RESULTS ON BREEDING AND SELECTING OF NEW PROMISING STRAWBERRIES FOR HIGHLANDS IN VIETNAM

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ABSTRACT

Research on breeding and selecting promising strawberry clones has been carried out at the Potato, Vegetable and Flower Research Center in Da Lat city, Lam Dong province and Bac Ha district, Lao Cai province since 2018. The research materials were imported from Korea, Japan and - local varieties in Vietnam. Applying sexual hybridization method to create hybrid combinations, evaluation and selection hybrid individuals combined with asexual propagation through tissue culture method was used in this study. As a result, 50 hybrid combinations were created through the research with 10.800 seeds. Six promising clones including PS1.07, PS7.01, PS8.07, PS8.10, PS8.14, PS17.04 were selected for trials that applying high technology in the net houses in Da Lat city, Lam Dong province and Bac Ha district, Lao Cai province. They are considered with high yield potential (27.8-32.6 tons/ha/year in Da Lat city and 12.7-13.2 in Bac Ha district), first classified fruit (73.6-82.1%), fruit sweetness (Total soluble solids(^{0}Brix):11.0 - 12.6%), good taste, very fragrant and firmness fruit; tolerated to some main diseases such as powdery mildew (*Sphaerotheca macularis*), Anthracnose (*Colletotrichum fragariae*) and Angular leaf spot (*Xanthomonas fragariae)*. Among of 6 promising tested clones, PS8.10 demonstrated to be a remarkable promising clone for high yield (32.6 tons/ha/year in Da Lat city and 13.2 tons/ha/year in Bac Ha district) that it was highly accepted by farmers in productions of Lam Dong and Lao Cai provinces.

Keywords: *Strawberry, promising clones, Da Lat - Lam Dong, Bac Ha - Lao Cai.*

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1. INTRODUCTION

Strawberry (*Fragaria* × *ananassa* Duchesne ex Rozier) is a commonly grown hybrid species and cultivated worldwide for their fruits [1] due to the fact that strawberry is one of the most important berry fruits and is accepted by a large number of consumers around the world [2]. Strawberries have countless health benefits as well, such as preventing some certain cancers, enhancing cardiovascular health, boosting insulin sensitivity and controlling a healthy immune system [3, 4]. In 2019, world production of strawberries was 9,125,913 ton, led by China with 3,801,865 ton and the United States with 1,420,570 ton. These two countries together got approximately 57% of the World's total in 2019.

Breeding and selecting of strawberries were strongly invested and developed in most advanced countries such as the United States, Canada, French, Netherlands, Spain, etc. In the 15th century, breeding started with selection and cultivation of European strawberry species in western Europe. While in 1966, a similar discovery and cultivation just occurred in Chile [5]. However, the first actual actions were carried out in the United Kingdom, the United States, France, Germany in the 19th century [6]. The program of breeding strawberries was mainly directed towards enhancing agronomic performance, resulting in varieties which produced high yields of large red and firm fruits, but fruit aroma was the major quality trait that had a strong impact on consumers [7, 8].

So far, there have been hundreds of strawberry varieties created by public agencies and private companies. The breeding of strawberries started

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with traditional methods and moved on to molecular breeding and genetic engineering in the 20th century to supply to the world's demand for fruits by overcoming adverse conditions and diseases. The back-cross method was also applied in cases to transfer essential genes, especially for transfering resistant genes or adaptive traits from wild species into *F. x ananassa*. The aphid resistance of *F. chiloensis* neutrally reacted to the photoperiod of *F. virginiana* spp. glauca was converted to *F. x ananassa* by this method [9, 10, 11].

In Vietnam, strawberries were mainly carried and grown in Da Lat city, Lam Dong province before 1970. In 1965, the commercial area for strawberries in Da Lat city was estimated to be around 10 hectares (ha) [12]. Up to now, the commodity strawberry area in Lam Dong province is about 200 ha. Lao Cai province is also a potential location with 30 ha for the development of strawberry. Strawberry breeding research in Vietnam is a newly developed field so it currently stops at collecting, importing, and selecting new varieties. From 2003 to 2011, Potato, Vegetable and Flower Research Center imported some varieties from Taiwan and the United States to conduct the research and evaluate, select, crossbreed to create new varieties under Da Lat city climatic conditions. As a result, two varieties Angelis (My Da) and Camarosa (Langbiang 2) were successfully selected during this period. They are the main varieties to open production field in Da Lat city, Lam Dong province, in which the Angelis has accounted predominantly for nearly 60% of the growing area, with an average yield of 13-14 tons/ha/year. During the past years, some organizations and individual enterprises had imported several varieties such as Albion, Monterey, New Zealand, Go Ha, Ha Na, Akihime, White Jewel from the United States, New Zealand, Korea and Japan for experiments in the net house conditions in Lam Dong province. The results showed that the New Zealand (Brix level at 7.5 - 8.7%) was the most suitable variety with high potential yield with red color, beautiful appearance, and slight firmness [13]. Whereas the cultivars from Korea and Japan had good quality but soft firmness and high sensitivity to Powdery mildew. These varieties are seriously degenerating leading to low productivity and quality. Therefore, new varieties need to be created to meet the demand for strawberry production.

