radiation, strong wind, and high humidity are contributory factors to this low rambutan yield. In rice farming, for example, it has been reported that increases in minimum temperature causing water stress in Los Baños and other areas in the Philippines led to a reduced rice yield (IPCC 2007; Lansigan 2009).

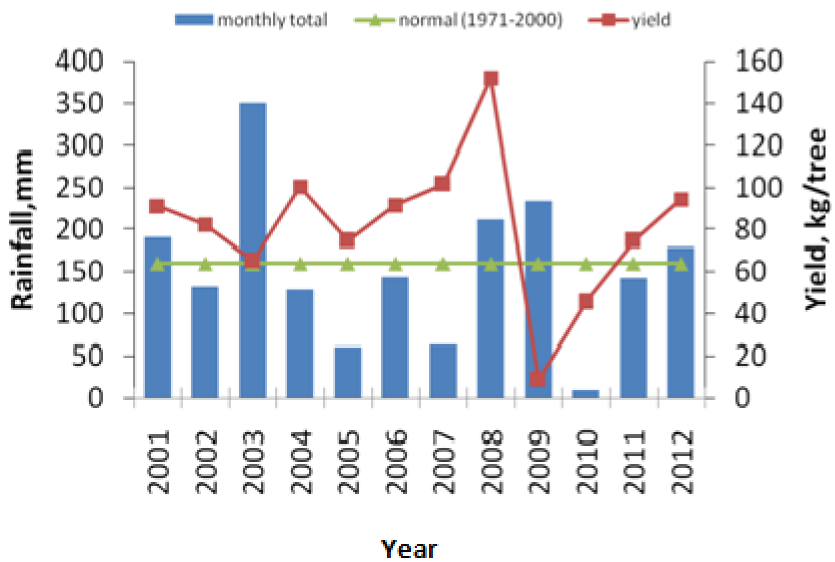

Figure 3. Amount of rainfall (mm) for May 2001 to 2012 and the annual rambutan yield in Calauan, Laguna, Philippines

Selection of Genotypes of Known-drought Tolerant Macopa, Siniguelas, and Native Santol

Macopa

The mean, range, standard deviation, and Shannon-Weaver diversity index of different fruit characters such as fruit weight, fruit length, fruit width, total soluble solids, flesh thickness, seed number, seed weight, and edible portion for 103 macopa genotypes evaluated are shown in Table 6. A wide variability was observed as indicated by the Shannon-Weaver diversity index for fruit weight (H'=0.87), total soluble solids (H'=0.86), and flesh thickness (H'=0.87). The same degree of variability was obtained for fruit weight and fruit length in rambutan (Magdalita and Valencia 2004). The wide variability in the present study suggests that a mass selection strategy for desirable tree genotypes of macopa could be done effectively in the natural population. The differences in phenotypic characteristics of the different genotypes evaluated are shown in Figure 4. The fruit weight of 103 macopa genotypes ranged from 6.70 to 78.15 g with a mean of 28.25 g, while the total soluble solids ranged from 0 to 13.66 °Brix with a mean of 5.27 °Brix. Flesh thickness ranged from 0.10 to 1.89 cm with a mean of 1.01 cm, while fruit length ranged from 2.01 to 9.05 cm with a mean of 3.77 cm. In contrast, the variability is narrow as indicated by the Shannon-Weaver diversity index for fruit width (H'=0.29), seed weight (H'=0.69), seed number (H'=0.79), and percentage of edible portion (H'=0.67). This narrow variability is expected because of the distinct varietal characteristics of each individual macopa trees evaluated.

Table 6. The mean, range, standard deviation, and Shannon-Weaver diversity index (H') of selected fruit characters in 103 tree genotypes of macopa

Fruit characters	Mean	Range	SD	H'*
Fruit weight (g)	28.25	6.70-78.15	11.95	0.87
Fruit length (cm)	3.77	2.01-9.05	0.80	0.80
Fruit width (cm)	4.60	2.25-43.01	3.94	0.29
Total soluble solids (°Brix)	5.27	0.00-13.66	3.03	0.86
Flesh thickness (cm)	1.01	0.10-1.89	0.44	0.87
Seed number	0.59	0.00-3.05	0.50	0.79
Seed weight (g)	1.62	0.00-13.53	2.11	0.69
Edible portion (%)	92.87	55.96-100.00	9.08	0.67

