Working Paper

Selection of son tra clones in North West Vietnam

Tiep Ha Van, Tuan Vu Van, Sammy Carsan,Chris Harwood, Bac Viet Dam, Nguyen La, Delia C. Catacutan and Ramni Jamnadass

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Abstract

Son tra (*Docynia indica*) is an indigenous tree species widely distributed at high elevations in northern Vietnam. Its fruit is traditionally used as a fruit and for making wine, providing a source of income for farmers. Selection of superior planting material can enhance its market potential and benefit growers, processors and consumers. The Agroforestry for Livelihood Improvement (AFLI) project implemented by the World Agroforestry Centre (ICRAF) and Forest Science Centre for Northwestern Vietnam (FSCN) is therefore promoting son tra domestication in Dien Bien, Son La and Yen Bai provinces of North West and North Central eco-region of Vietnam. Domestication activities involved evaluation, selection and testing of candidate trees to identify genotypes that could be propagated as clones to give son tra plantations with improved market potential. Key informant interviews drawn from various sectors such as agriculture, forestry, local traders and farmers were used to identify natural and plantation son tra populations where screening was carried out. Over 2,400 trees were screened in 13 selected locations. Screening involved a sequence of selection processes, first identifying 600 trees with superior fruit yield, then selecting 150 of these with superior fruit appearance, followed by taste trials to identify 10 candidate plus trees with high fruit yield, superior fruit morphology, fruit peeling characteristics and superior taste for fresh fruit consumption and 20 candidate plus trees with high yield, superior fruit morphology and suitable taste for wine production. The 30 selected trees were grafted onto seedling rootstocks. All selections grafted well, with over 90% grafting success. Grafts of the selected genotypes were then established in clonal field tests to evaluate their performance and adaptability to local growing conditions.

Key words: Son tra, *Docynia indica*, candidate plus tree, clone, Northwest Vietnam.

Acknowledgements

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Table of Contents

List of Figures

List of Tables

List of acronyms & abbreviations

ACIAR	Australian Centre for International Agricultural Research
AFLI	Agroforestry for Livelihood Improvement
CGIAR	Consortium of International Agricultural Research Centres
CSIRO	Commonwealth Scientific and Industrial Research Organization
dbh	diameter at breast height
FAO	Food and Agriculture Organization of the United Nations
FIPI	The Forest Inventory and Planning Institute
FSCN	Forest Science Centre for Northwestern Vietnam
FTA	Forest, Trees and Agroforestry
GPS	Global Positioning System
ICRAF	World Agroforestry Centre
ILRI	The International Livestock Research Institute
NOMAFSI	Northern Mountains Agriculture and Forestry Science Institute
NW	North West
REDD	Reducing Emissions from Deforestation and Forest Degradation
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization
VAFS	Vietnamese Academy of Forest Sciences

1. Introduction

Son tra, *Docynia indica* (Wall.) Decne, is a fruit tree species indigenous to forests in parts of Southwest China, Bhutan, India, Myanmar, Nepal, Pakistan, Sikkim, Thailand and Vietnam (Decne 1874; Chen et al., 1999). In Vietnam, son tra is abundant at elevations above 1,000m in the North West and North Central ecoregions. The fruit is commonly known as son tra or Tao Meo in Vietnamese.

It is famous for its distinctive flavour and aroma, and can be processed into an array of products, such as candy, dried fruit, jams, tea and wine. Raw fruits are edible or can be made into pickle. Demand for the fruit is on the increase with preference for traditional organic products in major cities such as Hanoi, making son tra a source of livelihood for thousands of farmers, collectors and traders. Growers consider that the tree requires little labour or investments in fertilizer or pesticides to obtain good yields. Much of the fruit traded in the urban and local market is collected from wild trees, with fruit quality varying from tree to tree. The species is included in government reforestation programmes as a source of non-timber forest products and at least 15,000 hectares of reforestation plantings have been established in the North West region (Forest Department reports of Son La, Dien Bien, Lao Cai and Yen Bai provinces, 2013; FIPI, 2011). Orchards are also planted by the local people to provide fruit and timber products. Market demand for the fruit has grown significantly in recent years, making it a good source of income for many local farmers.

The Agroforestry for Livelihood Improvement (AFLI) project implemented from 2011 in Son La, Dien Bien and Yen Bai in North West Vietnam by the World Agroforestry Centre (ICRAF), Forest Science Centre for Northwestern Vietnam, Tay Bac University, NOMAFSI (Northern Mountains Agriculture and Forestry Science Institute) and Provincial Departments of Agriculture and Rural Development, seeks to improve environmental conditions and farmers' incomes (Lua et al., undated). AFLI's focus on son tra domestication aims to attain wider cultivation of the fruits by smallholders by identifying superior genotypes and propagation techniques that could assist in scaling up their use.