2. MATERIALS AND METHODS

2.1. Time and location research

The researches were conducted from January 2018 to May 2021 in Da Lat city, Lam Dong province and Bac Ha district, Lao Cai province:

+ Cross-breeding, harvesting and sowing intervarietal crosses: January 2018 to April 2018, carried out in Da Lat city, Lam Dong province;

+ Growing cycle 1 (C1): May 2018 to December 2018, carried out Da Lat city, Lam Dong province;

+ Growing cycle 2 (C2): May 2019 to the end of May 2020, carried out in Da Lat city, Lam Dong province;

+ Experiment design: May 2020 to the end of May 2021, carried out in Da Lat city, Lam Dong province and Bac Ha district, Lao Cai province;

2.2. Materials

Cross-breeding: 18 varieties were introduced from the United States, New Zealand, Korea, Japan, and other local varieties being produced in Da Lat city, Lam Dong province, in which mainly focused on varieties with high yieldsranging from 20-30 tons/ha/year and Brix level ranging from 9-10%. Moreover, these varieties were resistant to pests and diseases.

Selection cycle 1 (C1): 10.800 seeds of 50 intervarietal crosses were created.

Selection cycle 2 (C2): 18 promising clones in cycle 1 (C1): PS1.01, PS1.05, PS1.06, PS1.07, PS3.01, PS7.01, PS7.02, PS8.01, PS8.02, PS8.03, PS8.07, PS8.09, PS8.10, PS8.14, PS17.01, PS17.02, PS17.03, and PS17.04.

Evaluation and chosen best promising clones:

+ 06 promising clones in cycle 2 (C2): PS1.07, PS7.01, PS8.07, PS8.10, PS8.14, and PS17.04.

+ 06 promising clones in cycle 3 (C3): PS1.07, PS7.01, PS8.07, PS8.10, PS8.14, and PS17.04 for trials on Da Lat city and Bac Ha district.

2.3. Methods

2.3.1. Cross-breeding method and selecting new clones

The program of breeding strawberry is recently applied to acquire new varieties improved for specific agronomic (yield and size), qualitative (firmness, sugars content and acidity) and sensorial (color and aroma) characteristics, all combined to level up the disease resistance and plant adaptability [14].

Strawberries have bisexual flowers. The female plants were emasculated and covered by paper bags.

Pollen was collected from the male plants and brought into the stigma of female plants by hand. Newly bred flowers were covered by paper bags to prevent self natural fertilization by insects. After around 2-3 days, they were uncovered to help the hybrid fruit grow and develop in natural conditions. Hybrid fruits were harvested to get their seeds when half the fruit bodies turned red. The seeds were directly sowed in the trays with light and nutritious soil. The soil was watered gently to keep it moist enough for seed germination. The trays were placed in a warm place with proper sunlight for the seeds to sprout. It took the seeds around 15 - 20 days to germinate and 40 - 45 days after to grow up. Finally, the plants were transplanted into the net house to evaluate and select the promising clones. This is a diagram of the cross-breeding and selection process of promising clones.

