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Performance of an Elite Strawberry Population Derived from
Wild Germplasm of *Fragaria chiloensis* and *F. virginiana*

presented by

Travis Lyle Stegmeir

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of the requirements for the

Master of Science degree in Plant Breeding and Genetics - Horticulture

James F. Hancock
Major Professor's Signature

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PERFORMANCE OF AN ELITE STRAWBERRY POPULATION DERIVED FROM WILD GERMPLASM OF *Fragaria chiloensis* AND *F. virginiana*

By

Travis Lyle Stegmeir

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ABSTRACT

PERFORMANCE OF AN ELITE STRAWBERRY POPULATION DERIVED FROM WILD GERMPLASM OF *Fragaria chiloensis* AND *F. virginiana*

By

Travis Lyle Stegmeir

Fragaria x *ananassa* Duchesne ex Rozier, or the cultivated strawberry, resulted from the accidental hybridization of two wild species, *F. chiloensis* (L.) Miller and *F. virginiana* Miller. In an attempt to recreate the cultivated strawberry, elite clones of *F. chiloensis* and *F. virginiana* were crossed within species and then hybridized to produce 23 reconstructed populations. Of these populations, FVC11 [(Frederick 9 x LH 50-4) x (Scotts Creek x 2 MAR 1A)] had unusually large fruit size and was selected for further analysis. In the summer of 2008, 78 individuals of this population were evaluated for their seasonal flowering patterns, inflorescence number, inflorescence height, crown production, flower number, fruit size, yield, internal color, soluble solids, fruit firmness and plant vigor. Progeny means were compared to those of the parental means and most traits exhibited transgressive segregation, most notably yield and fruit weight. Significant positive correlations were found between many of the production traits, although there were significant negative correlations between fruit firmness and flower number per inflorescence, fruit firmness and soluble solids and yield per plant and soluble solids. Overall performance scores were assigned to each genotype by summing their relative performance for each trait in the population. Individuals were identified that combined high values for fruit weight and yield with higher than average values for fruit color, firmness and soluble solids. Use of this population in breeding programs could help expand the genetic base of the cultivated strawberry with limited linkage drag.

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Introduction

The primary cultivated strawberry, *Fragaria* x *ananassa* Duchesne ex Rozier, is believed to have arisen from a chance hybridization between the two octoploid species *F. chiloensis* (L.) Miller and *F. virginiana* Miller in Europe around 250 years ago (Hancock, 1999). This hybridization combined the unique characteristics of both species including the larger, firmer fruit of *F. chiloensis* with the darker red, more aromatic fruit of *F. virginiana.*

In a study done by Sjulin and Dale (1987) comparing the pedigrees of 134 North American strawberry cultivars, it was found that all North American cultivars were derived from only 53 founding clones. They later concluded that there were fewer than 17 cytoplasms represented in the same set of 134 cultivars (Dale and Sjulin, 1990).

The fact that *Fragaria* x *ananassa* has a narrow germplasm base likely has breeding ramifications. The species tolerates inbreeding poorly (Shaw, 1991 and Niemirowicz-Szczytt, 1989) indicating that heterosis is important in the cultivated strawberry. A lack of genetic diversity also leaves concern for susceptibility to disease, abiotic and biotic stresses (Luby and Stahler, 1993). A narrow genetic base could inhibit cultivars from facing new environmental challenges, and also leaves less room for improvement due to restricted genetic diversity (Luby et. al., 1991).

Because of the accidental nature of the original hybridization, it has been proposed that strawberry breeders should reconstitute *F.* x *ananassa* by intercrossing elite wild *F.*

virginiana and *F. chiloensis* parents. This would increase the genetic base of *F.* x *ananassa* and introduce novel genetic diversity into the cultivated strawberry gene pool (Hancock et. al., 1993). There are, however, some potential problems with introgressing wild germplasm into *F.* x *ananassa*, including the possibility of incorporating unfavorable alleles through linkage drag. It has also been suggested that by incorporating wild germplasm into a breeding program, several generations of improvement will be necessary to restore fruit quality to that of industry standard (Scott and Lawrence 1975), especially when utilizing the small, soft-fruited *F. virginiana* (Scott, 1959). Previous studies have found that at least three rounds of backcrossing back to *F.* x *ananassa* were necessary to recover genotypes meeting commercial standards (Bringhurst and Voth, 1978, Scott and Lawrence 1975).

Evaluations have been done on selected wild-collected clones of both species in multiple locations to identify the possible beneficial traits which could be incorporated into the cultivated strawberry, and thereby select elite germplasm (Hancock et. al., 2001a, Hancock et. al., 2001b). At least 8 wild clones have been introgressed into *F.* x *ananassa* since the 1920's (Sjulin and Dale, 1987), bringing in such traits as day-neutrality, red stele and strawberry aphid resistance, drought and salinity tolerance and winter hardiness (Bringhurst and Voth, 1984; Galletta et. al., 1989; Barritt and Shanks, 1980; and Daubeny, 1990). Other promising traits which could be introgressed are a higher photosynthetic rate, lower requirements for fertilizer, heat tolerance, resistance to soil pathogens and vigor from *F. chiloensis*, and resistance to soil pathogens, vigor and resistance to powdery mildew and scorch from *F. virginiana* (Hancock et. al., 2002; Scott et. al., 1972; Bringhurst et. al., 1977; Hancock et. al., 2001b; and Cameron and Hartley, 1990).

In a previous study (Hancock et al., in prep), elite selections of *F. virginiana* and *F. chiloensis* were intercrossed in 23 combinations and evaluated in the field in Michigan and Oregon. The most impressive family was FVC11 [(Frederick 9 x LH 50-4) x (Scotts Creek x 2 MAR 1A)] which had the best combination of fruit size, color and yield and was composed of four different subspecies - *F. virginiana* ssp. *virginiana* from Ontario (Frederick 9, PI 612493), *F. virginiana* ssp. *glauca* from Montana (LH 50-4, PI 612495), *F. chiloensis* ssp. *chiloensis* from Chile (2 MAR 1A, PI 602567) and *F. chiloensis* ssp. *pacifica* from California (Scotts Creek, PI 612490). Herein, the population derived from this complex hybrid was more extensively studied for various horticultural traits including both plant and fruit characteristics.

Materials and Methods

In the fall of 2006, rooted runners from 78 genotypes of FVC11 were dug and transferred to East Lansing, MI from Corvallis, Oregon and Benton Harbor, Michigan where the original trials were conducted (Hancock et al, in prep). The genotypes were transplanted into a commercial potting mix in 4 x 4 x 6-inch pots and placed in an unheated greenhouse. In June of 2007, two to three replicates (runner plants) of each genotype were set in the field in Benton Harbor, MI in a Randomized Complete Block Design.

Plants were set in rows at 1.2 m x 1.2 m spacing and all runners were trained by cross cultivation into a 1.2 x 1.2 m square.

Genotypes were evaluated for their seasonal flowering patterns in 2007 and 2008 from mid-July to early September. Genotypes were considered remontant (RM) if they flowered both in the beginning of the season and after July 21st when day length exceeded 13 hours. Waiting until this date allowed any flowers that had been initiated under shorter days to finish blooming before the data were collected (Hancock et. al., 2002). All other plants were considered to be non-remontant. We have chosen the term remontant rather than the more common classification of day-neutral, as evidence is accumulating that repeat flowering is more strongly regulated by temperature than photoperiod (Bradford et al, submitted).

In early June 2008, data were taken on several reproductive and vegetative traits of each mother plant and three randomly selected daughter plants (when available) per plot. Three random inflorescences were selected per mother and daughter plants and their heights were measured from crown to tip, and their flower numbers were counted. The number of crowns was also counted on each mother plant and the three daughter plants, as well as the total number of plants within the block for each genotype. Overall plant vigor was estimated on a 1-7 (least to most vigorous) scale based on plot fill and individual plant vigor.

During the fruiting season of 2008 (June 9 to July 17), the plots were assessed about every five days and the first five ripe fruit, and any additional ripe fruit, were harvested in each. The plots were picked again when another five fruit per block were ripe; however, this time, both the ripe and unripe fruit were picked. If a plot had fewer than five fruit, all those available were picked when ripe. Mean fruit weight was calculated for the first five ripe berries in each plot. Mean yield per plant, per plot was also determined by dividing the total weight of green and ripe fruit from each genotype by the total number of plants in each plot.

Fruit firmness (g/mm^2) was measured on five ripe fruit per plot (when available) using the compression test of BioWorks' FirmTech 2 (Wamego, KS). Two ripe fruits from each replication were cut in half and percent internal color was estimated based on how deep the color penetrated the flesh. Soluble solids were taken by squeezing one drop of juice onto the handheld refractometer from the two fruits for two separate readings.

Pearson correlation values were calculated for 13 plant, flower and fruit characteristics using mean genotype values. The analysis was run using SPSS version 16 (Chicago, IL). Correlation values were considered significant at a 0.05 level. T-tests were used to compare the average values of the remontant and non-remontant genotypes using the proc ttest in SAS 9.1.3 (Cary, NC).

The overall performance of each genotype was rated by dividing the mean value of each genotype by the highest value of any genotype for fruit internal color, soluble solids, yield per plant, firmness, inflorescence height, plants per block, vigor, and fruit weight, to give a value less than or equal to 1 for each trait. The values for each genotype's traits were then added to generate a total performance score.

Results

In 2007, 25 genotypes proved to be remontant, with 21 repeat-flowering in more than one replicate (strongly remontant) and another 4 repeat-flowering in just one replicate (weakly remontant). Twenty-nine genotypes were classified as remontant in 2008, with 21 being strong and 8 being weak. Neither of the parents was classified as remontant in 2007, and the *F. virginiana* parent performed as a weak remontant in 2008. Only four genotypes, FVC11-015, FVC11-021 FVC11-022 and FVC11-031, were deemed remontant in 2007 and not 2008, of which all were "weak" except for FVC11-031 which did not survive the winter. In 2008, 9 genotypes were rated remontant that were non-remontant in 2007, 5 "weak" ones (FVC11-043, FVC11-048, FVC11-055, FVC11-070 and FVC11-077), and 4 strong ones (FVC11-014, FVC11-035, FVC11-054 and FVC11-066). The mean values of remontant and non-remontant genotypes were not significantly different ($P < 0.05$) for most traits, with the exception of yield per plant, daughter plants per mother, inflorescences per mother and vigor (Table 1).