The process starts with exploration of wild and planted populations in the NW ecoregion in order to identify potentially superior genotypes. The confirmation of superior genotypes that are well-adapted, high-yielding and have superior fruit quality then involves propagation of the selections by grafting and field testing in clonal trials (Catacutan et al., 2014; Harwood et al., 2016).

Despite the traditional value of son tra to household incomes, diets and to the Vietnamese rural and urban economy, selected cultivars[1] have not yet been developed. It is anticipated that selection and propagation of elite genotypes could result in son tra orchards producing higher yields of superior, more marketable products through improvement in fruit size, morphology, processing qualities (improved uniformity) and taste (as fresh fruit) or flavour when processed into wine or other processed products.

This approach is similar to that being implemented for indigenous African fruit species such as *Dacryodes edulis* where selection of superior trees was based on market-oriented 'ideotypes' (Tchoundjeu et al., 2006). Leakey and Akkinnifesi (2006) have used the concept of ideotype to describe the multiple-trait selection of superior trees for cultivar development to meet different market opportunities when describing the domestication of *Irvingia gabonensis* (bush mango), a priority indigenous fruit in Nigeria. This is a horticultural approach, aimed at improving the fruit value chain. Candidate genotypes are selected, tested as clones, and those which are found to be superior, are mass-propagated for planting by farmers, usually by grafting the selections onto unimproved rootstocks.

In this approach to domestication, selection can be undertaken in both natural forests and plantations. Once selections have been made for propagation and testing, each selected tree becomes the founder of a clone and is termed the ortet. Scion material collected from the tree is grafted onto seedling rootstocks, producing many ramets of the clone (Figure 1). The ortet and all the grafted scions have the same genotype (i.e., having the same genetic identity). Note that the selected genotype of the ortet is represented as the scion above the graft union, in each grafted ramet. The unselected seedling stocks are represented below the graft union as different genotypes.

The first and most important step in the horticultural pathway of domestication is to select superior scion genotypes, because it is the scion that confers the desired fruit quality traits and most strongly influences crown development and fruit yield of the grafted tree. At a later stage in fruit tree domestication, selected stock genotypes can be developed and adopted, to further improve the performance of the species in cultivation. For example, apple growers in many countries now use genetically-selected, disease-resistant and dwarfing or semi-dwarfing rootstocks, to improve orchard health and ease orchard management.

[1]A cultivar does not necessarily equate to a clone; it can be a sexually propagated variety that breeds true. It is very unlikely that son tra clones would breed true, so selected superior son tra genotypes would most likely be propagated as clones. See https://www.anbg.gov.au/acra/what-is-a-cultivar.html

This report describes the selection of son tra trees for domestication in the North West ecoregion. The goal was to select potentially superior trees and test them in clone trials so as to identify superior genotypes for fresh fruit and wine production.