°Brix - degree Brix
SD - Standard Deviation
H' - Shannon-Weaver diversity index
*Nearest to 1.0 means most diverse

Figure 4. The differences in phenotypic characteristics of different macopa genotypes evaluated for fruit qualities

While fruit crops are generally eaten fresh once they are ripe, the most important general criterion for selecting the best three genotypes in each fruit species is primarily centered on the most desirable qualitative traits like sweet taste and flavor of the flesh, flesh color, texture of the flesh, and edible portion or the fleshly part. These traits were given higher weights during the selection process and scored accordingly based on the criteria set by the FCTWG-NSIC (2009) because fruits are eaten fresh so taste is the primary consideration rather than using analyzed quantitative data which are of secondary importance. In the case of macopa, based on the Shannon-Weaver diversity index, and fruit qualities particularly flavor of the flesh, crunchiness and texture of the flesh, skin color, and edible portion, three genotypes of macopa out of 103 trees evaluated were selected, namely: Mc-13, Mc-43 and Mc-95 (Table 7). Mc-13 is sweet (7.15°Brix) and crispy, creamy white (RHCC 155 A) with fruits weighing 49.44 g, and has high edible portion (93.22%) (Figure 5-A). Mc-43 is a currant red (RHCC 46 A) selection with big fruits (42.46 g), crispy and sweet (6.83°Brix), and has very high edible portion (94.32%) (Figure 5-B). Mc-91 is a pea green (RHCC 149 B) selection with medium-size fruits (32.14 g), crispy and sweet (7.69%), and has high edible portion (92.41%) (Figure 5-C). The tree of Mc-13, Mc-45, and Mc-91 is hardy; a very prolific and regular bearer; and can stand both drought and flooding, and those places with less water and erratic rainfall. They can be also used for agro-reforestation in marginal areas.

Siniguelas

Table 8 shows the mean, range, standard deviation, and Shannon-Weaver diversity index of different fruit characters such as fruit weight, fruit length, fruit width, flesh thickness, total soluble solids, individual seed weight, seed length, seed width, seed thickness and edible portion of 114 siniguelas genotypes evaluated. The Shannon-Weaver diversity index indicated that a wide variability existed for fruit weight (H'=0.85), fruit length (H'=0.85), fruit width (H'=0.90), flesh thickness (H'=0.88), total soluble solids (H'=0.90), individual seed weight (H'=0.87) and percent edible portion (H'=0.88) (Table 8). This wide variability is not expected for siniguelas since it is an asexually propagated crop, usually by stem cuttings, hence, uniformity is expected. However, this wide variability could be due to somatic mutations that occurred within the mother plant, and when stem cuttings were taken and grown into another tree, the variation was expressed. In sweetsop, a similarly high degree of variability was observed for fruit weight, fruit length, fruit width, flesh thickness, total soluble solids and percent edible portion (Magdalita and Valencia 2004). Since, there is a wide variability observed for important traits like fruit weight, total soluble solids, and edible portion in the present study, this

Table 7. The average fruit qualities of selected tree genotypes of macopa, siniguelas, and native santol

Fruit species	No. of genotypes evaluated	Selected genotypes	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	Total soluble solids (°Brix)	Edible portion (%)	Trait for climate change adaptation
Macopa	103	Mc-13	49.44	4.25	5.41	7.15	93.22	Drought-tolerant
		Mc-43	42.46	3.69	5.33	6.83	94.32	
		Mc- 91	32.14	4.57	4.38	7.69	92.41	
Siniguelas	114	Sg-41	20.42	3.30	2.87	12.50	83.27	Drought-tolerant
		Sg-42	19.67	3.58	3.11	12.75	81.73	
		Sg-105	16.05	3.26	2.79	16.79	82.13	
Native Santol	101	Sn-47	105.43	5.18	5.84	4.76	86.44	Drought-tolerant
		Sn-59	58.27	3.91	4.99	5.56	84.99	
		Sn-74	51.96	4.00	4.69	4.17	82.20	

suggests that on-site selection, a strategy similar to mass selection process for desirable tree genotypes of siniguelas can be done in the natural population to identify superior siniguelas genotypes.

