Diversity Captured in the USDA-ARS National Plant Germplasm System Apple Core Collection

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ABSTRACT. The USDA-ARS National Plant Germplasm System *Malus* collection is maintained by the Plant Genetic Resources Unit (PGRU) in Geneva, NY. In the 1990s, a core subset of 258 trees was hand-selected to be representative of the grafted *Malus* collection. We used a combination of genotypic and phenotypic data to compare the diversity of the 198 diploid trees in the original core subset with that of 2114 diploid trees in the grafted field collection for which data were available. The 198 trees capture 192 of the 232 total microsatellite alleles and have 78 of the 95 phenotypic characters. An addition of 67 specific individuals increases the coverage to 100% of the allelic and phenotypic character states. Several de novo core sets that capture all the allelic and phenotypic character states in 100 individuals are also provided. Use of these proposed sets of individuals will help ensure that a broad range of *Malus* diversity is included in evaluations that use the core subset of grafted trees in the PGRU collection.

Large field collections of plant genetic resources, although critical for many clonal and perennial crops, are expensive to maintain and can be unwieldy for research purposes. In the 1980s, Brown and colleagues described a need to identify representative subsets of larger collections. These collections could be given higher priority for evaluations and could be made widely available at multiple locations, thus increasing access to associated data for the gene bank user community (Brown, 1989; Rubenstein et al., 2006). Core collections of crops have since been developed using a number of different strategies, including selection of materials from geographic or ecological groups or selection of highly differentiated materials. These stratified sampling techniques seek to maximize allelic richness and capture the available genetic and phenotypic diversity (Schoen and Brown, 1995). Various combinations of morphology, climatic, geographic, genetic distances, and genetic diversity assessments have been implemented to develop core collections for diverse crops (Balakrishnan et al., 2000; Balfourier et al., 2007; Bisht et al., 1998; Chavarriaga-Aguirre et al., 1999; Franco et al., 2001, 2006; Jansen and van Hintum, 2007; Lázaro and Aguinalde, 2006; McKhann et al., 2004; Ronfort et al., 2006; Wang et al., 2006a, 2006b, 2007). Many researchers have turned to optimization algorithms such as MSTRAT, which seek to maximize allelic and/or phenotypic richness by ensuring that the maximum number of character states is represented in the core set of individuals (Gouesnard et al., 2001). Further studies have examined the value of relying on neutral genetic markers to estimate collection diversity (Bataillon et al., 1996; Reeves et al., 2012).

Apple (*Malus ×domestica*) is a globally produced clonal crop for which field collections play a crucial role in preserving

genetic diversity and providing breeding material. In particular, apple production is currently threatened by disease, pest susceptibility, suboptimal cold and heat tolerance, minimal resistance to drought and wet soils, undesirable storage and transport characteristics, and expensive production methods (Yue et al., 2012). Simultaneously, there is rising consumer demand for organic produce and heritage apple cultivars. The USDA-ARS National Plant Germplasm System (NPGS) apple collection in Geneva, NY, has key genetic resources that can be used in breeding and research programs to address the threats to apple crop production and to provide disease- and climate-hardy heritage cultivars to interested growers. The grafted portion of this collection is a set of 3442 individuals maintained for their unique genotypes. These clonally maintained individuals are primarily cultivars but also include wild *Malus* species representatives. The trees were in an orchard that was planted on seedling rootstock when the phenotypic data for this research were collected. Since that time, the entire collection has been repropagated onto EMLA 7 rootstock. The grafted collection is complimented by a “species” collection consisting of over 3000 seedling trees grown from wild-collected seeds. The current study focuses on the grafted “clonally propagated” part of the NPGS apple collection.

Core collections have been developed for both the entire *Malus* grafted collection and for subsets of wild species collections using either phenotypic and/or genetic data. For example, over 1000 *M. sieversii* seedlings from the “species” collection that represent eight collection sites in Kazakhstan have been genotyped using microsatellite markers and evaluated for key phenotypic traits. In 2005, Volk et al. proposed two sets of 35 individuals that represent 174 and 278 trees of *M. sieversii* from Kazakhstan collection sites 6 and 9, respectively (Volk et al., 2005). In 2009, Richards et al. developed a third core set of 35 individuals that captures the measured genotypic and phenotypic diversity from the remaining

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Kazakhstan collection locations of *M. sieversii* (Richards et al., 2009a, 2009b). These smaller sets of individuals were designed to capture the diversity of the larger plantings so that a subset of individuals could be targeted for field maintenance as grafted clones and long-term back-up using cryopreservation technologies (Volk et al., 2005). Similarly, a core set of 27 *M. orientalis* individuals was proposed as a method to capture the genetic diversity represented by 776 seedling trees of *M. orientalis* in the “species” collection as measured using seven microsatellite markers (Volk et al., 2009).

In the 1990s, a set of 258 individuals was hand-selected to be a representative “core collection” of the grafted collection of apples at the Geneva, NY, repository (Supplemental Table 1). Phenotypic, genotypic, and image data are now available for most of the individuals in the core collection. These individuals have also been distributed to multiple locations, including Washington State University, the University of Illinois, and the University of Minnesota for inclusion in breeding programs as well as for horticultural trait, biotic, and abiotic resistance evaluations (Hokanson et al., 1998). Previous reports have focused on assessing the diversity and genetic relationships among accessions in the core collection (or a portion thereof) using microsatellite markers (Hokanson et al., 1998, 2001; Potts et al., 2012). In this project, we consider the phenotypic and allelic diversity of the diploid trees in the apple core collection in relation to the diversity in the grafted diploid apple collection. We assess the current diversity captured and propose additional individuals from the grafted collection that either complement or replace individuals in the current core collection so that a broader spectrum of diversity is represented.

Materials and Methods

PLANT MATERIAL. Most of the diploid trees in the grafted PGRU orchards were sampled for potential inclusion in the genetic analyses. Trees were genotyped at nine simple sequence repeat (SSR) loci (see below), and only diploid trees with microsatellite signatures that could be scored in a comparative manner were included in the final data set. The final data set comprised 2114 samples, also referred to as individuals or accessions, each identified with a unique PI number. Of these samples, 198 are part of the current core collection that was proposed in the 1990s (Table 1).