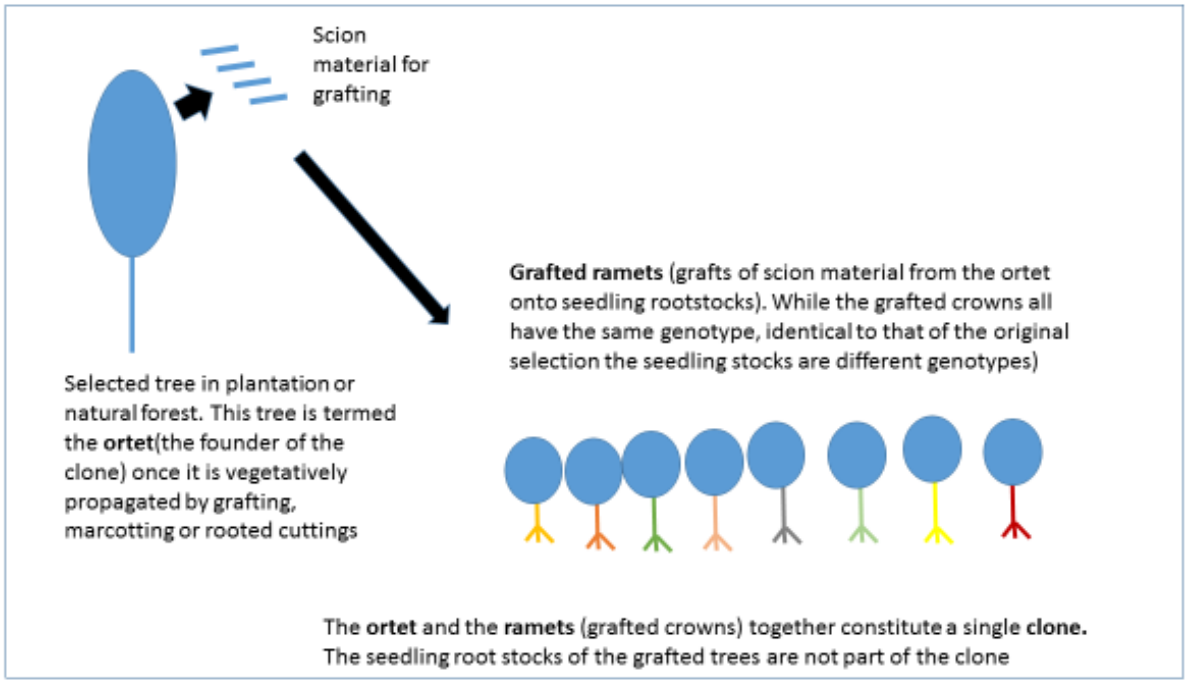

Figure 1. Terminology used in this report, to describe vegetative propagation of selected trees.

2. Materials and Methods

2.1 Overview

This study surveyed son tra populations in plantations and natural forest in the North West, and selected populations for screening to identify phenotypically superior trees. Some 2,400 trees in the selected populations were characterized for growth and fruit yield. Subsequently, 600 trees that were judged to be superior in fruit yield were then screened for fruit appearance. Fruit samples from 150 trees that were superior in both yield and appearance were then collected for taste testing, which ranked them for suitability for either fresh fruit consumption or production of wine, juice or other products. Thirty (30) final selections (10 for fresh fruit consumption and 20 for processing) were then documented and scion material collected and grafted onto seedling rootstocks for clonal testing. The stages in this selection process are described in detail below.

2.2 Study Area

The study area covered provinces of Dien Bien, Son La located in the North West and Yen Bai in the North Central forest ecoregions of Vietnam where natural son tra tree population occur (Lien et al., 2002; Lien et al., 2011; Fig. 2). The Hoang Lien Som mountain range strongly influences climate, hydrology, geology/soils and ecosystem distribution in these regions (FAO, 2011). Due to the mountainous, heavily dissected topography and range of elevations, major climatic variation is experienced within the regions. Areas at high elevation have higher rainfall, lower mean annual temperature and colder winters, while the climate is drier and warmer in the lowland valleys. A prolonged dry season is experienced during winter and spring. Historic climate data from three meteorological stations at different elevations in the North West are shown in Table 1. The climates of Mộc Châu and Pha Đin are representative of those areas where son tra occurs naturally or is grown in plantations, while Sơn La is at a lower altitude with a warmer climate that would be marginal for growing son tra.

Table 1: Historical climate data for three meteorological stations in the North West (source: Vietnam Hydro-Meteorological Service)

Station	Sơn La	Mộc Châu	Pha Đin
Province	Sơn La	Sơn La	Dien Bien
Latitude (N)	21°20	21°51	21°34
Longitude (E)	103°54	103°38	103°30
Altitude (m)	676	958	1347
Mean annual temperature (°C)	21.0	18.5	17.5
Mean daily minimum temperature of coldest month (°C)	10.2	8.8	9.5
Mean daily maximum temperature of hottest month (°C)	30.6	27.8	24.9
Mean annual rainfall (mm)	1443	1600	1818
Length of dry season (months)	5	5	3
Mean annual evaporation (mm)	884	895	895

Soils are mainly acrisols, humic ferralic acrisols, feralite rhodic ferralsols and xanthic ferralsols established on mica schist, shale and granite (FAO-UNESCO, 1979). Soil fertility ranges from medium to high and tends to decrease from the high elevation areas to lower elevations (FAO, 2011). Forest vegetation types are diverse. Evergreen mixed closed and broad-leaved humid forests have been heavily affected by human activities with little pristine forest remaining (FIPI, 2011). Rice and maize are the main food crops and population density stands at about 120 persons/km^2 (ILRI, 2014).

2.3 The process of selecting superior son tra genotypes

Step 1. Identification of stands for candidate tree selection

Son tra production areas, including plantations and stands in natural forest, were identified through desk study and interviews with key informants, including staff of agriculture and forest departments, local commune leaders, son tra collectors, processing companies, sale agents and farmers. This information was used to select 13 son tra populations for further study (Figure 2).

Son tra stands and trees on community forest lands have been allocated to farmers by the local government, while both provincial governments and individual farmers have established plantations. Permission was sought from tree owners before populations were studied and candidate trees selected for grafting. Discussion with tree owners confirmed that they were supportive of the research and would also ensure protection of the selected trees under their management. In return, they requested that grafted/improved son tra material be supplied to them for plantation establishment.