Many progeny displayed transgressive segregation, with their trait values being higher than their parental genotypes. For only two traits (soluble solids and plant vigor) were no transgressive segregates observed (Figures1-3). Significant ($P< 0.05$) negative correlations were observed between fruit firmness and flowers per inflorescence, fruit firmness and soluble solids, yield per plant and soluble solids, yield per plant and daughter plants per mother, flower number per inflorescence and crown number per mother plant and flower number per inflorescence and inflorescence number per mother plant. All other significant correlations were positive (Table 2). Only internal fruit color was not significantly correlated with any of the other traits studied. A significant negative correlation ($p = 0.029$) was found between the heaviest fruit weight of each genotype and soluble solids, and between mean fruit weight and soluble solids at the $p=0.07$ level.

The total performance values for each genotype studied in 2008 ranged from 3.38 to 5.90 (out of a possible 8) (Table 3). Values for the top 10 genotypes ranged from 5.34-5.90. The top 10 genotypes included three genotypes, FVC11-049, FVC11-057 and FVC11-058, that were remontant in both 2007 and 2008, and one genotype, FVC11-055, that was weakly remontant in 2008. The rest of the top 10 genotypes were all non-remontant.

Discussion

The reconstruction of *F.* x *ananassa* by crossing elite genotypes of *F. chiloensis* and *F. virginiana* appears to be an effective strategy for strawberry improvement. While none of the examined FVC11 genotypes are of commercial quality, many have characteristics superior to their parents. In the relatively small FVC11 population, individuals were identified that have high levels for several horticulturally important traits which could be used as parents to broaden the genetic base of the cultivated strawberry. Superior individuals were identified that were both remontant and non-remontant.

Shaw (1988) warns that care must be taken to not only consider size when utilizing wild germplasm to avoid narrowing the germplasm base for other important traits. Many of the FVC11 genotypes were superior for multiple traits. Where negative correlations were observed between characteristics such as between soluble solids and fruit weight and soluble solids and yield per plant, outliers could be found. For example, FVC11-049 had a 0.85 performance value for soluble solids and a 0.83 fruit weight value, while FVC11-059 had a 0.74 soluble solids value and a 0.95 yield per plant value. In fact, FVC11-044 had values of 0.70 or higher for 7 of the 8 traits examined.

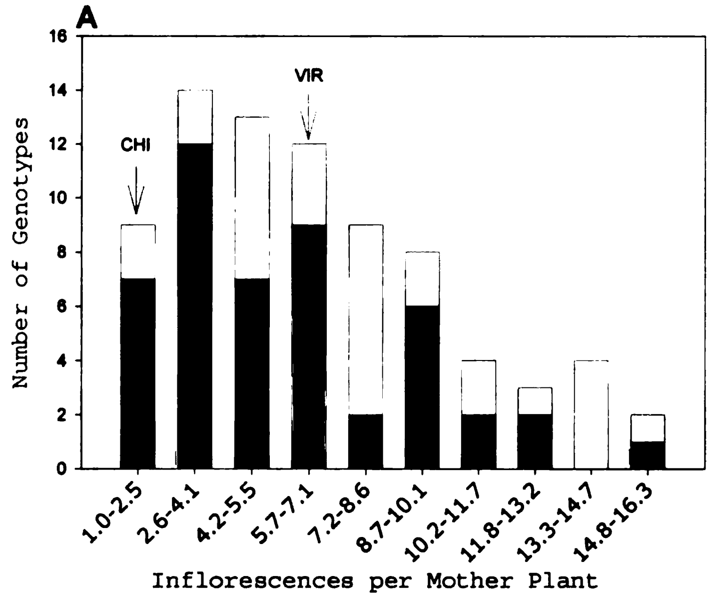
The question remains as to whether intercrossing within reconstructed populations will yield new cultivars. While the fruit size in the best FVC11 genotypes is far superior to any wild germplasm, it is still not close to commercial size. The most rapid breeding progress may be made by backcrossing the best FVC11 genotypes to cultivars. However, too many generations of backcrossing runs the risk of losing much of the genetic variation and novel epistatic interactions contained in the genotypes of FVC11. After six generations, a backcrossing approach leaves on average only 1.56% of the wild species in the selected germplasm (Dale et. al., 1993). A large part of the genetic variance for fruit size is epistatic (Hancock et. al., 2008), so maximizing allelic diversity could increase the occurrence of larger fruit when utilizing wild germplasm.

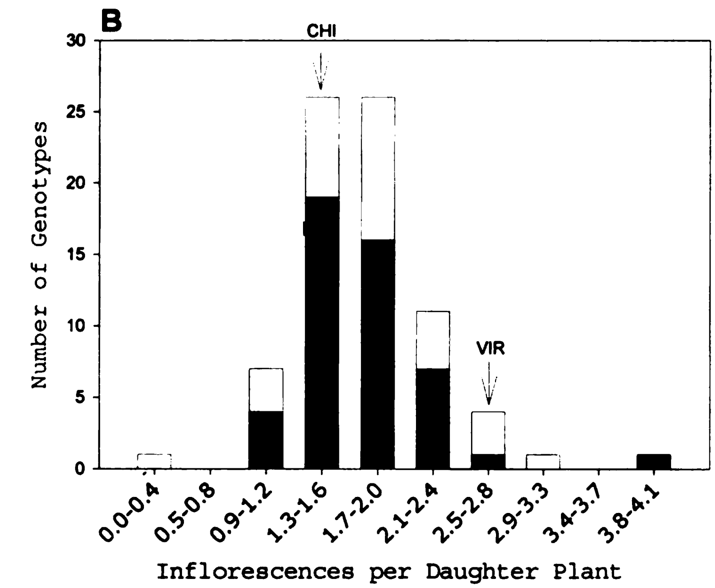
With proper assessments of wild germplasm for most horticulturally important traits, many beneficial traits can be introgressed with minimal amounts of linkage drag. With the use of genetic markers, these traits could be more easily followed in a breeding program. Because of this, several available SSR markers have been screened with a subset of this population to determine if they displayed polymorphisms, and therefore could be used, on futures studies with this population (see appendix 1). The FVC11 population presented here would be a great tool to breeders wishing to introduce novel genetic diversity into their breeding programs. We are currently expanding this population to increase the chances of acquiring genotypes with even more positive combinations of traits.

Table 1. T-test comparing remontant (RM) genotype and non-remontant (NRM) genotype means for the FVC11 population evaluated at Benton Harbor, MI. The t-values that were significant at the 0.05 level are bolded

Trait	NRM mean	RM mean	t-value
Inflorescences per Mother	5.86	8.09	**2.63**
Inflorescences per Daughter	1.71	1.79	0.59
Flowers per Inflorescence	5.63	5.31	-1.21
Inflorescence Height (cm)	9.84	9.76	-0.13
Crowns per Mother	4.25	5.08	1.57
Crowns per Daughter	1.44	1.51	0.82
Daughters per Mother	9.39	6.87	**-3.07**
Vigor (1-7)	4.07	3.65	**-2.35**
Yield per Plant (g)	6.88	11.97	**3.94**
Fruit Weight (g)	21.74	22.63	0.70
Internal Color (%)	57.75	54.73	0.60
Soluble Solids (brix)	8.58	8.58	0.04
Firmness (g/mm^2)	153.51	152.5	-0.28

Figure 1. Inflorescence characteristics of FVC11 genotypes at Benton Harbor, MI including mean number of inflorescences per mother plant (A), number of inflorescences per daughter plant (B), number of flowers per inflorescence (C) and inflorescent height (D). Black bars denote progeny which were non-remontant, while white bars denote progeny which were remontant in 2008. Arrows show the values of the *Fragaria virginiana* (VIR) and *F. chiloensis* (CHI) parents