PHENOTYPIC DATA. Phenotypic data were collected in orchard evaluations performed in Geneva, NY. Available data were downloaded from the Genetic Resources Information Network database [GRIN (U.S. Department of Agriculture, 2012)]. The data for each accession were collected in a single growing season after the trees had reached maturity (not necessarily in the same year for all of the accessions). Continuous descriptors were placed into categories to facilitate core collection assessments. Phenotypic data were primarily related to fruit trait characteristics. Data were collected on fruit that were mature, defined as when the overcolor on the fruit was apparent. “Fruit weight” was measured as the mean weight of 10 fruit at maturity and data were classified into 50-g increments. “Fruit shape” data were classified as globose, short, flat, conical, ellipsoid, or oblong. “Fruit ground color” at maturity data used the first color descriptor of the GRIN classification: light green, green, light yellow, yellow, orange, brown, pink, red, or purple. Similarly, “overcolor pattern” was classified as blush, striped, splashed, or none. “Fruit overcolor” was measured at maturity

and GRIN data were classified into the following categories: none, green, yellow, orange, brown, pink, red, dark red, and purple. “Overcolor intensity” was measured as the percent of overcolor on fruit and placed into categories. “Fruit russet” was measured as the percent of russetting on fruit and placed into categories in 10% increments between 0% and 100%.

“Fruit flesh color” data were reclassified into categories using only the first digit of the numerical code representing flesh colors white, cream, green, yellow, orange, pink, red, or rose red. “Fruit flesh firmness” at maturity was classified as soft, semifirm, firm, or hard according to standards described in GRIN. “Fruit flesh oxidation” was visually measured in cut fruit after 10 min at room temperature. Descriptor values ranged from non-oxidizing (0% to 1%), slightly oxidizing (1% to 4%), oxidizing (5% to 10%), and very oxidizing (greater than 10%). “Fruit juiciness” was measured as a rating of fruit flesh juiciness based on the apple weight to apple volume (specific gravity) and recorded as a mean of five apples at maturity. Code values were very dry (less than 0.75), dry (0.76 to 0.80), medium (0.81 to 0.85), moderately juicy (0.86 to 0.90), and very juicy (greater than 0.90) (Young, 1914). Percent “soluble solids” were measured as the average refractometer readings from juice sampled from three fruit at full maturity. Quantitative values were placed into categories as described on GRIN. “Fruit flesh flavor” was classified qualitatively as aromatic, sweet, sub-acid, acid, and astringent.

MOLECULAR DATA. Genomic DNA was extracted from leaf tissue using DNeasy 96 plant kits (Qiagen, Valencia, CA). Nine previously published SSRs [GD12, GD15, GD96, GD142, GD147, GD162, CH01h01, CH01f02, and CH02d08 (Hokanson et al., 1998; Liebhart et al., 2002)] were amplified in all samples. Primer sequences, amplicon size ranges, and annealing temperatures are listed in Gross et al. (2012a). Amplification and scoring were carried out according to Gross et al. (2012a). Briefly, polymerase chain reaction products were scored in one of two ways. Some were visualized on a slab sequencer (LI-4200; LI-COR, Lincoln, NE) and digital images were manually interpreted using Saga Generation 2 software (LI-COR). Others were visualized on a capillary sequencer (ABI 3730; Applied Biosystems, Foster City, CA) and chromatograms were scored automatically and then corrected manually using GeneMarker software (SoftGenetics, State College, PA). When a single SSR locus was scored using both systems, control individuals of known genotypes were run on both systems to control for allele length differences resulting from instrumentation.

EVALUATION AND DEVELOPMENT OF CORE COLLECTIONS. De novo core collections and amended cores were constructed using the maximization algorithm (M) of Schoen and Brown (1995) as implemented in the program MSTRAT (Gouesnard et al., 2001) with all character states of molecular and phenotypic data weighted equally. Marker data were also analyzed using a modified maximization procedure [M+ (Reeves et al., 2012)] with all character states of molecular data weighted equally. The M+ procedure improves on MSTRAT in several ways, including the ability to discard missing data (rather than counting it as a character state), the ability to consider two alleles at a single locus jointly rather than separately, and the ability to weight loci equally rather than giving a higher weight to more diverse loci (Gouesnard et al., 2001; Reeves et al., 2012).

MSTRAT was used to construct amended cores; these cores included the current core samples with additional samples to

Table 1. Taxonomic diversity in the grafted apple collection of the USDA-ARS Plant Genetic Resources Unit (Geneva, NY).^z

<i>Malus</i> species	Grafted diploid trees included in analyses (no.)	Original core collection trees (no.)	Original diploid core collection trees included in analyses (no.)
<i>M. angustifolia</i>	18	2	2
<i>M. baccata</i>	45	6	6
<i>M. brevipes</i>	2	1	1
<i>M. coronaria</i>	36	3	2
<i>M. doumeri</i>	0	1	0
<i>M. florentina</i>	3	2	2
<i>M. floribunda</i>	10	1	1
<i>M. fusca</i>	40	4	4
<i>M. halliana</i>	10	3	3
<i>M. honanensis</i>	2	2	2
<i>M. hupehensis</i>	3	6	1
Hybrid	298	37	35
<i>M. ioensis</i>	35	5	4
<i>M. kansuensis</i>	5	4	2
<i>M. komarovii</i>	0	0	0
<i>M. mandshurica</i>	3	1	1
<i>M. ombrophila</i>	3	2	2
<i>M. orientalis</i>	6	12	2
<i>M. orthocarpa</i>	1	0	0
<i>M. prattii</i>	4	3	3
<i>M. prunifolia</i>	35	8	8
<i>M. pumila</i>	11	2	2
<i>M. sargentii</i>	6	1	0
<i>M. sieversii</i>	166	28	10
<i>M. sikkimensis</i>	3	2	0
<i>Malus</i> sp.	27	2	2
<i>M. spectabilis</i>	6	2	1
<i>M. sylvestris</i>	15	7	7
<i>M. toringo</i>	11	7	3
<i>M. toringoides</i> (<i>M. bhutanica</i>)	3	4	1
<i>M. transitoria</i>	2	4	2
<i>M. trilobata</i>	0	1	0
<i>M. tschonoskii</i>	3	1	1
<i>M. ×adstringens</i>	3	0	0
<i>M. ×arnoldiana</i>	2	1	1
<i>M. ×asiatica</i>	16	4	4
<i>M. ×astracanica</i>	1	1	0
<i>M. ×atrosanguinea</i>	2	0	1
<i>M. ×dawsoniana</i>	2	1	1
<i>M. ×domestica</i>	1211	67	64
<i>M. ×hartwigii</i>	5	1	1
<i>M. ×magdeburgensis</i>	2	1	1
<i>M. ×micromalus</i>	14	5	4
<i>M. ×moerlandsii</i>	2	0	0
<i>M. ×platycarpa</i>	2	1	0
<i>M. ×purpurea</i>	5	0	0
<i>M. ×robusta</i>	11	3	3
<i>M. ×scheideckeri</i>	1	0	0
<i>M. ×soulardii</i>	2	1	1
<i>M. ×sublobata</i>	3	2	1
<i>M. yunnanensis</i>	14	3	3
<i>M. zhaojiaoensis</i>	2	2	2
<i>M. zumi</i>	2	1	1
Total	2114	258	198