The phenotypic characteristics of the different siniguelas genotypes evaluated are shown in Figure 6. The fruit weight of 114 siniguelas ranged from 11.03 to 30.88 g with a mean of 16.88 g, while the total soluble solids ranged from 6.55 to 17.40°Brix with a mean of 11.56°Brix (Table 8). Flesh thickness ranged from 0.38 to 0.89 cm with a mean of 0.61 cm, while the individual seed weight ranged from 2.50 to 3.77 g with a mean of 3.38 g. The fruit length ranged from 2.50 to 3.77 cm with a mean of 3.26 cm, while the fruit width ranged from 2.42 to 3.26 cm with a mean of 2.82 cm. In contrast, the Shannon-Weaver diversity index indicated a narrow variability for seed length (H'=0.30), seed width (H'=0.72), and seed thickness (H'=0.66). This narrow variability indicates that the seed characteristics of siniguelas are distinct to this species.

Siniguelas is another fresh fruit that is popularly eaten during summer because of its sweet flavor, its shiny skin, and fleshy part. In selecting the three best genotypes of siniguelas, the qualitative traits that were given more emphasis in selection and provided with more weight were flavor or taste, skin color, texture, and shiny skin and fleshy part. Among the 114 different siniguelas trees evaluated based on diversity index and fruit qualities like flavor of the flesh, skin color and texture, shininess of the skin, and edible part, three genotypes of siniguelas, namely Sg-41, Sg-42, and Sg-105, were identified as promising genotypes. Sg-41 is sweet