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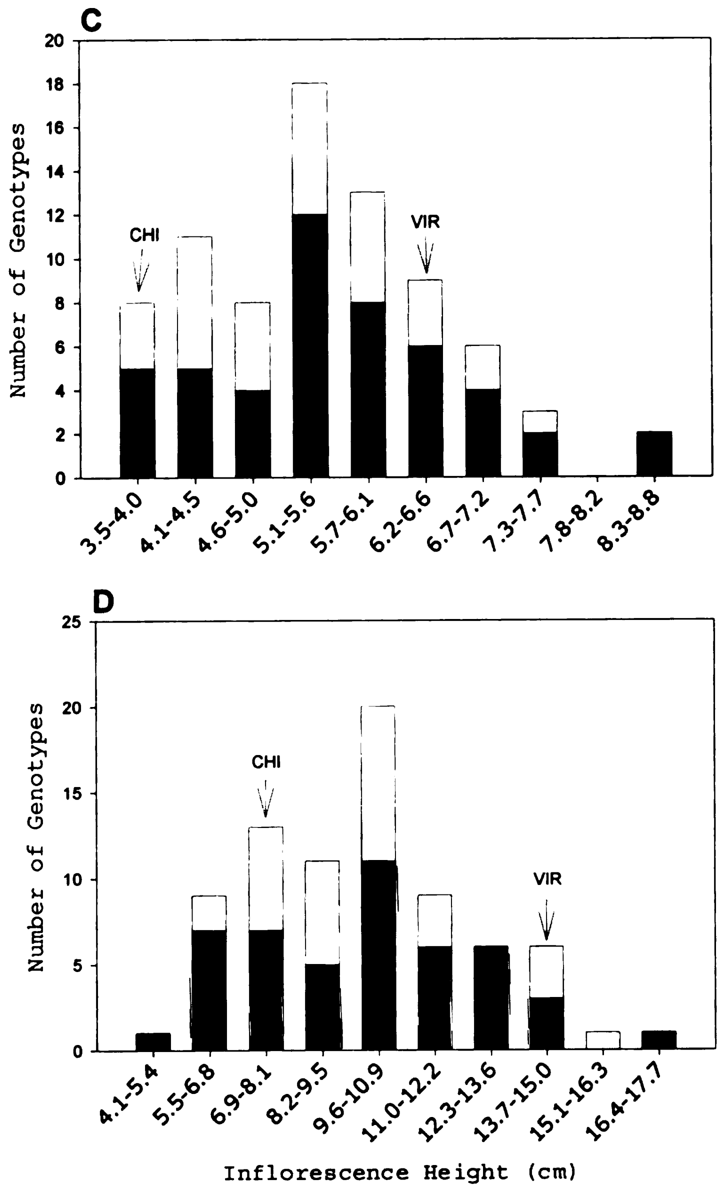
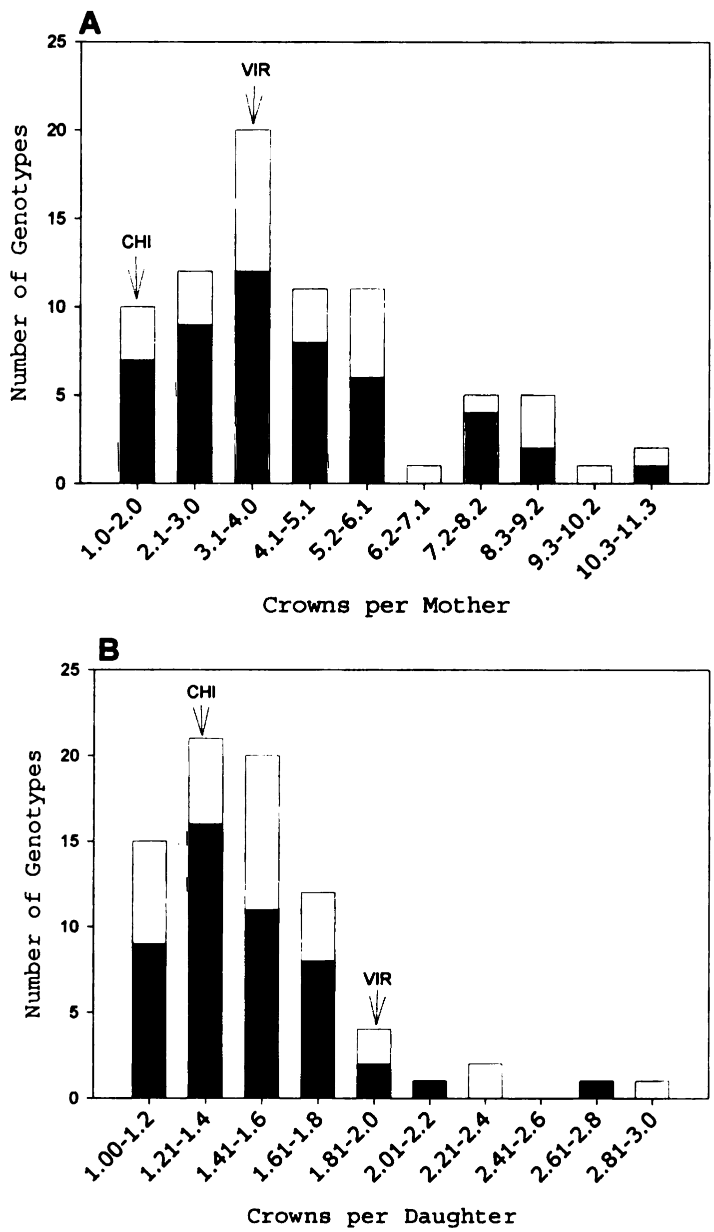


Figure 2. Plant characteristics of FVC11 genotypes at Benton Harbor, MI including mean of crowns per mother plant (A), number of crowns per daughter plant (B), number of daughter plants per mother plant (C) and plant vigor (D). Black bars denote progeny which were non-remontant, while white bars denote progeny which were remontant in 2008. Arrows show the values of the *Fragaria virginiana* (VIR) and *F. chiloensis* (CHI) parents



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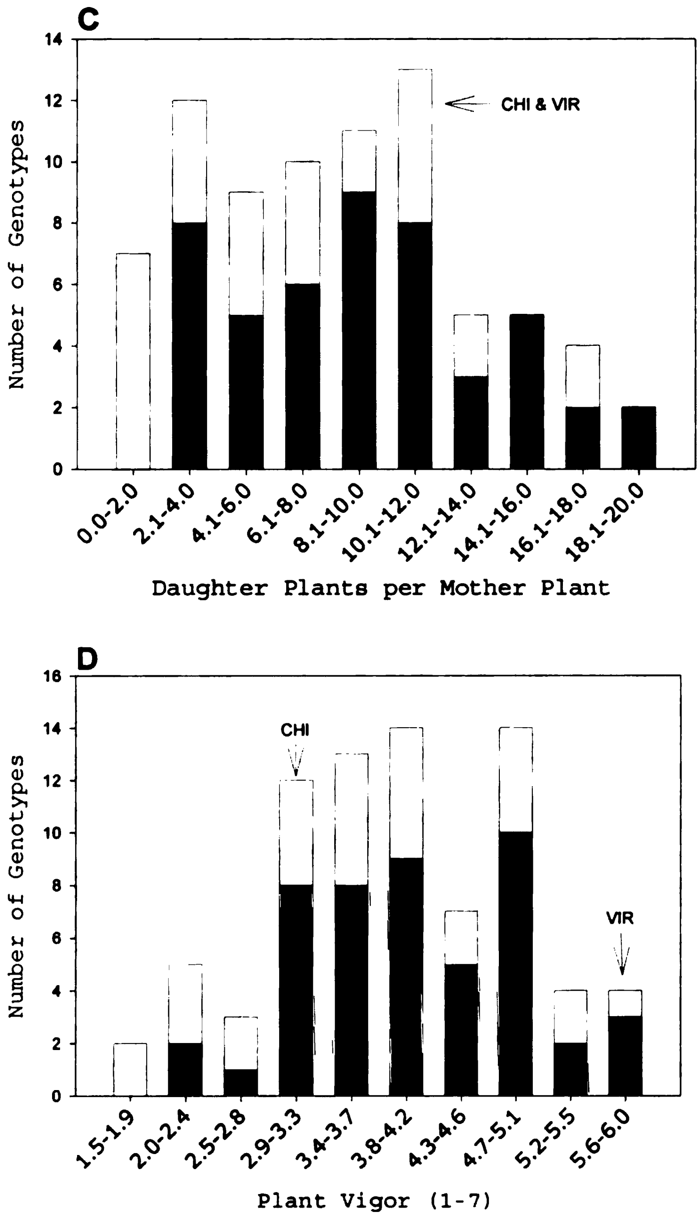
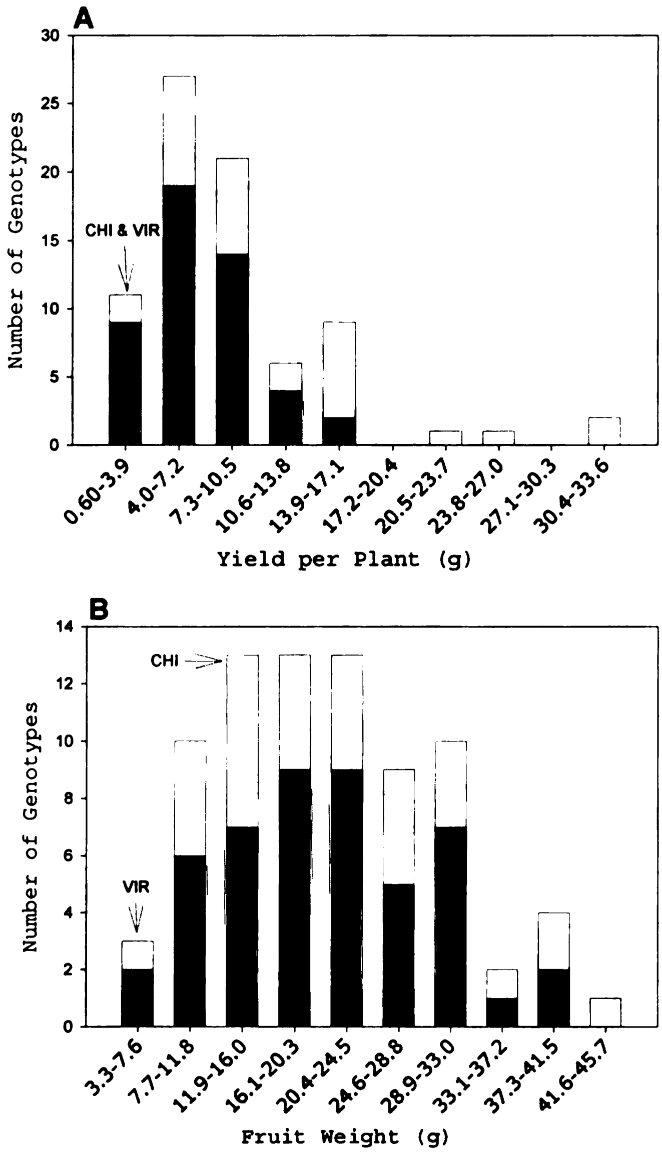


Figure 3. Fruit characteristics of FVC11 genotypes at Benton Harbor, MI including mean yield per plant (A), mean fruit weight (B), percent internal fruit color (C) soluble sugars (D), and fruit firmness (E). Black bars denote progeny which were non-remontant, while white bars denote progeny which were remontant in 2008. Arrows show the values of the *Fragaria virginiana* (VIR) and *F. chiloensis* (CHI) parents.