^zThe number of unique diploid trees included in the genotyping analyses, the number of core collection trees in the original core collection, and the number of diploid trees in the original core collection included in the genotyping analyses are provided for each species or hybrid.

maximize diversity. We allowed the program to add samples until all molecular and phenotypic characters were captured and ran 10 independent replicates of the amended core. Results for the amended core replicates were compared; samples that were present in 10 of 10 runs were considered as potential additions to the current core (Table 2; Supplemental Table 2). The modified MSTRAT program, M+, was used to generate de novo cores from the *Malus* main collection. As a result of computational constraints associated with the large size of the main collection, the M+ program was run, increasing the core size by increments of 20, until the core contained all the possible molecular and phenotypic characters; this was replicated 10 times. Full results of these runs are presented in the supplementary data (Supplemental Table 3).

General genetic diversity statistics were calculated for the 198 diploid samples of the current core, the diploid grafted collection, potential amended cores, and a representative de novo core using GenoDive (Meirmans and Van Tienderen, 2004). The number of alleles and phenotypic character states in the diploid existing core and diploid grafted collection were compared with the proposed cores to evaluate the percentage of variation captured (Table 3).

Results

CORE COLLECTION REPRESENTATION. In 2011, the PGRU grafted apple collection included 3442 individuals representing 51 species or named hybrids. The original core collection is represented by 258 individuals from 46 species. Of these, 67 individuals are *M. ×domestica*. The constraints resulting from ploidy levels and missing data left 2114 diploid individuals from the grafted collection included in the analysis. All but 169 of the 2114 diploid grafted collection individuals had phenotypic data available, and all but eight of the 198 current core diploid individuals had phenotypic data available.

We used principal component analyses to visualize how well the

Table 2. Potential additional apple accessions that could be amended to the original apple core collection to increase its genetic and phenotypic diversity.^z

In 10 of 10	Addition to existing core for improved diversity	PI no.	Genus	Species	Cultivar	Original source
x	x	392301	<i>Malus</i>	<i>baccata</i>		China
x	x	588907	<i>Malus</i>	<i>baccata</i>	Himalaica	China
x	x	590057	<i>Malus</i>	<i>baccata</i>		China
x	x	613925	<i>Malus</i>	<i>prattii</i>		China
x	x	589162	<i>Malus</i>	<i>coronaria</i>	Glabrata	United States
x	x	589423	<i>Malus</i>	<i>coronaria</i>		United States
x	x	123733	<i>Malus</i>	<i>domestica</i>	Bedan des parts	France
x	x	134668	<i>Malus</i>	<i>domestica</i>	Pomme Cloche	Germany
x	x	162062	<i>Malus</i>	<i>domestica</i>	Daux Belan	France
x	x	245048	<i>Malus</i>	<i>domestica</i>	Belle Fleur Rouge	France
x	x	264689	<i>Malus</i>	<i>domestica</i>	Djulabia	Serbia
x	x	589018	<i>Malus</i>	<i>domestica</i>	Cimitiere	The Netherlands
x	x	590136	<i>Malus</i>	<i>domestica</i>	Reinette de Cuzy	France
x	x	264693	<i>Malus</i>	<i>domestica</i>	Sumatovka	Serbia
x	x	322714	<i>Malus</i>	<i>domestica</i>	Kandil Kitaika	former Soviet Union
x	x	589080	<i>Malus</i>	<i>domestica</i>	Dermen Winesap 2-4-4	United States
x	x	613814	<i>Malus</i>	<i>domestica</i>	San Jacinto	United States
x	x	589099	<i>Malus</i>	<i>domestica</i>	Perrine Yellow Transparent	United States
x	x	141362	<i>Malus</i>	Hybrid	James Kirk	United Kingdom
x	x	296775	<i>Malus</i>	Hybrid	Ottawa 541	Canada
x	x	588887	<i>Malus</i>	Hybrid	Profusion	The Netherlands
x	x	588915	<i>Malus</i>	Hybrid	Beverly	
x	x	588984	<i>Malus</i>	Hybrid	Kensib	United States
x	x	589058	<i>Malus</i>	Hybrid	September	United States
x	x	589282	<i>Malus</i>	Hybrid	RMJ 105	
x	x	613799	<i>Malus</i>	<i>micromalus</i>		
x	x	590096	<i>Malus</i>	<i>pumila</i>		
x	x	657107	<i>Malus</i>	<i>sieversii</i>		Kazakhstan
x	x	613989	<i>Malus</i>	<i>sieversii</i>		Kazakhstan
x	x	629316	<i>Malus</i>	<i>sieversii</i>		Tajikistan
x	x	613865	<i>Malus</i>	<i>sylvestris</i>		Macedonia
x	x	613870	<i>Malus</i>	<i>sylvestris</i>		Macedonia
x	x	590101	<i>Malus</i>	<i>toringo</i>	Toringo Crab Apple	Japan
x	x	613860	<i>Malus</i>	<i>toringo</i>		Korea
x	x	590067	<i>Malus</i>	<i>yunnanensis</i>		China
x	x	590113	<i>Malus</i>	<i>yunnanensis</i>	Yunnan Crab Apple	China
	x	589769	<i>Malus</i>	<i>angustifolia</i>		United States
	x	589770	<i>Malus</i>	<i>angustifolia</i>		United States
	x	613879	<i>Malus</i>	<i>angustifolia</i>		United States
	x	104034	<i>Malus</i>	<i>domestica</i>	Renetta Dorata	Italy
	x	247314	<i>Malus</i>	<i>domestica</i>	Frequin Lacaille	France
	x	589196	<i>Malus</i>	<i>domestica</i>	Crow Egg	United States
	x	589242	<i>Malus</i>	<i>domestica</i>	Pomme Grise	Canada
	x	589657	<i>Malus</i>	<i>domestica</i>	Crawley Beauty	United Kingdom
	x	148478	<i>Malus</i>	<i>domestica</i>	Jewel	United Kingdom
	x	306321	<i>Malus</i>	<i>domestica</i>	Gibbs Golden Gauge	United Kingdom
	x	383513	<i>Malus</i>	<i>domestica</i>	Korobovka	Russia
	x	590157	<i>Malus</i>	<i>domestica</i>	Hudson's Golden Gem	United States
	x	590181	<i>Malus</i>	<i>domestica</i>	Tahir 3-1	
	x	589909	<i>Malus</i>	<i>domestica</i>	York	United States
	x	590036	<i>Malus</i>	<i>fusca</i>		Canada
	x	590091	<i>Malus</i>	<i>halliana</i>		China
	x	589456	<i>Malus</i>	Hybrid	Evelyn	United States
	x	589629	<i>Malus</i>	Hybrid	Chance	United States
	x	589241	<i>Malus</i>	<i>ioensis</i>	Prairie Rose	United States
	x	589406	<i>Malus</i>	<i>ioensis</i>		United States