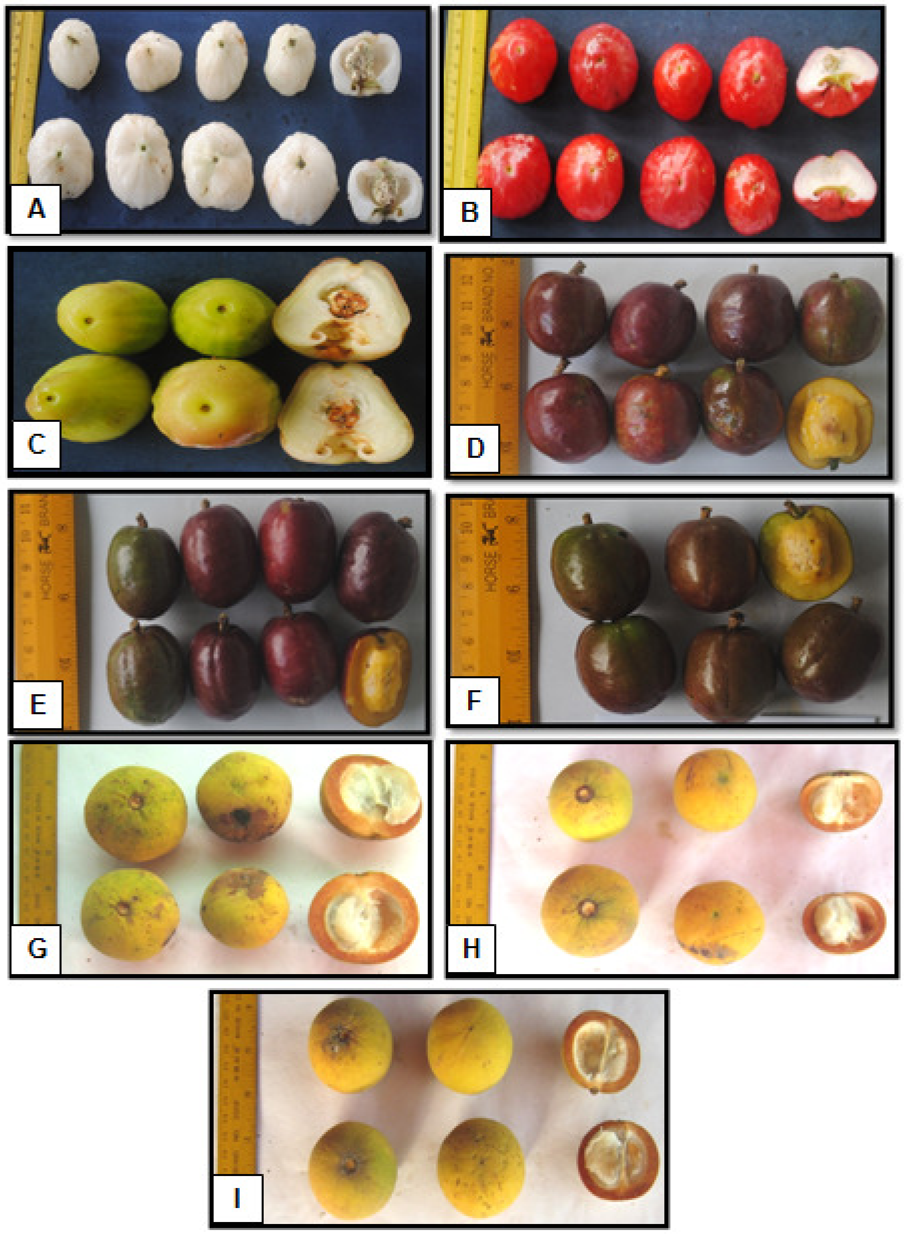

Figure 5. The selected genotypes of macopa (Mc-13) [A], (Mc-43) [B], (Mc-91) [C]; siniguelas (Sg-41) [D], (Sg-42) [E], (Sg-105) [F]; and native santol (Sn-47) [G], (Sn-59) [H], (Sn-74) [I]

(12.50°Brix), ruby red (RHCC 59 A), and has shiny and smooth skin, and the fruit weighs an average of 20.42 g, and has high edible portion of 83.27% (Figure 9-D). Sg-42 is also ruby red (RHCC 59 A) with a shiny and smooth skin, has an average weight of 19.67 g, has sweet flesh with a TSS of 12.75°Brix and has high edible portion of 81.73%. Sg-105 has grenadine red (RHCC N34 A) fruits with shiny and smooth skin weighing 16.05 g that are very sweet with 16.79°Brix and has high edible portion of 82.13%. The tree of Sg-41, Sg-42, and Sg-105 is very strong, hardy, prolific, regular bearer, and can withstand drought. This suggests that these siniguelas selections are ideal for growing in drought-prone areas and those places with less water and erratic rainfall. They can be also used for planting in marginal areas and for agro-reforestation in mined and less fertile areas.

Figure 6. The differences in phenotypic characteristics of different siniguelas genotypes evaluated

Table 8. The mean, range, standard deviation, and Shannon-Weaver diversity index (H') of some fruit characters evaluated in 114 genotypes of siniguelas

Fruit Characters	Mean	Range	SD	H'*
Fruit weight (g)	16.88	11.03-30.88	2.99	0.85
Fruit length (cm)	3.26	2.50-3.77	0.18	0.85
Fruit width (cm)	2.82	2.42-3.26	0.17	0.90
Flesh thickness (cm)	0.61	0.38-0.89	0.09	0.88
Total soluble solids (°Brix)	11.56	6.55-17.40	2.39	0.90
Individual seed weight (g)	3.38	1.56-4.98	0.70	0.87
Seed length (cm)	2.30	1.62-10.00	0.80	0.30
Seed width (cm)	1.60	1.43-2.57	0.12	0.72
Seed thickness (cm)	1.47	1.31-2.35	0.12	0.66
Edible portion (%)	78.77	61.86-91.58	5.96	0.88

°Brix – degree Brix
SD – Standard deviation
H' - Shannon-Weaver diversity index
*Nearest to 1.0 means most diverse

Native Santol

The mean, range, standard deviation, and Shannon-Weaver diversity index of different fruit characters such as fruit weight, fruit length, fruit width, pulp thickness, aril thickness, total number of seeds, total seed weight, skin weight, seed weight, seed length, seed width, seed thickness, total soluble solids, and percent edible portion of 101 santol genotypes evaluated are shown in Table 9. A wide variability indicated by the Shannon-Weaver diversity index existed for fruit weight (H'=0.87), fruit length (H' = 0.89), fruit width (H=0.89), aril thickness (0.90), total seed weight (H' = 0.89), skin weight (H'=0.87), seed width (H=0.87), seed thickness (H'=0.85), total soluble solids (H'=0.85), and percent edible portion (H'=0.85) (Table 8). Similarly, a high degree of variability was observed for fruit weight, seed weight, total soluble solids, and percent edible portion in rambutan (Magdalita and Valencia 2004), papaya (Magdalita and others 1984), and cashew (Ramadas and Thatham 1982). This wide variability observed for important traits in the present study also suggests that desirable tree genotypes of native santol could be selected effectively in the natural population. The fruit phenotypic characteristics of the different genotypes evaluated are shown in Figure 7. Fruit weight of 101 native santol