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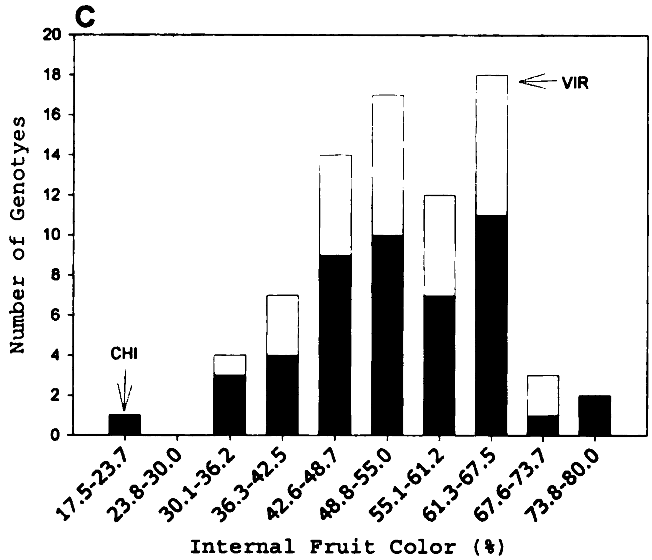

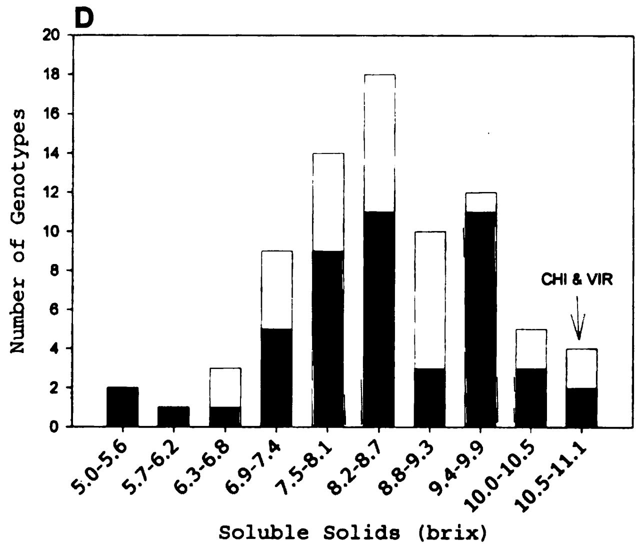

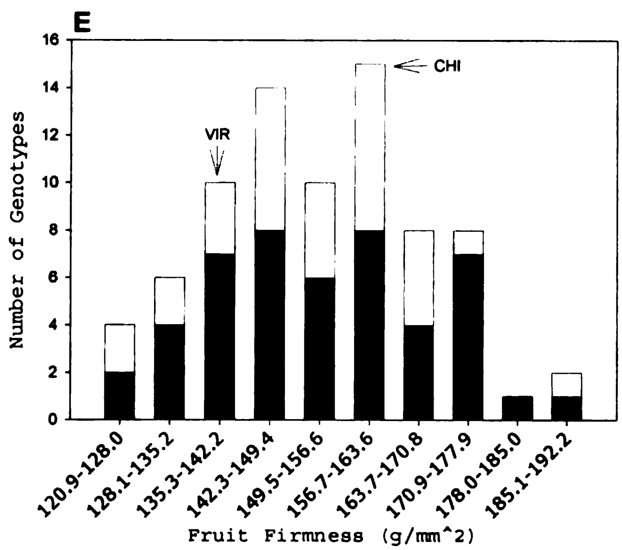

Table 2. Correlation matrix for 13 vegetative, flowering and fruiting characteristics using a Pearson Correlation 2-tailed test for the FVC11 population evaluated at Benton Harbor, MI. Correlations are significant when in bold at the 0.01 (**) and 0.05 (*) level.

	Inflor. height	Crowns/ daughter	Crowns/ mother	Inflor./ daughter	Inflor./ mother	Flowers/ inflor.	Daughters /mother	Plant vigor	Fruit weight	Internal color	Sol. Solids	Yield/ plant
Inflor. height												
Crowns/daughter	0.027											
Crowns/mother	-0.094	**.427****										
Inflor./daughter	-0.036	**.693****	**.402****									
Inflor./mother	-0.033	**.315****	**.914****	**.298****								
Flowers/inflor.	**.512****	-0.076	**-.269***	-0.002	**-.256***							
Daughters/mother	**.384****	-0.171	-0.141	-0.159	-0.152	**.269***						
Plant vigor	**.573****	0.15	0.076	0.133	0.055	**.289***	**.540****					
Fruit weight	**.425****	-0.14	-0.128	-0.191	-0.081	0.166	**.419****	**.344****				
Internal color	0.084	-0.063	-0.022	-0.02	-0.098	0.179	-0.008	0.014	-0.088			
Sol. Solids	0.154	0.048	-0.123	-0.016	-0.186	0.101	0.158	0.172	-0.206	0.074		
Yield/plant	0.201	0.172	0.199	0.055	**.264***	-0.006	**-.336****	-0.065	**.410****	-0.018	**-.246***	
Fruit firmness	-0.016	0.022	0.011	0.104	-0.028	**-.277***	-0.078	0.062	0.067	-0.049	**-.236***	0.12

Table 3. Progeny performance scores for the FVC11 population. Progeny performance scores were calculated by dividing each genotype's mean value by the highest value found in each category, and then summing them across all categories. Genotypes were also evaluated as being remontant (RM), weakly remontant (WRM) or non-remontant (NRM). Original values were collected in 2008 at Benton Harbor, MI.

genotype	intrnl. color	sol. solids	yield/ plant	firmness	inflor. height	plants/ block	vigor	fruit weight	Total	2007	2008
FVC11-044	0.73	0.88	0.30	0.73	1.00	0.78	0.78	0.70	**5.90**	NRM	NRM
FVC11-046	0.88	0.65	0.43	0.89	0.70	0.51	0.83	0.83	**5.73**	NRM	NRM
FVC11-057	0.53	0.67	0.49	0.88	0.91	0.49	0.72	1.00	**5.69**	RM	RM
FVC11-055	0.60	0.68	0.44	0.86	0.80	0.65	0.83	0.79	**5.67**	NRM	WRM
FVC11-056	0.58	0.87	0.39	0.73	0.75	0.57	0.94	0.80	**5.63**	NRM	NRM
FVC11-049	0.91	0.85	0.47	0.67	0.49	0.65	0.67	0.83	**5.55**	RM	RM
FVC11-058	0.72	0.65	0.79	0.87	0.78	0.35	0.67	0.69	**5.52**	RM	RM
FVC11-076	0.83	0.70	0.15	0.73	0.77	0.76	0.83	0.70	**5.47**	NRM	NRM
FVC11-029	0.56	0.85	0.29	0.71	0.73	0.76	0.83	0.64	**5.37**	NRM	NRM
FVC11-036	0.65	0.92	0.11	0.96	0.66	0.73	0.89	0.41	**5.34**	NRM	NRM
FVC11-030	0.78	0.66	0.17	0.90	0.55	0.92	0.83	0.51	**5.33**	NRM	NRM
FVC11-043	0.82	0.80	0.27	0.82	0.62	0.57	0.89	0.51	**5.31**	NRM	WRM
FVC11-050	0.49	0.82	0.38	0.85	0.65	0.59	0.56	0.90	**5.23**	RM	RM
FVC11-054	0.69	0.77	0.24	0.92	0.56	0.57	0.89	0.57	**5.21**	NRM	RM
FVC11-038	0.77	0.75	0.37	0.79	0.60	0.52	0.83	0.56	**5.20**	RM	WRM
FVC11-034	0.58	0.85	0.10	0.68	0.67	0.83	0.89	0.58	**5.18**	NRM	NRM
FVC11-041	0.91	0.83	0.28	0.76	0.69	0.43	0.56	0.71	**5.16**	RM	RM
FVC11-072	1.00	0.78	0.16	0.85	0.43	0.84	0.67	0.41	**5.14**	NRM	NRM
FVC11-064	0.73	0.72	0.20	0.79	0.67	1.00	0.50	0.53	**5.14**	NRM	NRM
FVC11-077	0.43	0.92	0.21	0.76	0.58	0.89	0.83	0.52	**5.13**	NRM	WRM
FVC11-065	0.67	0.72	0.43	0.86	0.82	0.24	0.83	0.52	**5.10**	NRM	NRM
FVC11-053	0.65	0.76	0.34	1.00	0.55	0.49	0.67	0.61	**5.06**	NRM	NRM
FVC11-075	0.52	0.82	0.20	0.83	0.51	0.83	0.67	0.68	**5.05**	RM	RM
FVC11-VIR	0.79	0.98	0.06	0.73	0.83	0.56	0.94	0.15	**5.04**	NRM	WRM
FVC11-059	0.57	0.74	0.95	0.80	0.59	0.13	0.67	0.55	**5.00**	RM	RM
FVC11-062	0.53	0.68	0.15	0.79	0.54	0.70	1.00	0.59	**4.99**	NRM	NRM
FVC11-042	0.81	0.87	0.25	0.82	0.75	0.35	0.72	0.41	**4.98**	NRM	NRM
FVC11-027	0.45	0.94	0.24	0.76	0.69	0.62	0.61	0.64	**4.95**	NRM	NRM
FVC11-018	0.79	0.71	0.31	0.75	0.56	0.60	0.72	0.50	**4.94**	NRM	NRM
FVC11-068	0.72	0.82	0.28	0.77	0.61	0.52	0.72	0.46	**4.92**	NRM	NRM
FVC11-026	0.74	0.74	0.20	0.75	0.61	0.54	0.67	0.66	**4.91**	NRM	NRM
FVC11-037	0.70	0.65	0.12	0.72	0.68	0.59	0.94	0.47	**4.86**	NRM	NRM
FVC11-004	0.83	0.65	0.21	0.93	0.83	0.35	0.72	0.34	**4.86**	NRM	NRM
FVC11-061	0.64	0.76	0.25	0.83	0.52	0.46	0.78	0.61	**4.84**	NRM	NRM
FVC11-060	0.60	0.73	0.12	0.86	0.64	0.65	0.83	0.33	**4.77**	NRM	NRM
FVC11-033	0.74	0.80	0.46	0.82	0.48	0.25	0.72	0.42	**4.70**	RM	RM
FVC11-067	0.67	0.89	0.40	0.67	0.62	0.29	0.61	0.55	**4.70**	NRM	NRM

Table 3 continued.