Continued next page

Table 2. Continued.

In 10 of 10	Addition to existing core for improved diversity	PI no.	Genus	Species	Cultivar	Original source
	x	590004	<i>Malus</i>	<i>ioensis</i>		United States
	x	613892	<i>Malus</i>	<i>ioensis</i>		United States
	x	337434	<i>Malus</i>	<i>prunifolia</i>	B-87	Former Soviet Union
	x	657018	<i>Malus</i>	<i>sieversii</i>		Kazakhstan
	x	657041	<i>Malus</i>	<i>sieversii</i>		Kazakhstan
	x	629305	<i>Malus</i>	<i>sieversii</i>		Kazakhstan
	x	629319	<i>Malus</i>	<i>sieversii</i>		Kazakhstan
	x	589748	<i>Malus</i>	<i>toringo</i>		
	x	589866	<i>Malus</i>	<i>×hartwigii</i>		Latvia
	x	589016	<i>Malus</i>	<i>×purpurea</i>	Aldenhamensis	
	x	589755	<i>Malus</i>	<i>×sublobata</i>		

^zSamples that were identified in 10 of the 10 replicate runs of MSTRAT (Gouesnard et al., 2001) are identified (in 10 of 10 column). A list of accessions identified from a single MSTRAT run that constitutes a core collection that fully captures the molecular and phenotypic diversity is provided.

Table 3. Diversity retained in diploid core collections for the grafted Geneva, NY, Plant Genetic Resources Unit *Malus* collection using several core assembly strategies.^z

	Samples (no.)	Avg alleles (no./locus)	Total allele (no.)	Total alleles (%)	Total phenotypic characters (no.)	Total phenotypic characters (%)
Core	198	21.3	192	83	78	82
Core+36	234	24.6	221	95	85	89
Core+67	265	25.8	232	100	95	100
De novo core	100	25.8	232	100	95	100
Main collection	2114	25.8	232	100	95	100

^zPercent total alleles was calculated by taking the number of total alleles and dividing it by the number alleles in the main collection.

core sets capture the diversity in multidimensional space represented by the grafted collection. The principal component analyses included samples for which complete genotypes were available: 103 core collection individuals and a total of 1415 individuals from the grafted collection. Although this analysis only visualized 50% of the core and 66% of the total collection, we feel that this is an unbiased sample and allows us to evaluate how well the core collection represents the larger set of genotypes. Regressing the first two principal components (accounting for 38% of the variance) shows a broad overlap (Fig. 1). When visualized as a graph, the three-dimensional plot with the first three principal components is a cloud of points with no obvious divisions and the core selections appear to be randomly distributed within the cloud. The first 11 principal components account for 80% of the variation (data not shown).

CORE COLLECTIONS. Our results from both the MSTRAT and M+ programs indicate that a smaller core collection may be sufficient to capture the molecular diversity documented using the nine SSR loci and the phenotypic diversity described by the 13 selected fruit character traits. Entirely new core sets were identified that capture the complete molecular and phenotypic diversity with 100 samples (Table 3; Supplemental Table 3). If this approach were to be taken, several of the individuals that are currently in the core collection would be retained. An average

Fig. 1. Principal component analysis visualizing the first two principal components (accounting for 38% of the variance) of 103 core collection individuals (gray) and 1415 grafted *Malus* individuals (black) for which complete genotypes were available.

of 15.4 (ranging from 13 to 17) samples were present in both the current core collection and the de novo core sets, and eight of these samples were present in both the current core and all 10 de novo replicates (Supplemental Table 3).

Alternatively, the current core could be amended with an additional 67 samples to capture 100% of the measured

molecular and phenotypic diversity or an additional 36 individuals to capture 95% of the molecular and 89% of the phenotypic variation (Tables 2 and 3). Because this analysis does not include polyploid individuals (either in the core or main collection), additional polyploid samples with unique phenotypic characteristics could be selected from the Geneva collections to complement the core sets identified in these analyses.

Discussion

The genetic composition of the *Malus* core collection, based on SSR analyses, has been previously published. Studies revealed that eight or nine SSR markers differentiate many of the collection accessions with potential “duplicates” or “sports” being the exceptions (Gross et al., 2012b; Hokanson et al., 1998). High levels of allelic diversity were present within the original core collection materials (Hokanson et al., 2001; Potts et al., 2012). To our knowledge, however, none of the previous research considered the extent to which the diversity in the grafted PGRU apple collection was captured in the original core collection. We used both molecular and phenotypic traits to assess the diversity of the core collection in relation to a larger portion of the grafted collection. Realizing that the original core collection has been used in multiple plantings and research projects, we thought it prudent to identify sets of individuals that could be added to existing projects or locations that wish to enhance the diversity of their research collections (Table 2). Future projects, however, may choose to make use of a smaller core collection that captures the diversity of the diploid accessions in the main collection with 100 individuals. The identity of the members of the new core sets is provided (Supplemental Table 3).

The phenotypic data available for the MSTRAT analyses are limited by the fact that they are collected from a single individual in a single season. The data are primarily categorical and have been broadly classified. These data were used as additional information to aid in the selection of core collections. Because the categories were broadly defined, it is likely that many of the traits would be classified similarly in subsequent years.