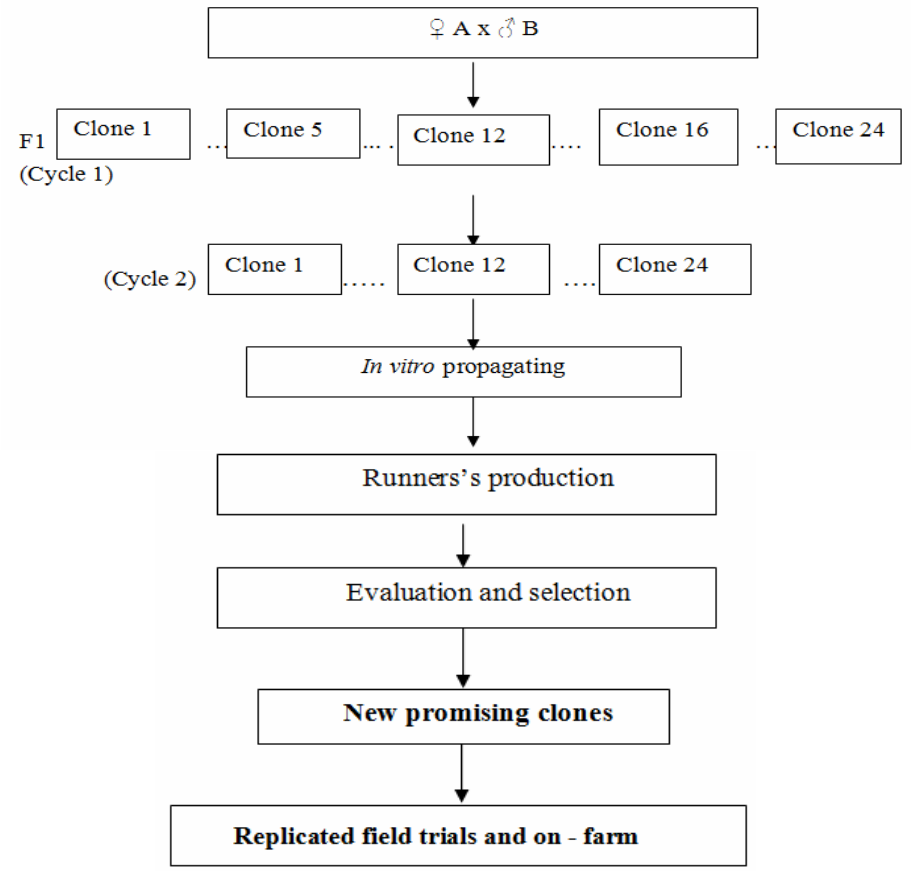

Figure 1. Breeding, selection and evaluation strawberry

2.3.2. Experiment methods

Selection cycles 1, 2 and 3: Experiments were arranged without replication with 50 - 100 plants in 1 plot. The plant's density was 80.000 plants per ha. The control was New Zealand - a common variety produced in the net house conditions in Da Lat city, Lam Dong province.

Experiment design: The experiment was arranged in randomized complete block design with 3 replications and 100 plants in 1 plot. The plant's density was 80.000 plants per ha. The control was New Zealand - a common variety produced in the net house conditions in Da Lat city, Lam Dong province and Bac Ha district, Lao Cai province.

Main selection criteria

*Growth and development indicators

- Plant vigor (1-9): (1) Weak; (5) Intermediate; (9) Vigorous.

- Flowering time (day): Days from transplanting to 50% of plants flowering.

- Ripened fruit time (day): Days from transplanting to fruit ripening.

* Pests and diseases: The assessed methods of pests and diseases in according to National

Technical Regulations QCVN 01-38: 2010/BNN and PTNT [15]:

- Powdery mildew (*Sphaerothe camacularis* f.sp. *fragariae*), Anthracnose (*Colletotrichum fragariae*), and Angular leaf spot (*Xanthomonas fragariae*): (1): Low < 1% of the area of stems, leaves, flowers, and fruits infested; (3): > 1 to 5% of the area of stems, leaves, flowers, and fruits infested; (5): > 5 to 25% of the area of stems, leaves, flowers, and fruits infested; (7): > 25 to 5% of the area of stems, leaves, flowers, and fruits infested; (9) > 50% of the area of stems, leaves, flowers, and fruits infested;

- Thrips (*Frankliniella* spp.), Spider mites (*Tetranichus* spp.): (1) Low (sparse appearance); (2) Medium (distribution of 1/3 leaves, flowers, and fruits; (3) High (distribution > 1/3 leaves, flowers, and fruits);

* Yield components and yield:

- Average number of fruits/plant (fruit): Number of harvested fruits per plot/number of harvested plants per plot.

- Average fruit weight/plant (gram): Weight of harvested fruits per plot/total number of harvested plants per plot.

- Average yield (ton/ha): Collect all fruits in the experimental plot, weigh the weight and convert to ton/ha.

- Average first classified fruit weight (gram): Weight of harvested first classified fruits per plot/Total number of harvested fruits.

- First classified fruit (%): Fruits achieved >10 gram.

* Biochemical qualities:

- Shapes of fruit: Rhombus, Egg, Cone, Heart, Cylinder.

- Firmness levels of fruit: (1): Soft; (2): Medium; (3): Firm.

- TSS (^{0}Brix) (%): measured with the refractometer.

- Taste: (1): Unacceptable; (3): Delicious; (5): Very delicious.

- Flavor: (1): No flavor; (3): Light flavor; (5): Very flavor.

Data analyzing method

The criteria average of each replication of the experiments were calculated by Excel program. Then the SAS 9.1 software was used to compare the data with the Duncan's test at the confidence level of $P < 0.05$.

High-tech technical applications

The experiments were conducted in the 6.0 m height net house conditions which was covered by plastic on the roof and surrounded by protected insect net (32 holes per cm^2);

Plants were grown above the ground on 1.0 m beds (35 cm in width x 30 cm in depth) and mulched by reflective aluminum plastic.