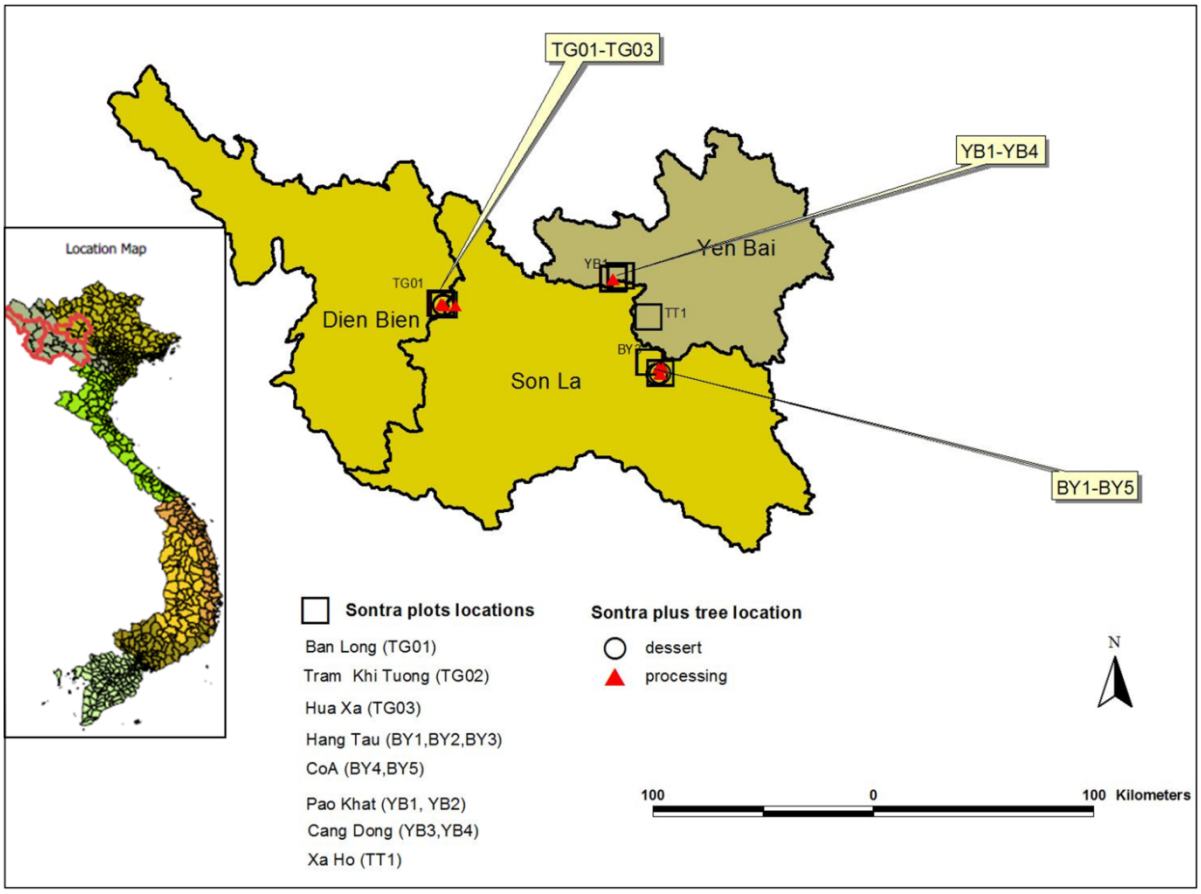

Figure 2. Map showing locations of 13 son tra populations plots studied in Son La, Dien Bien and Yen Bai provinces of Vietnam.

Step 2. Ranking trees in the selected populations for fruit yield

Tree assessments were carried out during the fruiting season (September 2012). Representative sample plots measuring 60 x 50m were established in each of the 13 selected populations at Dien Bien, Son La and Yen Bai provinces (Figure 2). Plots contained between 23 and 32 trees. Tree height, diameter at breast height and fruit yield (determined by harvesting and weighing the fruit) were measured for each tree. Notes were also made on pest and disease incidence.