A germplasm collection can potentially be represented by multiple core collections. These core collections may be identified based on geographical, molecular, or phenotypic diversity. Given the diverse user community that is served by the PGRU apple collection, it is reasonable to have core collections that are tailored to specific portions of the collection. For example, previously proposed core sets for the close wild relatives of apple, *M. sieversii* and *M. orientalis*, are available for in-depth analyses of the diversity within these species. *M. sieversii* is represented by three core collections selected from seedlings obtained from unique habitats in Kazakhstan.

The core collections herein are designed to be representative of the large, multispecies, grafted collection of trees at the PGRU. As a result of the complications resulting from obtaining reliable SSR data for polyploid individuals, only diploid individuals were used in our analyses. This reduced the number of individuals in our data sets from 258 in the original core to 198 and from 3442 in the grafted collection (as of 2011) to 2114. When just these diploid accessions are considered, the original core collection captures $\approx 83\%$ of the measured diversity in the grafted collection in $\approx 10\%$ of

the individuals. The newly proposed cores of 100 individuals capture 100% of the measured diversity in $\approx 5\%$ of the individuals (Table 3). Additional polyploid individuals could be selected to complement the core collections that have been proposed for the diploid accessions.

MSTRAT has been used extensively to identify core sets of individuals that capture the diversity of plant collections (Balfourier et al., 2007; Ellwood et al., 2006; Jansen and van Hintum, 2007; McKhann et al., 2004). MSTRAT has the advantage of allowing the inclusion of both phenotypic and genotypic categorical data sets that are very large. MSTRAT also lets the user “lock-in” certain individuals that already exist in core sets and identify complimentary individuals that capture more diversity, thus producing an amended core (Gouesnard et al., 2001). However, the current program includes missing data as a character state and considers the two alleles present at a particular diploid locus independently rather than considering them jointly (i.e., with MSTRAT, an allele would need to occur at both positions in a locus rather than only occurring once in the data set). The program M+ does not currently have the “lock-in” feature nor does it accept phenotypic data but does overcome the missing data and independent loci drawbacks of MSTRAT (Reeves et al., 2012). Both programs were used in our analyses to propose improved core sets based on the available data.

Conclusion

Large field collections are crucial to maintaining diversity in clonal and perennial crops, but these same collections can be unwieldy for researchers to evaluate or use as a result of their size. Core collections can streamline research that seeks to evaluate genetic or phenotypic diversity and provide a gateway into the collection for plant breeders screening for traits of interest. Although core collections can potentially be based on any number of different characters, it is reasonable to strive for full representation of the documented genetic and phenotypic diversity found in the main collection. We have proposed both a new 100 individual core and an additional 67 individuals that can be used to bring the current core up to 100% representation of the grafted collection. These collections can be supplemented with representatives having traits that were not measured in this study such as differing ploidy levels and geographic origins.

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Supplemental Table 1. Apple accessions in the original *Malus* core collection, which was designed to be representative of the Plant Genetic Resources Unit grafted apple collection in the 1990s.^z

Row (no.)	Genus	Species	PI no.	Included in analyses	Ploidy	Cultivar	Year
1	<i>Malus</i>	<i>angustifolia</i>	589727	x	2x		
2	<i>Malus</i>	<i>angustifolia</i>	589763	x	3x		
3	<i>Malus</i>	<i>×asiatica</i>	589869	x	4x	Seedling b from population of 10 of GMAL 1487	
4	<i>Malus</i>	<i>×asiatica</i>	594099	x	2x	GMAL 1879.01	
5	<i>Malus</i>	<i>×asiatica</i>	594107	x	2x	GMAL 3226.01	
6	<i>Malus</i>	<i>×asiatica</i>	613835	x	2x	GMAL 1879.a	
7	<i>Malus</i>	<i>baccata</i>	286599	x	2x		
8	<i>Malus</i>	<i>baccata</i>	322713	x	2x	Mandshurica 2330	
9	<i>Malus</i>	<i>baccata</i>	437055	x	2x	Flexilis	
10	<i>Malus</i>	<i>baccata</i>	588960	x	2x	Rockii	
11	<i>Malus</i>	<i>baccata</i>	589838	x	2x	Hansen's #2	
12	<i>Malus</i>	<i>baccata</i>	594110	x	2x	Jackii	
13	<i>Malus</i>	<i>brevipes</i>	589170	x	2x		
14	<i>Malus</i>	<i>coronaria</i>	589976	x	4x		
15	<i>Malus</i>	<i>coronaria</i>	590020	x	3x		
16	<i>Malus</i>	<i>domestica</i>	104727	x	2x	Irish Peach	1820
17	<i>Malus</i>	<i>domestica</i>	107196	x	2x	Antonovka 1.5 pounds	1888
18	<i>Malus</i>	<i>domestica</i>	123989	x	2x	Emilia	1915
19	<i>Malus</i>	<i>domestica</i>	188517	x	2x	Koningszuur	
20	<i>Malus</i>	<i>domestica</i>	246464	x	2x	James Grieve (Red Rosamund strain)	1893
21	<i>Malus</i>	<i>domestica</i>	280400	x	2x	Anna	1959
22	<i>Malus</i>	<i>domestica</i>	280401	x	2x	Ein Shemer	1963
23	<i>Malus</i>	<i>domestica</i>	383515	x	2x	Poeltsamaa Winter Apple	
24	<i>Malus</i>	<i>domestica</i>	392303	x	2x	Gala	1934
25	<i>Malus</i>	<i>domestica</i>	588747	x	2x	Florina	1977
26	<i>Malus</i>	<i>domestica</i>	588772	x	2x	Monroe	1910
27	<i>Malus</i>	<i>domestica</i>	588778	x	2x	Virginiagold	1944
28	<i>Malus</i>	<i>domestica</i>	588785	x	2x	Esopus Spitzenburg	1790
29	<i>Malus</i>	<i>domestica</i>	588806	x	2x	Chisel Jersey	1860
30	<i>Malus</i>	<i>domestica</i>	588835	x	2x	Burgundy	1953
31	<i>Malus</i>	<i>domestica</i>	588837	x	3x	Gravenstein Washington Red	
32	<i>Malus</i>	<i>domestica</i>	588838	x	2x	Nova Easygro	1956
33	<i>Malus</i>	<i>domestica</i>	588841	x	2x	Idared	1935
34	<i>Malus</i>	<i>domestica</i>	588842	x	2x	Empire	1945
35	<i>Malus</i>	<i>domestica</i>	588844	x	2x	Fuji Red Sport Type 2	
36	<i>Malus</i>	<i>domestica</i>	588848	x	2x	Cortland	1898
37	<i>Malus</i>	<i>domestica</i>	588849	x	2x	Russian	1613
38	<i>Malus</i>	<i>domestica</i>	588850	x	2x	Rome Beauty Law	1848
39	<i>Malus</i>	<i>domestica</i>	588853	x	2x	Cox's Orange Pippin	1825
40	<i>Malus</i>	<i>domestica</i>	588859	x	2x	Yellow Transparent	1850
41	<i>Malus</i>	<i>domestica</i>	588872	x	2x	Northern Spy	1800
42	<i>Malus</i>	<i>domestica</i>	588880	x	2x	Granny Smith	1868
43	<i>Malus</i>	<i>domestica</i>	588943	x	2x	Liberty	1867
44	<i>Malus</i>	<i>domestica</i>	588955	x	2x	Sweet Delicious	1911
45	<i>Malus</i>	<i>domestica</i>	588981	x	2x	Mollie's Delicious	1948
46	<i>Malus</i>	<i>domestica</i>	588995	x	2x	Antonovka Kamenichka	1889
47	<i>Malus</i>	<i>domestica</i>	588998	x	2x	Marshall McIntosh	1967
48	<i>Malus</i>	<i>domestica</i>	589006	x	2x	Spokane Beauty	1859
49	<i>Malus</i>	<i>domestica</i>	589053	x	2x	Lady	1628
50	<i>Malus</i>	<i>domestica</i>	589122	x	2x/4x	Kimball McIntosh 2-4-4-4	1948
51	<i>Malus</i>	<i>domestica</i>	589181	x	2x	Prima	1963
52	<i>Malus</i>	<i>domestica</i>	589255	x	2x	Redspur Delicious	1954
53	<i>Malus</i>	<i>domestica</i>	589312	x	2x	Russian sdlg.	
54	<i>Malus</i>	<i>domestica</i>	589434	x	2x	Viking	1969
55	<i>Malus</i>	<i>domestica</i>	589441	x	2x	Ingol	