Figure 7. The differences in phenotypic characteristics of some native santol genotypes evaluated

ranged from 49.18 to 151.49 g with a mean of 86.48 g, while total soluble solids ranged from 1.11 to 5.56°Brix with a mean of 2.28°Brix. Fruit length ranged from 3.80 to 6.0 cm with a mean of 4.72 cm while fruit width ranged from 4.60 to 6.89 cm with a mean of 5.56 cm. Aril thickness ranged from 0.18 to 0.66 cm with a mean of 0.40 cm, while the total seed weight ranged from 4.40 to 15.20 cm. The weight of the skin ranged from 11.73 to 48.37 g with a mean of 24.16 g. Seed width ranged from 2.29 to 1.71 cm with a mean of 1.48 cm, while seed thickness ranged from 0.96 to 1.60 cm with a mean of 1.16 cm. The total soluble solids, a relative measure of sweetness ranged from 1.11 to 5.56 with a mean of 2.28°Brix, while the percent edible portion ranged from 26.81 to 86.44% with a mean of 58.56%. Contrastingly, a narrow variability as indicated by the Shannon-Weaver diversity index was observed for pulp thickness (H'=0.73), total number of seeds (H'=0.73), and seed length (H'=0.75) (Table 9). This narrow variability for pulp thickness is unique for native santol since many native santol genotypes have relatively thin pulp. The narrow variability for total number of seeds and seed length are distinct traits to native santol, as an indicator trait of many native santol genotypes.

In selecting the best three native santol genotypes, the traits that were given emphasis in selection included pulp and aril flavor, fleshy part, and pulp thickness that were all scored accordingly based on the criteria of FCTWG-NSIC (2009). Among the 101 different native santol trees evaluated, based on the Shannon-Weaver diversity index, and fruit qualities particularly flavor of the pulp and aril, three genotypes of native santol namely: Sn-47, Sn-59, and Sn-74 were identified as promising genotypes. Sn-47 is sweet (4.76°Brix), has lemon yellow (RHCC 13 A) fruit with an average weight of 105.43 g, and an edible portion of 86.44%. On the other hand, Sn-59 has maize yellow (RHCC 21 B) fruit that weighs 58.77 g, with TSS of 5.56 °Brix and percent edible portion of 84.99%, while Sn-74 has butter cup yellow (RHCC 168 B) fruits that weigh 51.96 g, with TSS of 4.17°Brix and percent edible portion of 82.20%. The tree of Sn-47, Sn-59, and Sn-74 is a very prolific, deep rooted, regular bearer, very hardy, and can withstand drought. This suggests that these santol selections can be grown in drought- and flood-prone areas, and those areas with limiting water and erratic rainfall. Like any other hardy trees, native santol can be also used as border trees in windy areas and typhoon-prone areas to protect any crop susceptible to wind damage.

In general, the selections of macopa, siniguelas, and native santol can be used for agro-reforestation of marginal areas and denuded forests since they are all hardy, have strong root systems, and are fast growers. They can be also planted in places that are frequently visited by typhoons. In addition, the selections of native santol can be also grown in flood-prone areas since they are also tolerant to excessive water. Like other trees, these selections, besides being used as sources of food, also have environmental benefits for mitigating the ill effects of climate change. For instance, they can improve air quality, prevent soil erosion, improve soil quality, increase biodiversity, and provide aesthetic value to the natural landscape (Putz and Pinard 1993). In addition, these tree selections can be the best bet for storing carbon at very little cost and high return (Dixon and others 1994).