On the basis of the information from the sample plots, additional trees were then surveyed along transect lines at each location. Estimates of fruit yield were made from inspection of the fruit crops of these trees, relative to the crops in the sample plots. The fruit yields of all trees at a site (both the trees in the plot and the additional trees surveyed along the transects) were then ranked according to the excess index criterion (Schreiner, 1962, equation 1).

$$Excess\ index = \frac{Yt-Ym}{Ym} \text{ x } 100\ \% \qquad \text{(Equation 1)}$$

Where, *Yt* denotes yield of the individual tree and *Ym* denotes average yield of measured trees in the plot

The 25% of the total trees surveyed in each province with the highest excess index rankings were selected for evaluation of fruit quality. If two trees had the same excess index but belonged to different size classes, the tree with the smaller diameter (DBH) was selected. As a preliminary step in this selection for yield, trees were ranked into one of four excess index categories as follows:

Low	<1
Average	1-1.5
High	1.5-2
Very high	>2

An example of a very high-yielding tree with excess index > 2 is shown in Figure 3.

Figure 3 A very high-yielding son tra tree (excess index >2) at Pao Khat village, Nam Khat Commune of Yen Bai province.

Step 3. Ranking high-yielding trees according to fruit appearance

Fruits from the high-yielding trees selected in Step 1 were assessed on their fruit morphology characteristics. Phenotypic traits – fruit size, shape, colour and skin texture were scored as shown in Table 2.

Table 2: Criteria for Son tra fruit morphology score-ranking

Criterion	Category	Score
Size	Large (>2.5cm)	10-15
	Medium (1.5-2.5cm)	5-9
	Small (<1.5cm)	0-4
Shape	Flat (fruit width >length)	5-10
	Oblong (fruit width = length)	5-10
	Elongated (fruit length > width)	0-4
Colour of ripe fruit	Yellow, bright (5 = brightest)	3-5
	Yellow, dull	3-5
	Grey	0-2
Skin texture	Smooth	3-5
	Rough	0-2
Ranking (sum of individual scores)	Grade 1 (Poor)	0-8
	Grade 2 (Moderate)	9-16
	Grade 3 (Good)	17-25
	Grade 4 (Very good)	26-35

The top 25% or so of the high-yielding trees with the highest fruit appearance scores in each province were selected. If ranking of two trees was the same, the tree with higher fruit yield and no symptoms of pest or disease attack was selected. Rankings of fruit morphology from individual trees ranged from poor (0-8 points) to very good (26-35 points).

Step 4. Allocating selected trees to use categories of fresh fruit and processing

Trees selected in step 3 were then allocated to one of two classes: fresh fruit for eating and fruit for processing into wine or other products such as juices or teas. According to farmers, collectors and consumers, fruits with good appearance were selected for fresh fruit. Fifty (50) candidates with thin skin and bright yellow colour that were easy to peel were therefore classified as potentially suitable for fresh fruit consumption and evaluated as such. The remaining 100 candidates were evaluated for their potential for processing into wine or other products.

Step 5. Selection of candidate plus trees for fruit consumption and processing

This step involved ranking the 50 fresh fruit candidate trees for taste by evaluating a sample of about 0.5kg of fruits from each tree. Ten fruits from each tree were allocated to a panel of three tasters randomly selected from various industry sectors including researchers, plantation managers, processors, traders, collectors, farmers and harvesters. Five candidate trees were randomly allocated for evaluation to each of 10 tasting panels as follows: Trees 1-5 – panel 1; Trees 6-10 – panel 2; … Trees 45-50 – panel 10. Each taster graded the fruit from each tree with a score of 1 (worst) to 10 (best) for sweetness, good morphology and peeling ability, low acerbity (desirable) and low sourness (desirable). The total score for each tree was the sum of the scores of the three panel members.

The same panels further evaluated fruits from the candidate trees for processing. Fruit samples collected from the 100 candidate trees for processing were evaluated in Vietnamese as “Chua” (high sourness) and “Chát” (high acerbity/bitterness) – both traits desirable for processing, with each trait scored from 1 (worst) to 10 (best). Each three-person tasting panel was allocated 10 candidate trees for evaluation. The total score for each tree was the sum of the scores of the three panel members. The 10 trees with the highest scores from the 50 candidates for fresh fruit consumption and the 20 best-scoring trees out of 100 candidates for processing were identified as the final selections.

Step 6. Registration of selected trees

The 30 selected trees for different use categories were coded for registration and collection of scion material. The codes contain information on fruit characteristics (morphology and use category), location (administrative details, geographic coordinates) and other general information. The trees were labelled with their code identities, and exact locations recorded using GPS. Locations are held on file by the Forest Science Centre for Northwestern Vietnam (FSCN).

Step 7. Grafting for clonal field trials

Scion material was collected from all 30 final selections for grafting, so that clonal field trials could be established.

3. Results and Discussion

Step 1. Son tra distribution in North West Vietnam and choice of populations for study

In Dien Bien Province, son tra is distributed naturally in the high mountainous area of Tuan Giao district while plantations (>40 ha) are located in Hua Xa and Long villages of Toa Tinh commune. The plantations, with a density of 120 trees/ha are government-owned and were established in 2000/2001 under the 661 programme to promote the utilization of non-timber forest products.