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Supplemental Table 1. Continued.

Row (no.)	Genus	Species	PI no.	Included in analyses	Ploidy	Cultivar	Year
56	<i>Malus</i>	<i>domestica</i>	589469	x	2x	Haralson	1913
57	<i>Malus</i>	<i>domestica</i>	589478	x	2x	Novosibirski Sweet	
58	<i>Malus</i>	<i>domestica</i>	589486	x	2x	Murray	1980
59	<i>Malus</i>	<i>domestica</i>	589490	x	2x	Trent	1979
60	<i>Malus</i>	<i>domestica</i>	589491	x	2x	Korichnoe Polosatoje	
61	<i>Malus</i>	<i>domestica</i>	589520	x	3x	Rhode Island Greening	1650
62	<i>Malus</i>	<i>domestica</i>	589596	x	2x	Calville Blanc	1598
63	<i>Malus</i>	<i>domestica</i>	589645	x	2x	Winter Majetin	1820
64	<i>Malus</i>	<i>domestica</i>	589648	x	2x	Rosemary Russet	1831
65	<i>Malus</i>	<i>domestica</i>	589726	x	2x	Britegold	1980
66	<i>Malus</i>	<i>domestica</i>	589841	x	2x	Delicious	1879
67	<i>Malus</i>	<i>domestica</i>	589845	x	4x	Smith Jonathan	1950
68	<i>Malus</i>	<i>domestica</i>	589894	x	2x	Keepsake	1936
69	<i>Malus</i>	<i>domestica</i>	589913	x	2x	Dorsett Golden	
70	<i>Malus</i>	<i>domestica</i>	589956	x	2x	Antonovka 172670-B	
71	<i>Malus</i>	<i>domestica</i>	589962	x	2x	Jonafree	1965
72	<i>Malus</i>	<i>domestica</i>	589970	x	2x	Petrel	
73	<i>Malus</i>	<i>domestica</i>	590179	x	2x	E.8	1944
74	<i>Malus</i>	<i>domestica</i>	590183	x	2x	Dayton	1976
75	<i>Malus</i>	<i>domestica</i>	590184	x	2x	Golden Delicious	1890
76	<i>Malus</i>	<i>domestica</i>	590185	x	2x	Jonathan	1826
77	<i>Malus</i>	<i>domestica</i>	590186	x	2x	Wijcik McIntosh	1969
78	<i>Malus</i>	<i>domestica</i>	594108	x	2x	Medaille d'Or	1865
79	<i>Malus</i>	<i>domestica</i>	594111	x	2x	Redfree	
80	<i>Malus</i>	<i>florentina</i>	588868	x	2x		
81	<i>Malus</i>	<i>florentina</i>	589385	x	2x	Skopje P2	
82	<i>Malus</i>	<i>floribunda</i>	589827	x	2x	821	
83	<i>Malus</i>	<i>fusca</i>	589933	x	2x		
84	<i>Malus</i>	<i>fusca</i>	589941	x	2x		
85	<i>Malus</i>	<i>fusca</i>	589975	x	2x		
86	<i>Malus</i>	<i>fusca</i>	594105	x	2x		
87	<i>Malus</i>	<i>halliana</i>	589246	x	3x	Parkman	
88	<i>Malus</i>	<i>halliana</i>	589972	x	3x		
89	<i>Malus</i>	<i>halliana</i>	594112	x	2x		
90	<i>Malus</i>	<i>honganensis</i>	589879	x			
91	<i>Malus</i>	<i>honganensis</i>	594113	x			
92	<i>Malus</i>	<i>hupehensis</i>	589522	x	3x		
93	<i>Malus</i>	Hybrid	437057	x	2x	Roberts Crab	
94	<i>Malus</i>	Hybrid	588804	x	2x	Kansas K14	
95	<i>Malus</i>	Hybrid	588824	x	2x	Almey	
96	<i>Malus</i>	Hybrid	588866	x	2x	Kerr	
97	<i>Malus</i>	Hybrid	588870	x	2x	Dolgo	
98	<i>Malus</i>	Hybrid	588883	x	2x	Demir	
99	<i>Malus</i>	Hybrid	588992	x	2x	White Angel	
100	<i>Malus</i>	Hybrid	589570	x	2x	E36-7	
101	<i>Malus</i>	Hybrid	589572	x	2x	E14-32	
102	<i>Malus</i>	Hybrid	589775	x	2x	PRI 2382-1	
103	<i>Malus</i>	Hybrid	589776	x	2x	PRI 1316-1	
104	<i>Malus</i>	Hybrid	589777	x	2x	PRI 1918-1	
105	<i>Malus</i>	Hybrid	589780	x	2x	PRI 384-1	
106	<i>Malus</i>	Hybrid	589785	x	2x	PRI 1346-2	
107	<i>Malus</i>	Hybrid	589786	x	2x	PRI 77-1	
108	<i>Malus</i>	Hybrid	589789	x	2x	PRI 1744-1	
109	<i>Malus</i>	Hybrid	589790	x	2x	PRI 1484-1	
110	<i>Malus</i>	Hybrid	589791	x	2x	PRI 1279-9	
111	<i>Malus</i>	Hybrid	589792	x	2x	PRI 1850-4	

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Supplemental Table 1. Continued.