FVC11-073	0.63	0.75	0.16	0.80	0.58	0.60	0.67	0.49	**4.68**	NRM	NRM
FVC11-047	0.58	0.73	0.15	0.74	0.39	0.70	0.67	0.67	**4.62**	NRM	NRM
FVC11-070	0.67	0.71	0.49	0.81	0.56	0.14	0.83	0.40	**4.62**	NRM	WRM
FVC11-071	0.84	0.99	0.04	0.72	0.76	0.48	0.67	0.11	**4.61**	NRM	NRM
FVC11-052	0.77	0.77	0.12	0.87	0.55	0.46	0.75	0.28	**4.57**	NRM	NRM
FVC11-015	0.56	0.75	0.31	0.91	0.60	0.33	0.67	0.42	**4.56**	WRM	NRM
FVC11-003	0.96	0.83	0.17	0.82	0.38	0.41	0.50	0.45	**4.54**	NRM	NRM
FVC11-032	0.79	0.99	0.42	0.76	0.54	0.14	0.50	0.35	**4.49**	RM	RM
FVC11-028	0.73	0.81	0.14	0.71	0.41	0.54	0.50	0.62	**4.47**	RM	RM
FVC11-021	0.64	0.45	0.36	0.91	0.40	0.30	0.50	0.85	**4.43**	WRM	NRM
FVC11-069	0.56	0.85	0.25	0.85	0.47	0.24	0.83	0.35	**4.40**	NRM	NRM
FVC11-016	0.49	0.89	0.18	0.69	0.45	0.41	0.83	0.38	**4.32**	NRM	NRM
FVC11-074	0.83	0.75	0.22	0.78	0.43	0.30	0.56	0.42	**4.30**	NRM	NRM
FVC11-063	0.78	0.69	0.15	0.77	0.38	0.56	0.61	0.32	**4.26**	NRM	NRM
FVC11-008	0.70	0.61	1.00	0.76	0.44	0.03	0.25	0.45	**4.24**	RM	WRM
FVC11-019	0.77	0.67	0.21	0.66	0.51	0.43	0.56	0.41	**4.22**	NRM	NRM
FVC11-045	0.70	0.87	0.02	0.63	0.57	0.65	0.67	0.07	**4.18**	NRM	NRM
FVC11-013	0.72	0.76	0.23	0.75	0.58	0.24	0.56	0.34	**4.18**	RM	RM
FVC11-011	0.55	0.71	0.43	0.80	0.51	0.14	0.61	0.41	**4.16**	RM	RM
FVC11-078	0.59	0.69	0.16	0.91	0.46	0.49	0.56	0.30	**4.16**	NRM	NRM
FVC11-014	0.69	0.78	0.18	0.84	0.48	0.40	0.50	0.28	**4.14**	NRM	RM
FVC11-066	0.84	0.77	0.22	0.75	0.32	0.21	0.50	0.45	**4.09**	NRM	RM
FVC11-012	0.67	0.66	0.27	0.65	0.54	0.25	0.67	0.37	**4.08**	RM	RM
FVC11-048	0.79	0.90	0.19	0.70	0.55	0.22	0.44	0.28	**4.07**	RM	WRM
FVC11-006	0.83	0.89	0.20	0.90	0.38	0.16	0.44	0.25	**4.05**	NRM	NRM
FVC11-017	0.63	0.72	0.27	0.86	0.36	0.21	0.67	0.32	**4.02**	NRM	NRM
FVC11-022	0.42	0.47	0.29	0.77	0.39	0.37	0.58	0.71	**4.01**	WRM	NRM
FVC11-024	0.52	0.76	0.25	0.85	0.37	0.22	0.56	0.40	**3.92**	NRM	NRM
FVC11-020	0.73	0.85	0.11	0.77	0.35	0.37	0.50	0.22	**3.90**	NRM	NRM
FVC11-025	0.64	0.58	0.20	0.89	0.40	0.33	0.56	0.23	**3.84**	RM	RM
FVC11-005	0.60	0.72	0.62	0.83	0.48	0.06	0.28	0.22	**3.82**	RM	RM
FVC11-040	0.52	0.73	0.12	0.71	0.47	0.52	0.50	0.22	**3.80**	NRM	NRM
FVC11-CHI	0.22	1.00	0.03	0.82	0.40	0.52	0.50	0.29	**3.78**	NRM	NRM
FVC11-035	0.68	0.74	0.14	0.83	0.42	0.25	0.39	0.26	**3.72**	NRM	RM
FVC11-023	0.63	0.66	0.19	0.98	0.39	0.16	0.39	0.25	**3.64**	WRM	WRM
FVC11-039	0.41	0.54	0.25	0.69	0.54	0.32	0.33	0.47	**3.55**	NRM	NRM
FVC11-002	0.60	0.77	0.30	0.71	0.39	0.06	0.44	0.27	**3.54**	RM	RM
FVC11-051	0.63	0.87	0.07	0.80	0.23	0.17	0.50	0.21	**3.48**	NRM	NRM
FVC11-001	0.63	0.73	0.06	0.82	0.36	0.22	0.39	0.25	**3.45**	NRM	NRM
FVC11-010	0.58	0.61	0.08	0.81	0.43	0.16	0.50	0.25	**3.43**	NRM	NRM
FVC11-007	0.84	0.72	0.07	0.66	0.37	0.16	0.33	0.22	**3.38**	RM	RM
FVC11-009	-	-	-	-	-	-	-	-	**0.00**	NRM	-
FVC11-031	-	-	-	-	-	-	-	-	**0.00**	RM	-

APPENDIX

Appendix 1. A subset of the FVC11 population including the *F. virginiana* and *F. chiloensis* parents, 4 genotypes classified as RM in 2007, and 4 genotypes classified as NRM in 2007, were screened for polymorphic banding using 168 different SSR markers. Polymorphisms were classified as present and readable (yes), absent or non-readable (no), or undefined because of poor developing or gel imperfections (unclear).

Oligo	Name	Sequence	Polymorphisms
655	ARSFL9-U (M13)	TGTAAAACGACGGCCAGTGCGAGGCGATCATGGAGAGA	Yes
656	ARSFL9-L	GCGTTTCCTACGTCCCAATAAATC	
657	ARSFL10-U (M13)	TGTAAAACGACGGCCAGTGCGTCAGCCGTAGTGATGTAGCAG	Yes
658	ARSFL10-L	GCGCCAGCCCCTCAAATATC	
659	ARSFL13-U (M13)	TGTAAAACGACGGCCAGTGCGGGCAGCCTCCAGATCTCCTTA	Unclear
660	ARSFL13-L	GCGCCCCTATCTTCGACCAA	
661	ARSFL22-U (M13)	TGTAAAACGACGGCCAGTGCGAACCCCATTAACAGCTTCA	Yes
662	ARSFL22-L	GCGATCAAATTCCCCTCTAACAAT	
831	SCAR1 (M13)-U	TGTAAAACGACGGCCAGTCACGCTTAAATAGGAGTTCG	No
832	SCAR1-L	GGGTGAAACTGATTTCTTACC	
833	SCAR2 (M13)-U	TGTAAAACGACGGCCAGTGAAAAGTGAGGCGGATTTCG	Yes
834	SCAR2-L	CTTGAATTGTCTCCATTCCC	
943	CO818002(M13)-U	TGTAAAACGACGGCCAGTCTAGTAGCTCCACGCCAAGC	Yes
944	CO818002-L	AATGTGTGGGAGAGGTGAGC	
951	CO817823(M13)-U	TGTAAAACGACGGCCAGTCAAAGAGAGCAGAGGCCAAA	Yes
952	CO817823-L	ACGTTGTACTTGGACCGGAG	
955	CO817853(M13)-U	TGTAAAACGACGGCCAGTCCATTCAAAACCTCCTCTTCC	Unclear
956	CO817853-L	ATGGGTCCTTCGTCTGAGTG	
957	CO817234(M13)-U	TGTAAAACGACGGCCAGTGAACTCCCTTTTCTGGGTCC	Unclear
958	CO817234-L	CAATGAGTGGGAGAGGAAGG	
969	CO379568(M13)-U	TGTAAAACGACGGCCAGTGATTAGGGAGAGGCAACGTG	Yes
970	CO379568-L	GCTTCAAGCAAAATGCATCA	
975	CO816760(M13)-U	TGTAAAACGACGGCCAGTCCCACAAAACCCTAAACCCT	Unclear
976	CO816760-L	GTCGAAGAGATCGGAGCAAC	
979	CO816700(M13)-U	TGTAAAACGACGGCCAGTTCCGAAAGCTCACGATTCTT	Yes
980	CO816700-L	GTGCAGAGAATGAGCAACGA	
983	CO817389(M13)-U	TGTAAAACGACGGCCAGTCGAAGCCCAGCATCTATCTC	Yes
984	CO817389-L	TATCACCTGCGTCTGATTCG	
985	CO382125(M13)-U	TGTAAAACGACGGCCAGTCCCCCTGAATTTTGCAGATA	Unclear
986	CO382125-L	TCAGCTTCCAAGTCCCTCTC	
987	CO818147(M13)-U	TGTAAAACGACGGCCAGTAGGCAAAACTCAACCACCAC	Unclear
988	CO818147-L	TCGGAGTAATGCTTCTGGGT	
989	CO380455(M13)-U	TGTAAAACGACGGCCAGTACGAGGGTCACGGCTACTAA	No
990	CO380455-L	TGACCAATCCGAAAGAAATCA	