Table 9. The mean, range, standard deviation, and Shannon-Weaver diversity index (H') of some fruit characters evaluated in 101 genotypes of siniguelas

Fruit Characters	Mean	Range	SD	H'*
Fruit weight (g)	86.48	49.18-151.49	21.41	0.87
Fruit length (cm)	4.72	3.80-6.04	0.47	0.89
Fruit width (cm)	5.56	4.60-6.89	0.50	0.89
Pulp thickness (cm)	0.32	0.11-0.93	0.15	0.73
Aril thickness (cm)	0.40	0.18-0.66	0.10	0.90
Total number of seeds	4.09	2.90-10.17	0.77	0.73
Total seed weight (g)	10.87	4.40-16.20	2.20	0.89
Skin weight (g)	24.16	11.73-48.37	7.60	0.87
Seed length (cm)	2.61	2.19-4.60	0.28	0.75
Seed width (cm)	1.48	1.29-1.71	0.08	0.87
Seed thickness (cm)	1.16	0.96-1.60	0.09	0.85
Total soluble solids (°Brix)	2.28	1.11-5.56	0.87	0.85
Edible portion (%)	58.56	26.81-86.44	8.10	0.85

°Brix-degree Brix
SD - Standard deviation
H' - Shannon-Weaver diversity index
*Nearest to 1.0 means most diverse

CONCLUSION AND RECOMMENDATION

The fruit yield of rambutan trees growing in a selected farm in Calauan, Laguna, Philippines, remarkably dropped from 152.2 kg/tree in 2008 to 8.6 kg/tree in 2009. This decline in yield could be traced back from the abnormal flowering of rambutan. This could be due to the effect of the abnormally high rainfall observed for the month of April 2009 at 334.4 mm, based on the analysis of monthly data on rainfall from 2001 to 2012. Other environmental factors like temperature, solar radiation, humidity, and wind contributed to this yield decline. The month of April is usually considered a dry month with a normal rainfall of 41.6 mm that was observed from 1971 to 2000. In addition, no dry months were observed during 2009 which promoted the vegetative growth of rambutan instead of flowering. Also, a lower yield was recorded at 45.5 kg/tree in 2010. This can be explained by an abnormally reduced rainfall at only 9.1 mm for May 2010 which could be inadequate for the flowering of rambutan, hence the yield decreased. Usually, the month of May is considered a wet month with a normal rainfall at 159.7 mm based on rainfall data from 1971 to 2000.

Preliminary evaluation and selection among 103 macopa genotypes resulted in selection of three most promising selections, namely: Mc-13, Mc-43, and Mc-91. However, a follow-up study is needed to ascertain the performance of these selections in the face of climate change. Mc-13 is sweet (7.15 °Brix) and crispy, creamy white (RHCC 155 A) and has fruit weighing an average of 49.44 g, with high edible portion (93.22%) while Mc-43 is a currant red (RHCC 46 A) selection with fruits weighing 42.46 g, with very high edible portion (94.32%). Mc-91 is a pea green (RHCC 59 A) selection with medium fruits (32.14 g), crispy and sweet (7.69 °Brix) and has high edible portion (92.41%). Among 114 siniguelas genotypes evaluated, three genotypes namely: Sg-41, Sg-42 and Sg-105 were selected. Sg-41 has sweet (12.50 °Brix) and juicy fruits weighing an average of 20.42 g, ruby red (RHCC 59 A), and has high edible portion (83.27%) while Sg-42 has fruits weighing an average of 19.67 g, ruby red (RHCC 59 A), juicy and sweet (12.75 °Brix) with high edible portion (81.73%). Sg-105 has medium fruits (16.05 g) that are grenadine red (RHCC N34 A), very sweet (16.79 °Brix) and has high edible portion (82.13%). Among 101 native santol genotypes evaluated, Sn-47, Sn-59 and Sn-74 were selected. Sn-47 has sweet (4.76B °Brix) and juicy fruits weighing an average of 105.43 g, lemon yellow (RHCC 13 A), and has high edible portion (86.44%) while Sn-59 has medium (58.27 g) fruits that are maize yellow (RHCC 21 B), juicy and sweet (5.56 °Brix) fruits with high edible portion (84.99%). Sn-74 has also medium fruits (51.96 g) that are butter cup yellow (RHCC 16 B), sweet (4.17 °Brix) with high edible portion (82.20%). The selections of macopa including Mc-13, Mc-43, and Mc-91; siniguelas such as Sg-41, Sg-42, and Sg-105; and native santol like Sn-47, Sn-59, and Sn-74 are being recommended for planting in marginal, drought- and flood-prone areas around the country. It is further recommended that grafted materials should be used for planting to maintain the true-to-type nature of the selections.

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