Row (no.)	Genus	Species	PI no.	Included in analyses	Ploidy	Cultivar	Year
112	<i>Malus</i>	Hybrid	589795	x	2x	PRI 2482-100	
113	<i>Malus</i>	Hybrid	589805	x	2x	Co-op 15	
114	<i>Malus</i>	Hybrid	589807	x	2x	PRI 1773-6	
115	<i>Malus</i>	Hybrid	589812	x	2x	PRI 2377-1	
116	<i>Malus</i>	Hybrid	589819	x	2x	PRI 2050-2	
117	<i>Malus</i>	Hybrid	589820	x	2x	Prairie Fire	
118	<i>Malus</i>	Hybrid	589824	x	2x	Jonsib Crab	
119	<i>Malus</i>	Hybrid	589829	x	2x	PRI 333-9	
120	<i>Malus</i>	Hybrid	589946	x	2x	PRI 1732-2	
121	<i>Malus</i>	Hybrid	589959	x	2x	MA # 8	
122	<i>Malus</i>	Hybrid	590069	x	2x	E7-47	
123	<i>Malus</i>	Hybrid	590070	x	2x	E7-54	
124	<i>Malus</i>	Hybrid	590071	x	2x	E29-56	
125	<i>Malus</i>	Hybrid	590072	x	2x	E31-10	
126	<i>Malus</i>	Hybrid	590079	x	2x	PRI 1312-6	
127	<i>Malus</i>	Hybrid	590085	x	2x	PRI 1176-1	
128	<i>Malus</i>	<i>ioensis</i>	588991	x	3x	Bechtel Crab	1888
129	<i>Malus</i>	<i>ioensis</i>	589999	x	3x		
130	<i>Malus</i>	<i>ioensis</i>	590008	x	2x		
131	<i>Malus</i>	<i>ioensis</i>	590015	x	2x		
132	<i>Malus</i>	<i>kansuensis</i>	588944	x	2x	Calva	
133	<i>Malus</i>	<i>kansuensis</i>	594097	x	2x		
134	<i>Malus</i>	<i>mandshurica</i>	588753	x	2x		
135	<i>Malus</i>	<i>micromalus</i>	589753	x	2x		
136	<i>Malus</i>	<i>micromalus</i>	589955	x	2x		
137	<i>Malus</i>	<i>micromalus</i>	594093	x	2x		
138	<i>Malus</i>	<i>micromalus</i>	594096	x	2x		
139	<i>Malus</i>	<i>ombrophila</i>	596278	x	2x		
140	<i>Malus</i>	<i>ombrophila</i>	596281	x	2x		
141	<i>Malus</i>	<i>orientalis</i>	594095	x	2x		
142	<i>Malus</i>	<i>orientalis</i>	594101	x	2x		
143	<i>Malus</i>	<i>prattii</i>	588933	x	2x		
144	<i>Malus</i>	<i>prattii</i>	633804	x	2x	CH97 01-26	
145	<i>Malus</i>	<i>prattii</i>	633813	x	2x	CH97 05-03	
146	<i>Malus</i>	<i>prunifolia</i>	589816	x	2x	19651	
147	<i>Malus</i>	<i>prunifolia</i>	589832	x	2x	Xanthocarpa	
148	<i>Malus</i>	<i>prunifolia</i>	589930	x	2x	Nagano	
149	<i>Malus</i>	<i>prunifolia</i>	589932	x	2x	M0-84	
150	<i>Malus</i>	<i>prunifolia</i>	594102	x	2x		
151	<i>Malus</i>	<i>prunifolia</i>	594103	x	2x	Inuringo	
152	<i>Malus</i>	<i>prunifolia</i>	594109	x	2x	Microcarpa	
153	<i>Malus</i>	<i>prunifolia</i>	613845	x	2x		
154	<i>Malus</i>	<i>pumila</i>	323617	x	2x		
155	<i>Malus</i>	<i>pumila</i>	594106	x	2x		
156	<i>Malus</i>	<i>sieversii</i>	589380	x	2x		
157	<i>Malus</i>	<i>sieversii</i>	590043	x	2x		
158	<i>Malus</i>	<i>sieversii</i>	594104	x	2x		
159	<i>Malus</i>	<i>sieversii</i>	596280	x	2x	USSR-89-23-02	
160	<i>Malus</i>	<i>sieversii</i>	596282	x	2x	USSR-89-06-03	
161	<i>Malus</i>	<i>sieversii</i>	596283	x	2x	USSR-89-31-04	
162	<i>Malus</i>	<i>sieversii</i>	613969	x	2x	FORM 181 (35-01)	
163	<i>Malus</i>	<i>sieversii</i>	613976	x	2x	KAZ 95 08-06	
164	<i>Malus</i>	<i>sieversii</i>	613998	x	2x	KAZ 96 08-16	
165	<i>Malus</i>	<i>sieversii</i>	633798	x	2x	KAZ 93-42-01	
166	<i>Malus</i>	sp.	589420	x	2x	M. hartwigii	
167	<i>Malus</i>	sp.	589421	x	2x	M. rockii	

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Supplemental Table 1. Continued.