Substrates used for production were the mixture of raw coconut fiber and fresh rice husk according to the ratio of 70:30 (ratio followed by volume). Raw coconut fiber was treated to release tannin and lignin by soaking and rinsing with clean water.

Drip irrigation and automatic fertilizing systems were applied during the growing season.

Strawberry nutrient management

No.	Ingredient	Contain (kg/1000L)	
		Nutrients for the growth season	*Nutrients for the everbearing season*
1	MKP	0.03	0.07
2	KNO_3	0.2	0.2
3	Ca	0.4	0.5
4	$MgSO_3$	0.1	0.1
6	Gold max	0.005	0.005
7	MAP	0.04	0.03
8	Iron Chelate (EDTA) (6%)	0.007	0.007
9	H_3BO_3(17.5%)	0.001	0.001
		EC: 0.6 - 0.8 dS/m; pH: 6.0 - 6.3	EC: 1.1 - 1.4 dS/m; pH 6.0 - 6.3

Adequate mineral nutrition, weather conditions and cultivars decide the yield level of quality production [15]. The plants must be monitored and determined when they need additional nutrient

irrigation solutions. Irrigation should be administered at frequent enough intervals to keep the moisture supply even.

+ Growing season (two months before flowering): Nutrient irrigation solution was given 350-400 ml/plant/day, EC: 0.6-0.8. The concentration was gradually increased to 0.1 after each week and not over 0.3 per time to stress the plant.

+ Flowering to everbearing season (from 60 days to 120 days after planting): Nutrient irrigation solution was given 300 - 350 ml/plant/day. EC: 1.1 - 1.4.EC exceeded over 1.5 (EC at the bottom>2.0) leading to sweet fruits but salty plants and dried leaf tips and calyx.

+ Plants were irrigated 6 times per day for 2 - 3 minutes each. The proper time to irrigate depended on weather conditions to adjust. In the everbearing season (everbearing season and fruit harvesting: after 2 months onwards): Watering solution ensured 400 - 500 ml/plant/day and the rate of solution escaping was about 25%; EC: 2.0-2.5.

Planting care

The temperature for strawberries to grow was around 17 - 24°C. The humidity requirement for each stage: 60 - 75% during the growing season, 60 - 65% during the flowering season and 60% for the everbearing season. These were the suitable conditions for strawberries to absorb good nutrients, gain high yield and reduce diseases.

Extra stems and leaves needed pruning regularly to create good ventilation to reduce pests and diseases. Maintaining two stems per one plant and 3 - 4 leaves per one stem to reduce nitrogen in the plants and make the neck's roots create large flower clusters. It helped to stimulate flower sprout differentiation in the everbearing season. Plants remained 5-6 leaves per one stem at the period of flower and fruit.

If there were too many flowers per bundle, small flowers needed to be pruned to achieve large and uniform fruits only. There should have been only 7 - 10 fruits per plant. In addition, bees were put in the flowering stage to improve pollination.

3. RESULTS AND DISCUSSION

3.1. The results of promising clones' selection in cycle 1 (C1)

50 intervarietal crosses with 10.800 seeds and 75 - 80% germination rate was focused on high yield, good quality and resistance to some major diseases. After 45 sowing days, 8,200 seedlings were planted to evaluate and select promising clones in generation 1. Out of the 8,200 seedlings planted, the results selected 18 promising clones with the main characteristics such as vigor growth graded from 8 - 9/9 points, light infection with pests and diseases graded from 1 - 3/9 points as powdery mildew (*Sphaerotheca macularis*), anthracnose (*Colletotrichum fragariae*), angular leaf spot (*Xanthomonas fragariae*), thrips (*Frankliniella* spp.), and spider mite (*Tetranichus* spp.) It took 75 - 80 days after planting (DAP) for the promising clones to flower after the planting and 95 - 100 DAP for the fruits to ripen. Most of the promising clones had fruit bearing types in clustered type except for eight clones that were single. The shapes of fruit were in different forms such as heart, rhombus, egg, cone, cylinder. All fruit turned red when ripened with few seeds, compact, and good firmness. The TSS of all clones was quite high (10.5 - 12.3^{0}Brix). There were 8 promising clones that tasted delicious (PS1.05, PS1.07, PS7.01, PS8.07, PS8.01, PS8.10, PS8.14, PS17.04). Most promising clones tasted light to very flavorful.

The promising clones had the average fruits/plant ranging from 27 - 36 fruits/plant in which first classified fruit reached the ratio of 65.8 to 79.2% and the average weight of first classified fruit was from 10.6 to 14.3 g/fruit. The total yield of promising clones obtained 28.4 to 32.7 tons/ha/year in which six clones achieved over 28 tons/ha/year like PS 1.07 (30.4 tons/ha), PS7.01 (28.4 tons/ha), PS8.07 (29.3 tons/ha), PS8.10 (32.7 tons/ha), PS8.14 (30.1 tons/ha), PS17.04 (31.6 tons/ha).