Average annual fruit production from the entire area of plantations was about 100 tons over the period of 2010-2012. Fruit production begun in 2006 and yields stabilized in 2008 with yields of about 25kg $tree^{-1}y^{-1}$. Records show that some trees yielded up to 250kg y^{-1} by 2012. Empirical measurements in the 13-sample population are shown in Table 3. Yields from sample plots established in Long village and former meterological station had higher fruit yield per tree compared to those found in the Hua Xa village in Dien Bien (Table 3).

Table 3: Characteristics of son tra trees surveyed in 13 locations covering Son La, Dien Bien and Yen Bai Provinces of Vietnam

Province	Location (sample plots)	Forest type	Tree age	No. of trees surveyed	Mean Dbh (cm)	Mean Height (m)	Mean fruit yield (kg $tree^{-1}$)	Range of fruit yield (kg $tree^{-1}$)
Dien Bien	Long	Plantation	14	31	15.7	5.7	33.5	0-70
	Former met-stations	Plantation	14	29	14.2	7.9	22.8	0-71
	Hua Xa	Plantation	14	29	14.4	6.7	19.5	0-50
Son La	Hang Tau	Natural	15	32	16.1	5.5	18.2	6-45
	Hang Tau	Natural	15	30	15.1	5.8	18.4	5-40
	Hang Tau	Natural	15	29	16.0	5.9	19.1	4-45
	Lang Cheu	Natural	14	32	14.8	5.9	21.8	3-47
	Lang Cheu	Natural	20	30	18.2	6.7	22.3	5-45
Yen Bai	Pao Khat	Natural	14	30	15.2	5.3	24.7	10-80
	Pao Khat	Natural	14	30	15.9	5.6	32.0	10-120
	Cang Dong	Natural	14	27	15.7	5.9	28.3	10-70
	Cang Dong	Natural	14	25	15.6	5.7	21.0	5-50
	Xa Ho	Natural	18	23	18.2	6.7	22.3	5-65

In Son La, natural son tra populations extend over an area of 400 hectares. The total area of plantations (less than 6 years old) is about 1000 hectares, making these plantations some of the largest populations available in the North West (FIPI, 2011). The natural forests are concentrated in BacYen (300ha) and Muong La (100ha) and scattered in Thuan Chau districts. In Bac Yen, son tra is especially found in the mountains, from Ta Xua to Hang Chu communes, located at elevations of 1200-1800m.

Annual fruit production in Bac Yen is about 600 tons. Forest areas consist of the mature forest area in Lang Cheu and Hang Chu communes, and recent regeneration forest (15-25 years old) in Lang Cheu, Hang Tau and Hang Chu communes. Tree measurements using five sample plots established in Hang Tau and Lang Cheu communes are shown in Table 3. Fruit yield averaged about 19kg tree^{-1} in Hang Tau and 22kg tree^{-1} in Lang Cheu.

In Yen Bai, a province with a thriving market for son tra, there are about 300 hectares of son tra natural forest distributed in the slopes of Cang Dong, Pao Khat and Xa Ho communes. The natural forests here are derived from natural regeneration of upland forest resulting from protection efforts implemented by government programmes from 1995 to 2000. Measurements from five sample plot locations marked here, showed little difference in mean tree size but yields, were higher in Pao Khat and Cang Dong plots (Table 3).

Step 2. Tree selection according to yield

In Dien Bien, 800 son tra trees were evaluated at Hua Xa and Long villages for fruit yield per tree grouped in grades 1 (lowest) to 4 (highest). Some 125 trees (15.6%) were ranked 'very high' in terms of individual fruit yields, while 160 trees were ranked 'high'. A total of 200 trees were eventually selected in the 'very high' or 'high' grades in Hua Xa (110) and Long (90) villages (Table 4).

In Son La, 100 trees (10.4%) had 'very high' grade and 140 (14.6%) had 'high' grade. Some 135, 90 and 15 trees were selected from Lang Cheu, Hang Tau and Song Chong villages respectively, giving a total of 240 individuals selected for further assessments (Table 4).

In Yen Bai, the numbers of trees with 'very high' and 'high' fruit yield were 65 and 120, respectively. In total, 120 trees were selected from Pao Khat village and 40 trees from Cang Dong village providing a total of 160 trees for subsequent evaluations. A total of 600 high-yielding trees were selected for subsequent fruit characteristics evaluation in the three provinces (Table 4).