991	CONSTANS(M13)-U	TGTAAAACGACGGCCAGTCCAAGAACACCGAAAAGGAA	Unclear
992	CONSTANS-L	TGATCCGCGGTCTAGTCTCT	
1001	AP3(M13)-U	TGTAAAACGACGGCCAGTCCAAGGAAGCAAACCAAGAA	Unclear
1002	AP3-L	CCTTGGCATCACAGAGAACA	
1007	CO817671(M13)-U	TGTAAAACGACGGCCAGTGCCAAAATCACCTCTGCTTC	Unclear
1008	CO817671-L	CATTGTTGTTGGGAGCTGTG	
1017	CO816733(M13)-U	TGTAAAACGACGGCCAGTTCCCAACACCTCACTTGTCC	Yes
1018	CO816733-L	ATTCAGCCAGGTCTGAGCAT	
1023	CO817443(M13)-U	TGTAAAACGACGGCCAGTTGTGTCTTCTCCGAAACTCG	Yes
1024	CO817443-L	AACTTCAAATCGTATGCGGC	
1025	CO817535(M13)-U	TGTAAAACGACGGCCAGTTTCCATGGCCTTGTTTTCTC	Yes
1026	CO817535-L	TTGACCACCTTCACCTCCTC	
1045	CO816667(M13)-U	TGTAAAACGACGGCCAGTCATACAATGTTGCCCCTCCT	Yes
1046	CO816667-L	CCAAACTGCCCTGATAGCAT	
1047	CO816938(M13)-U	TGTAAAACGACGGCCAGTCGAGGCCTTGTCTTCTTTGT	Yes
1048	CO816938-L	GCGGAGGTAGCTGTTGTAGC	
1053	CO818160(M13)-U	TGTAAAACGACGGCCAGTGGAAACCCCAAAGTGGAGAT	Yes
1054	CO818160-L	GACGAGGCCATCTGAAACAT	
1055	AI795160(M13)-U	TGTAAAACGACGGCCAGTCCCCTATTCGACAACCAATG	No
1056	AI795160-L	AACATGATCACAAGGCCACA	
1059	CO378873(M13)-U	TGTAAAACGACGGCCAGTGCATTGGCACCCGCTA	No
1060	CO378873-L	GCTTCAAGCAAAATGCATCA	
1063	CO379009(M13)-U	TGTAAAACGACGGCCAGTTGTGATTGGGAGAGAGGAGG	Yes
1064	CO379009-L	CTGCCCCAAACTTGGTTTTA	
1073	CO380936a(M13)-U	TGTAAAACGACGGCCAGTCATTCTGCTGCCTCATCTCA	No
1074	CO380936a-L	GACCTCTAACAAGCCCACCA	
1075	CO381075(M13)-U	TGTAAAACGACGGCCAGTTCTGTCATTGCTCAACCTCG	Yes
1076	CO381075-L	CTGGGAGGGAAGACAGACAA	
1079	CO381605(M13)-U	TGTAAAACGACGGCCAGTCCACCCCTTTACCTTTCACA	Yes
1080	CO381605-L	CAATTCCGAAGGCACAACTT	
1081	CO382036(M13)-U	TGTAAAACGACGGCCAGTTCTGATTGGGAGAGAGGAGG	No
1082	CO382036-L	GCTTCAAGCAAAATGCATCA	
1091	CO818160a(M13)-U	TGTAAAACGACGGCCAGTGGAAACCCCAAAGTGGAGAT	Yes
1092	CO818160a-L	GACGAGGCCATCTGAAACAT	
1093	AI795160a(M13)-U	TGTAAAACGACGGCCAGTCCCCTATTCGACAACCAATG	Unclear
1094	AI795160a-L	AACATGATCACAAGGCCACA	
1097	CO378873a(M13)-U	TGTAAAACGACGGCCAGTGCATTGGCACCCGCTA	Unclear
1098	CO378873a-L	GCTTCAAGCAAAATGCATCA	
1103	CO817505(M13)-U	TGTAAAACGACGGCCAGTTCCTGAAGCAACGATGACTG	Yes
1104	CO817505-L	CACTTGCCGCAGAAGAAAA	
1105	CO817563(M13)-U	TGTAAAACGACGGCCAGTGGGTTTCCAAGAAGACTCCC	Yes
1106	CO817563-L	GGAGTAGCGGTTGTCGTTGT	
1107	CO817772(M13)-U	TGTAAAACGACGGCCAGTTCACAACCGACGAGTTTCAG	Yes
1108	CO817772-L	TTTCTTCACTGCCCTGCTCT	
1113	CO818022(M13)-U	TGTAAAACGACGGCCAGTACCACAAAACCTCAACGTCC	Yes
1114	CO818022-L	TTCTGGCACATGTTGTTGGT	
1119	CO378579(M13)-U	TGTAAAACGACGGCCAGTCCCCTATTCGACAACCAATG	Unclear
1120	CO378579-L	TGGCTACCAAAGAACACGAA	

1129	CO378890(M13)-U	TGTAAAACGACGGCCAGTTCGAGTTCTACGCTTGCTGA	Yes
1130	CO378890-L	TTCTCAGTCGTCACTTTCACC	
1131	CO379045(M13)-U	TGTAAAACGACGGCCAGTCACGAGGCTGATTGGTGTAG	No
1132	CO379045-L	CAATCCAACCCATTTTCCAC	
1133	CO379079(M13)-U	TGTAAAACGACGGCCAGTCCACCCCTTTACCTTTCACA	Yes
1134	CO379079-L	TGGACAACAGCAAGAGAAGG	
1141	CO379548(M13)-U	TGTAAAACGACGGCCAGTCTAGCAGCTTTGGCTTTTGG	Yes
1142	CO379548-L	CAATCCAACCCATTTTCCAC	
1147	CO380097(M13)-U	TGTAAAACGACGGCCAGTTGTGAAGTTGTGTGGGCATT	No
1148	CO380097-L	TAGCTGCTGCTGCTCTCTTG	
1151	CO380164(M13)-U	TGTAAAACGACGGCCAGTATGAAGCGCTCAAAGTCCAT	Unclear
1152	CO380164-L	CAAACACACATGAAACGGCT	
1165	CO381134(M13)-U	TGTAAAACGACGGCCAGTGGCACACACAGCAGTTACCA	Unclear
1166	CO381134-L	GATGATGATGTCGATGCAGG	
1169	CO381174(M13)-U	TGTAAAACGACGGCCAGTCCACAAGAAAGGAGACGAGC	Unclear
1170	CO381174-L	TCAGGAGCATGAATCAATCG	
1171	CO381214(M13)-U	TGTAAAACGACGGCCAGTATGGCCCTAAATTCCGTCTT	Yes
1172	CO381214-L	AACATGTTGATCACGGCAAA	
1179	CO381360(M13)-U	TGTAAAACGACGGCCAGTTCAGCTTCCCAATGACAACA	Unclear
1180	CO381360-L	ATAATCCAGGCACCCCACTT	
1189	CO381917(M13)-U	TGTAAAACGACGGCCAGTTGGTGTGATCAGTGATGGGT	No
1190	CO381917-L	GGACATGCCCTGCTGTTATT	
1193	CO816689(M13)-U	TGTAAAACGACGGCCAGTCCGACTTTTACTGAAATGGGT	Yes
1194	CO816689-L	GCCAGGAGAAAGCAGTGTTC	
1197	CO816780(M13)-U	TGTAAAACGACGGCCAGTGAAGACTCTGGCTTTGCAGC	No
1198	CO816780-L	GCGCTCGATTTCTTGTTCTT	
1211	CO817054(M13)-U	TGTAAAACGACGGCCAGTGGTGGCTACCCAAAAACAGA	Yes
1212	CO817054-L	CTGGAGGAGCCAAGTTTGAG	
1219	CO817178(M13)-U	TGTAAAACGACGGCCAGTGAGGCCTAGAATCAGTTTCGC	No
1220	CO817178-L	GAGGATGGAGACCCAACAGA	
1221	CO817184(M13)-U	TGTAAAACGACGGCCAGTCAAACCGCCATCTTCATCTT	Unclear
1222	CO817184-L	GCCTCACTAGGCAGGAACAG	
1231	CO817343(M13)-U	TGTAAAACGACGGCCAGTCCGTAACATCACCGTCAATG	Unclear
1232	CO817343-L	CCATATCCACCACCACTTCC	
1235	CO817516(M13)-U	TGTAAAACGACGGCCAGTACAACCAAAGCCTCCCTCTT	No
1236	CO817516-L	GACTTGGTCAGCTCCGAGAC	
1239	CO817622(M13)-U	TGTAAAACGACGGCCAGTTTCACCTTGCACAGTTCCTG	Yes
1240	CO817622-L	TACTAGGCGTGCTATCCAGC	
1241	CO817658(M13)-U	TGTAAAACGACGGCCAGTTGCTTGATGATGGAAATGGA	Yes
1242	CO817658-L	TGTCAGCAACAAGTATTTCGG	
1259	CO817919(M13)-U	TGTAAAACGACGGCCAGTCAGAATCCACCGGCTTACAT	Yes
1260	CO817919-L	CGCTAGCTTTTCTGCTCGAT	
1261	CO818058(M13)-U	TGTAAAACGACGGCCAGTCTGGACTAGCTCGCCAAAAC	Yes
1262	CO818058-L	ACGCATTCCGATACAACCTC	
1263	CO818090(M13)-U	TGTAAAACGACGGCCAGTACTTCCCTTGGGATGGATTC	Unclear
1264	CO818090-L	TTTTCAAATCCCTTTGCACC	
1265	CO818118(M13)-U	TGTAAAACGACGGCCAGTCATCTCCACAAATCCTCTCCA	Unclear
1266	CO818118-L	CGTGGCTAGAGTGCATGAGA	