3.2. The results of promising clone selection in cycle 2 (C2)

18 promising clones in cycle 1 were propagated clonally by tissue culture and produced runners for the second observational trial to evaluate and select the promising clones in cycle 2 (grown during May 2019 to the end of May 2020). During the trial, superior genotypes were selected for the second round as the most promising clones for basic evaluation. The observations showed that the most promising clones, in general, had profuse growth and achieved the vigorous growth of 8 - 9/9 points. Flowering time ranged from 70 to 78 DAP and matured from 94 to 102 DAP. During the growth period, all clones were slightly infected by pests and diseases (Table 1).

Table 1. Some growth characteristics and level of infection by pests and diseases of 18 promising clones in cycle 2 (C2) in May, 2019 to the end of May, 2020

Name of promising clones	Vigor plant (1-9)	Flowering time (day)	Ripened fruit time (day)	Powdery mildew (1-9)	Anthrac-nose (1-9)	Angular leaf spot (1-9)	Thrips (1-3)	Spider mite (1-3)
PS1.01	9	70-75	96-100	3	3	1	1	2
PS1.05	9	70-75	95-100	3	2	1	1	1
PS1.06	9	70-75	96-100	3	2	2	1	1
PS1.07	9	70-75	94-98	2	2	1	1	1
PS3.01	8	72-75	98-102	3	3	1	1	2
PS7.01	9	70-72	96-100	2	2	1	1	1
PS7.02	8	70-72	95-98	3	2	1	1	1
PS8.01	9	75-78	98-102	3	2	1	1	1
PS8.02	9	75-78	96-100	3	2	3	1	1
PS8.03	9	75-78	97-102	3	3	3	1	2
PS8.07	9	75-78	98-100	2	2	1	1	1
PS8.09	8	75-78	97-100	3	2	1	1	1
PS8.10	9	75-80	98-102	2	2	1	1	1
PS8.14	9	75-80	98-102	3	2	1	1	1
PS17.01	8	72-75	96-100	3	3	2	1	1
PS17.02	9	72-74	96-100	3	2	1	1	1
PS17.03	8	72-74	95-100	3	2	1	1	1
PS17.04	9	72-74	94-98	2	1	1	1	1
New Zealand	8	72-74	95-98	4	3	2	1	2

Yield is conditional on the combination of a characteristic list including the number of flowers, and the consequences of fruits such as size, hardiness, and resistance to diseases [16]. The results in table 2 showed that the average fruits/plant of promising clones was 28 - 34 fruits/plant. The fruits were quite large and relatively uniform, leading to a high percentage of first classified fruit. The first classified fruit achieved 64.8 - 80.2%, in which most of the promising clones gained above 70%. In terms of average fruit weight/plant, the promising clones obtained 307.9 - 401.0 g/plant. Out of the 18 promising clones, the six (PS1.07, PS7.01, PS8.07, PS8.10, PS8.14, PS17.04) gave 357.1 - 401.0 g/plant. The total yield of 18 promising clones gained 24.4 - 32.3 tons/ha/year. Six promising clones continued achieving the high yield 28.4 - 32.2 tons/ha/year found in PS1.07 (29.0 tons/ha), PS7.01 (28.8 tons/ha), PS8.07 (29.3 tons/ha), PS8.10 (32.2 tons/ha), PS8.14 (28.4 tons/ha), and PS17.04 (30,1 tons/ha).

Table 2.Yield components and yield of 18 promising clones in cycle 2 (C2) in Da Lat city, Lam Dong province in May, 2019 to the end of May, 2020

Name of promising clones	Fruits/plant (fruit)	First classified fruit (%)	First classified fruit weight (g)	Average fruit weight/plant (g/plant)	Total yield (tons/ha/ year)
PS1.01	30	75.4	12.7	325.3	26.0
PS1.05	32	71.5	13.5	339.5	27.2
PS1.06	30	64.8	14.6	326.6	26.1
PS1.07	29	77.5	14.7	362.0	29.0
PS3.01	31	67.5	13.8	307.9	24.6
PS7.01	33	78.2	13.1	358.2	28.8
PS7.02	30	77.9	11.8	307.9	24.4