Table 4: Tree selection according to fruit yield excess index category

Province	Location	Ranking				No. of trees selected
		Category 1	Category 2	Category 3	Category 4	
Dien Bien	Hua Xa	180	170	90	80	110
	Long	90	75	70	45	90
	Total	*270*	*245*	*160*	*125*	*200*
Son La	Lang Cheu	260	105	80	55	135
	Song Chong	25	20	10	5	15
	Hang Tau	210	100	50	40	90
	Total	*495*	*225*	*140*	*100*	*240*
Yen Bai	Cang Dong	80	60	40	20	40
	Pao Khat	195	120	80	45	120
	Total	*275*	*180*	*120*	*65*	*160*
Total		1040	650	420	190	**600**

Step 3. Selection on fruit morphology

The 600 trees selected for high fruit yield were then assessed on fruit morphological attributes. 148 trees were ranked as grade 4 for morphology, implying very good morphological qualities (Table 5). Five trees, recruited from Long, Lang Cheu and Song Chong villages were not selected because they appeared susceptible to pest attack. All in all, 50 trees were selected in Dien Bien; 60 in Son La and 40 in Yen Bai (Table 5). The range in morphological characteristics of some of the selected trees is shown in Figure 4.

Table 5: Trees selected on fruit morphology

Location	Province	Fruit morphology ranking				No. of trees selected for taste evaluation
		Grade 1	Grade 2	Grade 3	Grade 4	
Dien Bien	HuaXa	10	20	48	32	32
	Long	8	27	35	20	18
Son La	Lang Cheu	10	35	55	35	33
	Song Chong	2	3	7	3	2
	Hang Tau	10	20	40	20	25
Yen Bai	Cang Dong	5	7	20	8	10
	PaoKhat	10	20	60	30	30
Total		55	132	265	148	**150**

Figure 4. Fruits from some of the selected candidate trees for fresh fruit (BY 13, 14, 19, 22 & TG4, TG7) and processing (TG2, 6, 9, YB 26 & BY 21, 24). Samples from the two use categories show variations in terms of size, colour, peel texture and shape.

Steps 4 and 5. Selection for fresh fruit and processing

Ten "fresh fruit" trees were selected for propagation, taking into account fruit yield, appearance and taste. Three of the selected "fresh fruit" trees were from plantations in Tuan Giao, Dien Bien and seven were from natural populations in Bac Yen, Son La (Table 6). Twenty (20) trees were selected for wine processing from the plantations and natural forests in Son La and Dien Bien and natural forests in Yen Bai. Overall, nine of the "processing" trees selected were obtained from plantations while 11 were from natural populations (Table 6). Son tra fruit phenotypic traits (size, shape, colour, skin texture) and sweetness attributes were scored to determine fresh fruit selection, while fruits for processing were selected based on high sourness ("Chua") and acerbity ("Chát") attributes. Results showed that the 10 candidates selected for fresh fruits and the 20 candidates selected for processing scored between 6 and 8, while fruit phenotypic traits scores were between 26 and 33 (Table 6).

Table 6: Ranking of son tra selections for fresh fruit and processing qualities

Location, Province	Tree code	Tree age	Morphology score	Fruit taste score	Processing taste score	Purpose	Forest type
Long, Dien Bien	TG4	14	27	8		Fruit	Plantation
Long, Dien Bien	TG7	14	30	6		Fruit	Plantation
Long, Dien Bien	TG8	14	33	8		Fruit	Plantation
Cao A, Son La	BY13	20	33	7		Fruit	Natural
Cao A, Son La	BY14	15	31	6		Fruit	Natural
Cao A, Son La	BY15	14	31	7		Fruit	Natural
Cao A, Son La	BY16	20	30	7		Fruit	Natural
Cao A, Son La	BY17	20	31	7		Fruit	Natural
Cao A, Son La	BY19	14	29	6		Fruit	Natural
Cao A, Son La	BY22	14	32	6		Fruit	Natural
Long, Dien Bien	TG1	14	29		7	Processing	Plantation
Long, Dien Bien	TG2	14	33		6	Processing	Plantation
Long, Dien Bien	TG3	14	27		6	Processing	Plantation
Long, Dien Bien	TG5	14	32		6	Processing	Plantation
Long, Dien Bien	TG6	14	29		6	Processing	Plantation
Long, Dien Bien	TG9	14	31		7	Processing	Plantation
HuaXa, Son La	TG10	14	31		6	Processing	Plantation
HuaXa, Son La	TG11	14	30		7	Processing	Plantation
HuaXa, Son La	TG12	14	29		6	Processing	Plantation
Cao A, Son La	BY18	14	32		7	Processing	Natural
Cao A, Son La	BY20	14	30		6	Processing	Natural
Cao A, Son La	BY21	14	30		6	Processing	Natural
Cao A, Son La	BY23	18	29		8	Processing	Natural
Song Chong, Son La	BY24	18	32		7	Processing	Natural
Song Chong, Son La	BY25	14	26		7	Processing	Natural
Pao Khat, Yen Bai	YB26	10	29		7	Processing	Natural
Pao Khat, Yen Bai	YB27	14	29		6	Processing	Natural
Pao Khat, Yen Bai	YB28	16	30		6	Processing	Natural
Pao Khat, Yen Bai	YB29	14	30		6	Processing	Natural
Pao Khat, Yen Bai	YB30	10	31		6	Processing	Natural