1275	CO378708a(M13)-U	TGTAAAACGACGGCCAGTATTCGGCACGAGGGAGAT	Unclear
1276	CO378708a-L	AGTTCTCCATCAGCAAGCGT	
1279	CO378890a(M13)-U	TGTAAAACGACGGCCAGTCGGCAAGTCTAGAAGACGCT	No
1280	CO378890a-L	TCTCGATCAGCAAGCGTAGA	
1283	CO379203(M13)-U	TGTAAAACGACGGCCAGTTCGCAAGATTCTGGACATCA	No
1284	CO379203-L	TCGATCGTTTCACATCCAAA	
1295	ARSFL1-U (M13)	TGTAAAACGACGGCCAGTGCGGACCCATAGCACACTGTTGAC	Unclear
1296	ARSFL1-L	GCGCCTTCCCTTGATACAACTTAC	
1297	ARSFL2-U (M13)	TGTAAAACGACGGCCAGTGCGAAGCGAAGCGGTGATG	Unclear
1298	ARSFL2-L	GCGAACGTCGAGGAGCATTCTCAT	
1299	ARSFL3-U (M13)	TGTAAAACGACGGCCAGTGCGGGTGCTTAGGTTTTCACAACT	Unclear
1300	ARSFL3-L	GCGCAAGTGGTATTTAAGGGTTAG	
1301	ARSFL4-U (M13)	TGTAAAACGACGGCCAGTGCGGTCGCATTGAGTTGGAGGATA	Yes
1302	ARSFL4-L	GCGTAGCCAAACACCGATCTACC	
1307	ARSFL11-U (M13)	TGTAAAACGACGGCCAGTGCGAAGCATAACTGGCAGTATCTG	Yes
1308	ARSFL11-L	GCGGGCCTAGGTGATCTTGGA	
1311	ARSFL14-U (M13)	TGTAAAACGACGGCCAGTGCGTTAAACGGAAACTTAGAGAGA	Unclear
1312	ARSFL14-L	GCGGAACGGCTCAAACATC	
1313	ARSFL15-U (M13)	TGTAAAACGACGGCCAGTGCGGGCTGTCCACACTCCTTTCT	Unclear
1314	ARSFL15-L	GCGATGCGTAAGTCTCTTCAAATA	
1317	ARSFL17-U (M13)	TGTAAAACGACGGCCAGTGCGCATCACAATCGCCATAGAAAC	Yes
1318	ARSFL17-L	GCGAACACGCCTTCAACAACCAC	
1321	ARSFL19-U (M13)	TGTAAAACGACGGCCAGTGCGAAACCGAAGAAGAACAAATGC	Yes
1322	ARSFL19-L	GCGGCCCAAACGGACAAGA	
1325	ARSFL23-U (M13)	TGTAAAACGACGGCCAGTGCGGCCGCTTGAAGAGGAG	No
1326	ARSFL23-L	GCGTCCCCACTGTCAAGGTAAAGA	
1331	ARSFL26-U (M13)	TGTAAAACGACGGCCAGTGCGTGAGGTCCCTTAAGCACTAAA	Yes
1332	ARSFL26-L	GCGCAGGGTAACGAAACCTAAAA	
1333	ARSFL27-U (M13)	TGTAAAACGACGGCCAGTGCGAAGCCCAGACTCAATTACC	No
1334	ARSFL27-L	GCGTACCCGCCATTGTTAC	
1337	ARSFL29-U (M13)	TGTAAAACGACGGCCAGTGCGGGGGGATATTGGTGGTGATG	Unclear
1338	ARSFL29-L	GCGCGGGTTTTCACGTAATTTCCT	
1343	CO380277a(M13)-U	TGTAAAACGACGGCCAGTACGTCCGTAGGTCCTGTTGT	No
1344	CO380277a-L	TCTTTCCCAAAATGAGGACG	
1345	CO380376(M13)-U	TGTAAAACGACGGCCAGTTGATGATGATGAGGTCCCAG	Unclear
1346	CO380376-L	GGGTCGAATCAAACATGGTC	
1349	CO380542(M13)-U	TGTAAAACGACGGCCAGTGGAGGAAGGGTTTGAAGGAG	Unclear
1350	CO380542-L	GTTACGGGCAAGCACAAAAT	
1351	CO380682(M13)-U	TGTAAAACGACGGCCAGTTTGCTTCAATTCTTGGACCC	No
1352	CO380682-L	AGCTAGTATATCCCGGCGGT	
1357	CO380995(M13)-U	TGTAAAACGACGGCCAGTCATGTTTCTGCCATGTCACC	No
1358	CO380995-L	CCATGTTATTGCCGTTTCCT	
1363	CO381118(M13)-U	TGTAAAACGACGGCCAGTAATCTGGTACTGGTGGGTGG	No
1364	CO381118-L	GATAAAGAGGGCAAGCAAACC	
1367	CO381341(M13)-U	TGTAAAACGACGGCCAGTACCAACCAAGGCATTCACTC	Yes
1368	CO381341-L	TGTTGACGAGATTGGGATCA	
1369	CO381434(M13)-U	TGTAAAACGACGGCCAGTGACAACGTGAAGGCCAAGAT	Unclear
1370	CO381434-L	ATGAAATTGAAACGCTTGCC	

1375	CO381732a(M13)-U	TGTAAAACGACGGCCAGTGAAGCAGCAGCAGCAGTAAA	No
1376	CO381732a-L	ACACCGAGGCAATACCAAAC	
1381	CO381823(M13)-U	TGTAAAACGACGGCCAGTGAGGGTCTGGTGGTTTTGAA	No
1382	CO381823-L	AACACCGAGGCAATACCAAA	
1383	CO381897(M13)-U	TGTAAAACGACGGCCAGTAGAGGCTGAGGATCATGGTG	Unclear
1384	CO381897-L	GGCAAATACAATGCTAAACCA	
1389	CO382063(M13)-U	TGTAAAACGACGGCCAGTATTGATGATGATGCCGTTGA	Yes
1390	CO382063-L	TGGTACCGAAATGCATTGAA	
1395	CO816672(M13)-U	TGTAAAACGACGGCCAGTAACCAGAAGCAGAGAAGCCA	No
1396	CO816672-L	CTTCTGTGGCAACAACCTCA	
1399	CO816776(M13)-U	TGTAAAACGACGGCCAGTCCTGGTCTCTCCTCCATCAG	No
1400	CO816776-L	GAAGGAAGAGGAAGTTGCCA	
1401	CO816795(M13)-U	TGTAAAACGACGGCCAGTATTGAACAGCTCTGGCGAGT	Yes
1402	CO816795-L	ATGTATACTCCCGCAGGTCG	
1405	CO816809(M13)-U	TGTAAAACGACGGCCAGTCCGTCGTTTGTTTCTGGTCT	No
1406	CO816809-L	GCAGTGCATTGCAGAAGTGT	
1411	CO816864(M13)-U	TGTAAAACGACGGCCAGTCACCCAAGGCTGAGAAGAAG	No
1412	CO816864-L	ACCTGCTTGAGGACCTTGAA	
1413	CO816871(M13)-U	TGTAAAACGACGGCCAGTAGGTTGGTGCTGAGTCTGCT	No
1414	CO816871-L	GTCGAGATGCAACTGCAAGA	
1419	CO816936(M13)-U	TGTAAAACGACGGCCAGTTTCTCTCCGATCTTCTCCGA	Yes
1420	CO816936-L	CATCGACTGGCTTCTCCTTC	
1425	CO816959(M13)-U	TGTAAAACGACGGCCAGTTCCACGCTCTTCTTGTTCCT	Yes
1426	CO816959-L	TCCAATGTCCTCCGTCTCTC	
1433	CO817004(M13)-U	TGTAAAACGACGGCCAGTCGTCAGCCCTAAGAAGATGG	Yes
1434	CO817004-L	ACGACCAATACAGACCAGGG	
1441	CO817063(M13)-U	TGTAAAACGACGGCCAGTGAGGTTCATCAGAGGGCGT	Yes
1442	CO817063-L	CAAGGCAGTAAAGCTCCCAG	
1455	CO817098(M13)-U	TGTAAAACGACGGCCAGTAACACCCAACAATCCAGCTC	Yes
1456	CO817098-L	CACCCGGTTTATCAGCCTTA	
1467	CO817185(M13)-U	TGTAAAACGACGGCCAGTCGCTAGCTTTTCTGCTCGAT	Unclear
1468	CO817185-L	ACACTCCACCGGCTTACATC	
1475	CO817242(M13)-U	TGTAAAACGACGGCCAGTAATCCCCAAATCCTCAAACC	Yes
1476	CO817242-L	CTCCACGCTCTTCTTGTTCC	
1485	CO817364(M13)-U	TGTAAAACGACGGCCAGTGCCTTCCCCTTCTTCAAATC	Yes
1486	CO817364-L	GTCCATTTTCCAGTGGTGCT	
1499	CO817507(M13)-U	TGTAAAACGACGGCCAGTAAGCTCCAGTTGCACCAGTT	Yes
1500	CO817507-L	CTTCTGTGGCAACAACCTCA	
1501	CO817509(M13)-U	TGTAAAACGACGGCCAGTTCACCGTCCTCCTTCTCAAC	Unclear
1502	CO817509-L	CGAAGAGGAAATTGAGCCAG	
1505	CO817538(M13)-U	TGTAAAACGACGGCCAGTAGGTTAGGGGCTGTGGTTCT	Yes
1506	CO817538-L	TTTTGGACCCAAGGTGAAAC	
1507	CO817548(M13)-U	TGTAAAACGACGGCCAGTAGAGGATGGTGAGGCTGCTA	No
1508	CO817548-L	CAGGTCGTGAAGAGATGCAA	
1513	CO817578(M13)-U	TGTAAAACGACGGCCAGTGCAGCTAGCTTGAAGGATGG	Unclear
1514	CO817578-L	GGCACTTTCAGCAACAACAA	
1515	CO817610(M13)-U	TGTAAAACGACGGCCAGTCAAGCTTCACCAACGACTGA	No
1516	CO817610-L	TGCAGAGTGATTTGGAGCAG	