PS8.01	34	70.5	11.2	335.6	26.8
PS8.02	33	70.9	12.1	328.2	26.3
PS8.03	33	73.3	11.4	318.7	25.5
PS8.07	31	76.0	12.6	365.9	29.3
PS8.09	31	75.1	12.9	333.4	26.7
PS8.10	32	80.2	13.6	401.0	32.2
PS8.14	33	74.8	12.0	357.1	28.4
PS17.01	34	70.5	12.3	346.9	27.8
PS17.02	33	74.8	11.9	334.1	26.7
PS17.03	28	78.2	12.5	351.8	27.3
PS17.04	34	78.3	12.6	380.3	30.1
New Zealand	33	67.7	11.7	312.7	25.0

Fruit size and color development demonstrate the fruit quality, whereas taste, texture, and flavor attract consumer's acceptance [17, 18]. Therefore, creating and selecting good qualities of strawberry were the most important goal of the research and beautiful fruit appearance will intensely hit the customers. The fruits of promising clones varied deeply and beautifully in shapes that created a variety of fruit shapes such as rhombus, egg, cone, and cylinder. The firmness of fruit decides the shelf life, packaging, and transportation of strawberries. The fruit with higher firmness is more easily accepted by transporters and customers. Most of the promising clones had good firmness, but some were only intermediate with taste and flavor. The TSS (^{0}Brix) of promising clones ranged from 10.2 - 12.3%. Flavor plays an important role in consumers' satisfaction and influences further consumption of fruits in general [19]. The observations showed that the most promising clones expressed the flavor from fragrant to very fragrant (Table 3).

Table 3. Some main biochemical qualities of 18 promising clones in cycle 2 (C2) in Da Lat city, Lam Dong province in May, 2019 to the end of May, 2020

Name of promising clones	Shape of fruit	Firmness (1-3)	TSS (^{0}Brix)	Taste (1-5)	Flavor (1-5)
PS 1.01	Rhombus	3	10.2	3	3
PS 1.05	Rhombus	2	10.4	5	3
PS 1.06	Rhombus	3	12.5	3	3
PS 1.07	Rhombus	2	11.2	5	3
PS 3.01	Cone	2	12.0	3	3
PS 7.01	Egg	3	11.4	5	5
PS 7.02	Egg	2	10.5	3	5
PS 8.01	Cone	2	10.4	5	3
PS 8.02	Cone	3	10.3	3	3
PS 8.03	Cone	2	11.8	3	3
PS 8.07	Cone	3	12.1	5	5
PS 8.09	Cone	3	11.6	3	3
PS 8.10	Cone	3	12.3	5	5
PS 8.14	Cone	3	11.8	5	5
PS 17.01	Rhombus	3	11.0	3	3
PS 17.02	Rhombus	3	11.0	5	3
PS 17.03	Rhombus	3	10.7	3	5
PS 17.04	Rhombus	3	11.3	5	3
New Zealand	Cylinder	3	8.6	3	3

After the evaluation in cycle 2, six promising clones (PS1.07, PS7.01, PS8.07, PS8.10, PS8.14, and PS17.04) gaining high yield and good quality were multiplied and re-evaluated in larger trials in Da Lat city, Lam Dong province and three promising clones (PS8.10, PS8.14, and PS17.04) were assessed in various location (Bac Ha district, Lao Cai province).

3.3. The results of the trial of six promising clones in highland conditions

3.3.1. In Dalat city, Lam Dong province

The trial was carried out from May 2020 to the end of May, 2021 to re-evaluate the potential yield quality and resistance to main pests and diseases of the promising clones in cycle 3. The results showed that the promising clones continued growing strongly and achieved the vigorous growth of 9/9 points. Flowering time was ranging from 70 to 76 DAP and maturing from 94 to 100 DAP. Major pests and diseases were assessed during the growing season. The level of infestation was similar or milder to that of the check New Zealand. Powdery mildew was the major threat of strawberry cultivation directly affected yield and fruit quality. Powdery mildew infection was not significant for the promising clones, ranging from 2 to 3/9 points while the control was more seriously infected (5/9 points). Most of the clones had low levels of infestation by anthracnose and angular leaf spot (2 - 3/9 points). Thrips infection level was not significant for the promising clones while spider mites caused damage at 2/3 points for PS7.01 and PS17.04. The check was seriously infected at 3/3 points (Table 4).