Step 6. Marking final selections and collecting scion material for clonal propagation

The 30 trees selected for clonal propagation and testing were relocated in the field. Each of the recruited trees was marked with a unique code and GPS coordinates recorded. The selected trees were pruned by removing old and diseased branches and spot weeding was carried out around the trees to reduce competition from surrounding vegetation. Trees were labelled with field codes. Scion material, sufficient for 80 grafts per tree, was collected from high parts of the crown for each tree. The scions from each selected tree were labelled with the tree's identity code (Figure 5). Local stakeholders were informed of the locations of selected trees (ortets).

Figure 5. Identity code painted on the trunk of a selected tree and labelled scion material from the tree, for grafting.

Step 7. Grafting

Scions from the 30 selected trees were collected in the morning hours of 15-20 December, 2012 and wrapped in damp bags before transportation in cool boxes to the North West Forest Science Centre nursery in Son La City for grafting in the late afternoon of the same day. Rootstocks were raised from seeds collected from natural stands in Son La province. Grafts success rate was 90%, indicating a high grafting compatibility for son tra (Figure 6). All grafts were labelled with the correct clone identity in the nursery and when planting for clone tests on selected farmers' fields. Establishment and findings from the clonal tests will be covered in a separate report.

4. Efficiency of selection

The 30 final selections were chosen using a multi-stage selection strategy:

(i) Location of suitable natural or planted base populations

(ii) Within populations, selecting trees with superior fruit yields (≈25% of trees selected, from a total of over 2,400 trees screened)

(iii) Fruits of 600 high-yielding trees were assessed for morphology and appearance and the 150 highest-scoring trees, free of pest attack, were selected for further evaluation (50 trees selected for fresh fruit use and 100 trees for processing characteristics (≈ best 25% of trees from stage (ii) selected)

(iv) The 150 trees with high yield and good fruit morphology were assessed for fresh fruit taste and processing characteristics by panels of tasters. Ten (10) trees for fresh fruit and 20 trees for processing were finally selected (≈ best 20% of trees from stage (iii) selected).

The overall selection intensity in the multi-stage selection process is about 1 in 80 (1 in 4 best fruit yield x 1 in 4 best fruit morphology x 1 in 5 best taste or best processing characteristics), but the effective selection intensity for increase in market value is lower than this, for a number of reasons:

(i) Selection for superior fruit yields is somewhat complicated by tree size and tree age, particularly in uneven-aged natural forests. Older trees will tend to have larger canopies and heavier fruit crops. Adjustments were made within localities by selecting trees of smaller diameter if two trees had the same yield excess score. However, this does not provide an exact adjustment because tree age is not known for certain. In addition, fruit yields are affected by the local environment around each tree.

(ii) The fruit morphology score is calculated by summing several attributes including size, shape, colour and texture and it is not known for certain how important these different attributes are in determining market value, although they are all judged to be important.

(iii) Similarly the fruit taste characteristics are added to give an overall taste score, although it is not yet clear which taste characteristics really drive market value for fresh fruit or processing.

(iv) The fruits used in the taste trials come from different regions with different climates, so they have been picked at somewhat differing stages of ripening. It is known that ripeness affects taste, so the rankings for fresh fruit taste and processing suitability confound genetic and environmental effects.

(v) Dividing the different candidate trees among different tasting panels reduces the efficiency of rankings for taste characteristics. This is inevitable, as a single panel cannot be expected to taste fruit from 150 candidate trees.

Clone trials established by the AFLI project will enable more accurate comparison of the final selected trees, grown together in common environments. They can be compared with nearby unselected control trees for fruit yield, fruit appearance, taste and processing qualities.

Figure 6. Successful grafts in the nursery at Son la, 6 months after grafting.

5. Conclusion

This study has identified 30 phenotypically superior trees of son tra, including 10 selections for fresh fruit production and 20 for processing, from populations in natural and plantations forests in three provinces of North West Vietnam. All selections were successfully grafted and the 30 clones are now being evaluated in clonal field trials to rank the selected clones and determine the level of genetic improvement that has been achieved through selection.

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