1517	CO817641(M13)-U	TGTAAAACGACGGCCAGTGCCCAAGGCTGAGAAGAAG	No
1518	CO817641-L	CTTGCTGGAGATCCCAATGT	
1519	CO817706(M13)-U	TGTAAAACGACGGCCAGTCCATGGACTTCTCCAAGAGC	Unclear
1520	CO817706-L	ACCTCCATATCAGTCGGCAC	
1525	CO817908(M13)-U	TGTAAAACGACGGCCAGTAAGACCTTGACAACAAACGCT	Yes
1526	CO817908-L	AACCTTCCCAGGTCCTCTGT	
1533	CO818047(M13)-U	TGTAAAACGACGGCCAGTAGAACCAGCCGGAAAGACTC	No
1534	CO818047-L	CTTGCTGGAGATCCCAATGT	
1545	ARSFL12(M13)-U	TGTAAAACGACGGCCAGTGCGGAACCAAGCCAATAAGATG	Unclear
1546	ARSFL12-L	GCGACCACGACAGTTTCTCACTCT	
1563	CO818048(M13)-U	TGTAAAACGACGGCCAGTGGGGGAGAAGGACAAGACTC	Unclear
1564	CO818048-L	CGGAGCAGTAGCTGCCTTAG	
1567	CO818131(M13)-U	TGTAAAACGACGGCCAGTCCTTCCTCCGAAACCCTACT	Yes
1568	CO818131-L	GGGCTCAGGTTATACGAGCA	
1591	CO380466(M13)-U	TGTAAAACGACGGCCAGTGATGGTGACGTGTTTGATCG	Unclear
1592	CO380466-L	GCTGGAAAGCTCAAATAGGC	
1599	CO381023(M13)-U	TGTAAAACGACGGCCAGTTGAGGGAGAGGAGAGTGCAT	Yes
1600	CO381023-L	GGAGGAAAGTGAATTTGAAGC	
1601	CO381173a(M13)-U	TGTAAAACGACGGCCAGTACACTCCACCGGCTTACATC	Unclear
1602	CO381173a-L	CGTGTGTGCATGATTGATGA	
1605	CO381452(M13)-U	TGTAAAACGACGGCCAGTGACCACCAGCATCGAAAAGT	Unclear
1606	CO381452-L	AAAGTGCACCAACTGCTGTCT	
1623	CO816806(M13)-U	TGTAAAACGACGGCCAGTCGAGGGAGAAACCCTAACCT	Unclear
1624	CO816806-L	GGACGATCCCTTGTAGTGGA	
1631	CO817185b(M13)-U	TGTAAAACGACGGCCAGTTCATCCACTGGGAAGAAAGG	Yes
1632	CO817185b-L	CATCAATCATGCACACACGA	
1661	PSContig10410(M13)-U	TGTAAAACGACGGCCAGTCCAAGATCCTTCATTGGCTC	No
1662	PSContig10410-L	CCGTGGGGTCTTGTTTACTC	
1683	PSContig11520a(M13)-U	TGTAAAACGACGGCCAGTTCTGTCATTGCTCAACCTCG	Unclear
1684	PSContig11520a-L	AGCAGAAACCCAGAAAACCA	
1685	PSContig11520b(M13)-U	TGTAAAACGACGGCCAGTTGGTTTTCTGGGTTTCTGCT	Unclear
1686	PSContig11520b-L	ATTGCCATTTGCCAAAGAAG	
1743	PSContig5362a(M13)-U	TGTAAAACGACGGCCAGTTCCTTGGAATTCACCGTCTC	Yes
1744	PSContig5362a-L	CGGCGAATCGATTTACAGAT	
1745	PSContig5362b(M13)-U	TGTAAAACGACGGCCAGTATTCACCGTCTCTCACCACC	Yes
1746	PSContig5362b-L	CGGCGAATCGATTTACAGAT	
1753	PSContig6467(M13)-U	TGTAAAACGACGGCCAGTGCTTCATGGCTTCGTTCTTC	No
1754	PSContig6467-L	GATCAGACTTTAGCGGCGAC	
1803	PSContig944(M13)-U	TGTAAAACGACGGCCAGTTCGAATATTCCCTCCTTCCC	Yes
1804	PSContig944-L	CTTGCCGAACTTCATGTTGA	
1933	CX661047a(M13)-U	TGTAAAACGACGGCCAGTGAAAAACGAAGCTCATCTGAA	Yes
1934	CX661047a-L	TCCGGTTGTACTTGTCCTCC	
1945	CX661101(M13)-U	TGTAAAACGACGGCCAGTTGGGTTTCTGTTTGTCTCCC	Unclear
1946	CX661101-L	GGCCTAGTGGGTTACTGGGT	
1963	CX661187(M13)-U	TGTAAAACGACGGCCAGTTCCACAAGCCATCTCTCCTC	Unclear
1964	CX661187-L	TTGGAGAGATCGTAGGCGTT	
1969	CX661225(M13)-U	TGTAAAACGACGGCCAGTGCTCTCCTCCTCCGTCTCTT	Yes
1970	CX661225-L	GTTTAGCTTCTCCGCTGACG	

1971	CX661229(M13)-U	TGTAAAACGACGGCCAGTCTTCAGCCTTTCCCCTCTTT	Unclear
1972	CX661229-L	GACTGTGTTTGGGCTGGAGT	
1981	CX661264(M13)-U	TGTAAAACGACGGCCAGTGCTCTCAGATCCCTCTACCG	Unclear
1982	CX661264-L	AATTTGCAGCCATCAAGTCC	
1983	CX661264a(M13)-U	TGTAAAACGACGGCCAGTTTCCAGATCTTACCGAACCG	Yes
1984	CX661264a-L	AAAGCGTAGAGCAGCTGAGG	
1987	CX661272(M13)-U	TGTAAAACGACGGCCAGTAATATTCTGATTCGCTCCGC	Yes
1988	CX661272-L	TCTTGATGGGAGCTTCGAGT	
1995	CX661292(M13)-U	TGTAAAACGACGGCCAGTCCCAAATCTCAGAGAACCCA	Yes
1996	CX661292-L	GTTGGCTGAGATGGTGGAGT	
1999	CX661315(M13)-U	TGTAAAACGACGGCCAGTGCCTCGAGAAGCCTCCTATT	Yes
2000	CX661315-L	GAAGCTTCTTCAGCACCACC	
2007	CX661360(M13)-U	TGTAAAACGACGGCCAGTACCTCTCTCTCCATTTCCCG	Unclear
2008	CX661360-L	AAACCTCCCAAAACCCCTAA	
2023	CX661393(M13)-U	TGTAAAACGACGGCCAGTTACCACCAGTACCAGCAGCA	Unclear
2024	CX661393-L	AGTGATGCAAATCTCCGACC	
2039	CX661428a(M13)-U	TGTAAAACGACGGCCAGTCAAAGGGTTCATGACGGACT	Unclear
2040	CX661428a-L	CATGCTGTTCTGCAACTCGT	
2041	CX661428b(M13)-U	TGTAAAACGACGGCCAGTGAAGACGGTGGATGAGGTGT	Unclear
2042	CX661428b-L	CTGCTGAAACCCGAATCCTA	
2043	CX661432(M13)-U	TGTAAAACGACGGCCAGTACCCGGTTCGGTTTTATTTC	Unclear
2044	CX661432-L	AACCCAAATCAGAATCGCTG	
2055	CX661446(M13)-U	TGTAAAACGACGGCCAGTTCCGTCAAGTTCAGTGCATC	Unclear
2056	CX661446-L	GGCAGCCTAATTGAACCAAA	
2059	CX661465(M13)-U	TGTAAAACGACGGCCAGTTGATGCACCTCTCTGTCCAC	No
2060	CX661465-L	TGAAATTGAAATTGAGGGGG	
2073	CX661492(M13)-U	TGTAAAACGACGGCCAGTCCCCATAAAACATCACACATT	Unclear
2074	CX661492-L	CCTCTTGCTTCTTGGAATGC	
2089	CX661544(M13)-U	TGTAAAACGACGGCCAGTGCTCCTCACAAAAGGAGTCG	No
2090	CX661544-L	GTGGCGTAAATCCTCATCGT	
2097	CX661573(M13)-U	TGTAAAACGACGGCCAGTAGGCTCACATGCTCACACTG	Yes
2098	CX661573-L	GAATTCGGAGAAGAAAGGGC	
2105	CX661591(M13)-U	TGTAAAACGACGGCCAGTCTCTCTCAAAGATGCCTCGAA	Yes
2106	CX661591-L	TTGAACAGCGAGAAGTGGTG	
2109	CX661601(M13)-U	TGTAAAACGACGGCCAGTCCGCATCAATCCAAATCTCT	No
2110	CX661601-L	ATGAATCTGAGGCTCGCTGT	
2111	CX661603(M13)-U	TGTAAAACGACGGCCAGTATCAACCACACCGCTACTCC	Yes
2112	CX661603-L	ATTTACGAAAATGCCATCGG	
2119	CX661626(M13)-U	TGTAAAACGACGGCCAGTCCCTCTCTACACACACAGCG	Unclear
2120	CX661626-L	AACGAGGTGGTGGAATCTTG	
2123	CX661626b(M13)-U	TGTAAAACGACGGCCAGTACAGAGCTGCGTAACCGACT	Unclear
2124	CX661626b-L	AACGAGGTGGTGGAATCTTG	
2163	CX661736(M13)-U	TGTAAAACGACGGCCAGTTAGCTCTACACAGGTCCGCA	Unclear
2164	CX661736-L	TTGGGTTTTCTAGTGGGACG	
2169	CX661746(M13)-U	TGTAAAACGACGGCCAGTCGCTGACCCTGTTGTCACTA	Unclear
2170	CX661746-L	TTCAACCGGTTTCTCCTTTG	
2173	CX661752(M13)-U	TGTAAAACGACGGCCAGTACCTGACCTGACCAAACCAG	Yes
2174	CX661752-L	TGGGGATGAGGATGAGAGTC	

2177	CX661761(M13)-U	TGTAAAACGACGGCCAGTTTAGCCACCTTCTCCACCAC	Unclear
2178	CX661761-L	TTGGGTTGGAATTTGGAGAG	
2179	CX661761a(M13)-U	TGTAAAACGACGGCCAGTCCACCACGAAGCTCTCTCTC	Yes
2180	CX661761a-L	GGGACTCTCTGAAATGCCAA	
2191	CX661786(M13)-U	TGTAAAACGACGGCCAGTACCCTCCTCCCACTCTCACT	Yes
2192	CX661786-L	ACTCGAATCTCGTCGTCGTC	
2195	CX661792(M13)-U	TGTAAAACGACGGCCAGTAATGCCACTCCGAAACTCAC	Yes
2196	CX661792-L	GGACTCCTTGACTCTGTCGC	
2201	CX661803(M13)-U	TGTAAAACGACGGCCAGTTCGAAAACCCAGCTCAATTC	Unclear
2202	CX661803-L	AGCATGTTGCTGTACATGGC	
2233	CX661874(M13)-U	TGTAAAACGACGGCCAGTAGAGCCATGGCAATCTCAAC	Yes
2234	CX661874-L	GTGGAGGGGTTAAGGAAGGA	
2235	CX661889(M13)-U	TGTAAAACGACGGCCAGTGGAAGCTTGGAAATCATGGA	No
2236	CX661889-L	CTCTGCGAGAAACCACACAA	

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