Table 4. Some growth characteristics and level of infection by pests and diseases of 6 promising clones in cycle 3 (C3) in Da Lat city, Lam Dong province in May, 2020 to the end of May, 2021

Name of promising clones	Vigor plant (1-9)	Flowering time (day)	Ripened fruit time (day)	Powdery mildew (1-9)	Anthrac-nose (1-9)	Angular leaf spot (1-9)	Thrips (1-3)	Spider mite (1-3)
PS1.07	9	70-72	94-98	2	2	2	1	1
PS7.01	9	70-72	96-98	3	3	1	1	2
PS8.07	9	74-75	96-100	3	2	1	1	1
PS8.10	9	74-76	96-100	2	2	1	1	1
PS8.14	9	74-76	95-98	3	2	1	1	1
PS17.04	9	72-74	94-98	3	2	1	1	2
New Zealand	8	70-72	95-98	5	3	3	1	3

In this trial, the yield remained high and was comparable to results from generation 2 from previous years. The average fruits/plant of promising clones varied from 31.1 to 34.2 fruits/plant, being the lowest in PS1.07. No significant differences in fruits/plant were found between the remaining clones (33.4 to 34.2 fruits/plant) while the control gave 32.2 fruits/plant. The first classified fruit of promising clones accounted for 76.4 to 82.1%. Among the promising clones, the first classified fruit weight gained from 12.2 to 14.8 g, being the largest in PS1.07. The average fruit weight/plant ranged from 347.6 to 407.9 g/plant. The total yield indicated significant differences between promising clones, in which PS1.07, PS8.07, PS8.10, and PS8.14 continued proving to be the superior clones for high yield (30.2 - 32.6 tons/ha/year) (Table 5).

Table 5. Yield components and yield of 6 promising clones in cycle 3 C3) in Da Lat city, Lam Dong province in May, 2020 to the end of May, 2021

Name of promising clones	Fruits/plant (fruit)	First classified fruit (%)	First classified fruit weight (g)	Average fruit weight/plant (g/plant)	Total yield (tons/ha/ year)
PS1.07	31.1c	77.8b	14.8a	384.1ab	30.7ab
PS7.01	33.6a	76.4b	12.2c	347.6c	27.8c

PS8.07	33.9a	80.2a	12.8bc	388.2ab	31.1ab
PS8.10	33.4a	81.8a	13.6b	407.9a	32.6a
PS8.14	33.4a	82.1a	12.9bc	377.3b	30.2b
PS17.04	34.2a	80.1a	12.3c	372.3bc	29.8bc
New Zealand	32.3b	71.0c	11.9c	320.8d	25.7d
$LSD_{0.05}$	0.8	2.5	0.9	26.7	2.1
CV (%)	5.1	4.8	3.9	5.8	6.9

The top priority of creating new strawberry varieties is high yield in quality berry production as red, sweet, ripe and juicy fruits like those freshly picked from a garden are always the consumers' choice [20]. The main qualities of promising clones were unchanged from generation 2. Most of the promising clones had good firmness except for PS1.07 which gave medium firmness. The TSS (^{0}Brix) had not changed significantly compared to the previous season, graded from 11.2 to 12.6%. In addition, the taste and flavor remained the same as the previous trial (Table 6).

Table 6. Some main biochemical qualities of 6 promising clones in cycle 3 (C3) in Da Lat city, Lam Dong province May, 2020 to the end of May, 2021

Name of promising clones	Shape of fruit	Firmness (1-3)	TSS (^{0}Brix)	Taste (1-5)	Flavor (1-5)
PS1.07	Rhombus	2	11.2	5	3
PS7.01	Egg	3	11.6	5	5
PS8.07	Cone	3	12.3	5	5
PS8.10	Cone	3	12.6	5	5
PS8.14	Cone	3	11.7	5	5
PS17.04	Rhombus	3	11.2	5	3
New Zealand	Cylinder	3	8.8	3	3

Figure 1. The fruits of six promising clones

Figure 2. The field trip to introduce promising clones in Da Lat city, Lam Dong province

3.3.2. In Bac Ha district, Lao Cai province

Three promising clones (PS8.10, PS8.14, PS17.04) introduced by the Potato, Vegetable, and Flower Research Center were planted in Bac Ha district, Lao Cai province at the same time as in Da Lat city. Three promising clones had shown to be relatively well adapted in Bac Ha district. The results showed that the promising clones grew well and achieved the vigor growth of 8 - 9/9 points while the control got 7/9 points. Flowering time ranged from 72 to 75 DAP and matured from 96 to 100 DAP. Powdery mildew infection was not significant for the promising clones (3/9 points) while the control was more seriously infected (5/9 points). PS8.10 and PS8.14 were not significantly infested by anthracnose and angular leaf spot (1/9 points) while PS17.04 was infected in 3/9 points. In this area, thrips infection level was not significant for the promising clones while spider mites caused damage at 2/3 points for PS17.04 and the check (Table 7).

Table 7. Some growth characteristics and level of infection by pests and diseases of 3 promising clones in cycle 3 (C3) in Bac Ha district, Lao Cai province in May, 2020 to the end of May, 2021

Name of promising clones	Vigor plant (1-9)	Flowering time (day)	Ripened fruit time (day)	Powdery mildew (1-9)	Anthrac-nose (1-9)	Angular leaf spot (1-9)	Thrips (1-3)	Spider mite (1-3)
PS8.10	9	73-75	98-100	3	1	1	1	1
PS8.14	8	72-75	98-100	3	1	1	1	1
PS17.04	8	72-74	96-98	3	3	3	1	2
New Zealand	7	70-73	94-97	5	4	3	1	2

In Bac Ha district, yield components and yield are lower than in Da Lat city because Da Lat city is the ideal area for strawberry production in Vietnam. The average fruits/plant of promising clones gained from 17.0 to 18.6 fruits/plant, being the lowest in PS8.14. No significant differences in fruits/plant were found between PS8.10 and PS8.14 (18.0 to 18.6 fruits/plant) while the control gave 17.5 fruits/plant. The first classified fruit of promising clones accounted for 73.6 to 77.0%. The first classified fruit weight in Bac Ha district was smaller than in Da Lat city, gained from 10.6 to 11.4 g, being the largest in PS8.10. The average fruit weight/plant ranged from 158.9 to 172.7 g/plant. Under the climatic conditions in Bac Ha district, the total yield dropped to 1/2 of that in Da Lat city but the yield was acceptable in Bac Ha district conditions. The total yield indicated significant differences between promising clones (12.7-13.2 tons/ha/year), in which PS8.10 continued proving to be the superior clone in Bac Ha district (Table 8).

Table 8. Yield and yield components of 3 promising clones in generation 3 (C3) in Bac Ha district, Lao Cai province in May, 2020 to the end of May, 2021

Name of promising clones	Fruits/plant (fruit)	First classified fruit (%)	First classified fruit weight (g)	Average fruit weight/plant (g/plant)	Total yield (tons/ha/ year)
PS8.10	18.0ab	77.0a	11.4a	172.7a	13.2a
PS8.14	17.0c	75.3a	11.0b	158.9b	12.7b

PS17.04	18.6a	73.6a	10.6c	160.9b	12.9b
New Zealand	17.5bc	66.3b	10.7c	140.6c	11.3c
$LSD_{0.05}$	0.9	3.7	0.3	4.6	0.3
CV (%)	4.7	5.8	4.6	5.2	5.1

The main qualities of the three promising clones in Bac Ha district were unchanged in comparison to those in Da Lat city. All promising clones had good firmness and high TSS (^{0}Brix), from 11.0 to 12.4%. The taste and flavor of PS8.10 and PS8.14 reached 4/5 points while PS17.04 got 3/5 points. The check New Zealand gave 3/5points in taste and flavor (Table 9).

Table 9. Some main biochemical qualities of 3 promising clones in generation 3 (C3) in Bac Ha district, Lao Cai province in May, 2020 to the end of May, 2021

Name of Promising clones	Shape of fruit	Firmness (1-3)	TSS (^{0}Brix)	Taste (1-5)	Flavor (1-5)
PS8.10	Cone	3	12.4	5	5
PS8.14	Cone	3	11.6	4	5
PS17.04	Rhombus	3	11.0	3	3
New Zealand	Cylinder	3	8.4	3	3

After the experiment design, PS8.10 demonstrated to be a remarkably promising clone for high yield (32.6 tons/ha/year in Da Lat city and 13.2 tons/ha/year in Bac Ha district), first classified fruit (77.0 - 82.1%), and TSS (^{0}Brix): 12.4 - 12.6%.

4. CONCLUSION

Under the favorable climatic conditions in Da Lat city, breeding for strawberries is practically feasible that holds a promise for domestic breeding of new cultivars: 10.800 seeds of 50 intervarietal crosses were created and evaluated.

Six promising clones (PS1.07, PS7.01, PS8.07, PS8.10, PS8.14, PS17.04) were selected to apply high technology in the net houses in Da Lat city, Lam Dong province: high yield potential (27.8 - 32.6 tons/ha/year, first classified fruit (76.4 - 82.1%), fruit sweetness (TSS (^{0}Brix): 11.2 - 12.6%). Three promising clones (PS8.10, PS8.14, PS17.04) were selected to apply high technology in the net houses in Bac Ha district, Lao Cai province: High yield potential (12.7 - 13.2 tons/ha/year), first classified fruit (73.6 - 77,0%), fruit sweetness (TSS (^{0}Brix): 11.0 - 12.4%). All promising clones gave good taste, very fragrant and hardness fruit. In addition, they were tolerant to some main diseases such as powdery mildew (*Sphaerotheca macularis*), *Colletotrichum fragariae* and *Xanthomonas fragariae*).

PS8.10 demonstrated to be a remarkably promising clone for high yield (32.6 tons/ha/year in Da Lat city and 13.2 tons/ha/year in Bac Ha district), first classified fruit (77.0 - 82.1%), and TSS (^{0}Brix): 12.4 - 12.6%.

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