Row (no.)	Genus	Species	PI no.	Included in analyses	Ploidy	Cultivar	Year
168	<i>Malus</i>	<i>spectabilis</i>	594100	x	2x		
169	<i>Malus</i>	<i>sylvestris</i>	369855	x	2x	GMAL262	
170	<i>Malus</i>	<i>sylvestris</i>	589382	x	2x	GMAL1820	
171	<i>Malus</i>	<i>sylvestris</i>	619168	x	2x	GMAL2524.a	
172	<i>Malus</i>	<i>sylvestris</i>	633824	x	2x	Oberwartha 5 × Klipphausen	
173	<i>Malus</i>	<i>sylvestris</i>	633825	x	2x	Barenhecke 3 × Klipphausen	
174	<i>Malus</i>	<i>sylvestris</i>	633826	x	2x	Oelsen 2 × Hartmann-Muhle 1	
175	<i>Malus</i>	<i>sylvestris</i>	633827	x	2x	Hartmann-Muhle 1 × Oberwartha 2	
176	<i>Malus</i>	<i>toringo</i>	589957	x	2x	MA #1255	
177	<i>Malus</i>	<i>toringo</i>	589958	x	2x	MA #4	
178	<i>Malus</i>	<i>toringo</i>	594094	x	2x		
179	<i>Malus</i>	<i>toringoides</i>	633811	x	3x	GMAL4396	
180	<i>Malus</i>	<i>transitoria</i>	589384	x	2x		
181	<i>Malus</i>	<i>transitoria</i>	589422	x	2x		
182	<i>Malus</i>	<i>tschonoskii</i>	589395	x	2x		
183	<i>Malus</i>	× <i>arnoldiana</i>	589222	x	2x	Arnold Crab	1883
184	<i>Malus</i>	× <i>atrosanguinea</i>	589253	x	2x	Carmine Crab	1869
185	<i>Malus</i>	× <i>dawsoniana</i>	483254	x	2x		
186	<i>Malus</i>	× <i>hartwigii</i>	588757	x	2x		
187	<i>Malus</i>	× <i>magdeburgensis</i>	588959	x	2x	M. spectabiles × M. pumila	
188	<i>Malus</i>	× <i>robusta</i>	588825	x	2x	Robusta 5, A robusta clone	1880
189	<i>Malus</i>	× <i>robusta</i>	589003	x	2x	Korea	
190	<i>Malus</i>	× <i>robusta</i>	589383	x	2x	Persicifolia	
191	<i>Malus</i>	× <i>soulardii</i>	589391	x	2x		
192	<i>Malus</i>	× <i>sublobata</i>	590174	x	2x	Novole	
193	<i>Malus</i>	× <i>zumi</i>	589840	x	2x	Calocarpa	
194	<i>Malus</i>	<i>yunnanensis</i>	271831	x	2x	Vilmorin	
195	<i>Malus</i>	<i>yunnanensis</i>	589399	x	2x		
196	<i>Malus</i>	<i>yunnanensis</i>	589758	x	2x	Veitchii	
197	<i>Malus</i>	<i>zhaojiaoensis</i>	633816	x	2x	CH97 06-02	
198	<i>Malus</i>	<i>zhaojiaoensis</i>	633817	x	2x	CH97 06-07	
199	<i>Malus</i>	<i>coronaria</i>	589996		4x		
200	<i>Malus</i>	<i>domestica</i>	483257			Reinette Simirenko	
201	<i>Malus</i>	<i>domestica</i>	588798			Rambo-Red Summer	
202	<i>Malus</i>	<i>domestica</i>	589024			Crimson Beauty	1880
203	<i>Malus</i>	<i>doumeri</i>	589882				
204	<i>Malus</i>	<i>hupehensis</i>	594098		3x		
205	<i>Malus</i>	<i>hupehensis</i>	613834		4x		
206	<i>Malus</i>	<i>hupehensis</i>	633807		3x		
207	<i>Malus</i>	<i>hupehensis</i>	633812		4x		
208	<i>Malus</i>	<i>hupehensis</i>	633818		3x		
209	<i>Malus</i>	Hybrid	589571		2x	E11-24	
210	<i>Malus</i>	Hybrid	589794		2x	PRI 1754-2	1967
211	<i>Malus</i>	<i>ioensis</i>	596279		5x	Texana	
212	<i>Malus</i>	<i>kansuensis</i>	633809		2x		
213	<i>Malus</i>	<i>kansuensis</i>	633810		2x		
214	<i>Malus</i>	<i>micromalus</i>	594092				
215	<i>Malus</i>	<i>orientalis</i>	633819		2x		
216	<i>Malus</i>	<i>orientalis</i>	633820		2x		
217	<i>Malus</i>	<i>orientalis</i>	633821		2x		
218	<i>Malus</i>	<i>orientalis</i>	633822		2x		
219	<i>Malus</i>	<i>orientalis</i>	633823		2x		
220	<i>Malus</i>	<i>orientalis</i>	633828		2x		
221	<i>Malus</i>	<i>orientalis</i>	633829		2x		
222	<i>Malus</i>	<i>orientalis</i>	633830		2x		
223	<i>Malus</i>	<i>orientalis</i>	633831		2x		

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Supplemental Table 1. Continued.

Row (no.)	Genus	Species	PI no.	Included in analyses	Ploidy	Cultivar	Year
224	<i>Malus</i>	<i>orientalis</i>	633832		2x		
225	<i>Malus</i>	<i>sargentii</i>	588761		4x		
226	<i>Malus</i>	<i>sieversii</i>	613958		2x		
227	<i>Malus</i>	<i>sieversii</i>	613991		2x		
228	<i>Malus</i>	<i>sieversii</i>	613992		2x		
229	<i>Malus</i>	<i>sieversii</i>	613994		2x		
230	<i>Malus</i>	<i>sieversii</i>	614000		2x		
231	<i>Malus</i>	<i>sieversii</i>	633797		2x		
232	<i>Malus</i>	<i>sieversii</i>	633799		2x		
233	<i>Malus</i>	<i>sieversii</i>	633800		2x		
234	<i>Malus</i>	<i>sieversii</i>	633801		2x		
235	<i>Malus</i>	<i>sieversii</i>	633802		2x		
236	<i>Malus</i>	<i>sieversii</i>	633803		2x		
237	<i>Malus</i>	<i>sieversii</i>	633918		2x		
238	<i>Malus</i>	<i>sieversii</i>	633919		2x		
239	<i>Malus</i>	<i>sieversii</i>	633920		2x		
240	<i>Malus</i>	<i>sieversii</i>	633921		2x		
241	<i>Malus</i>	<i>sieversii</i>	633922		2x		
242	<i>Malus</i>	<i>sieversii</i>	633923		2x		
243	<i>Malus</i>	<i>sieversii</i>	637780		2x		
244	<i>Malus</i>	<i>sikkimensis</i>	589390		3x		
245	<i>Malus</i>	<i>sikkimensis</i>	589834		3x		
246	<i>Malus</i>	<i>spectabilis</i>	613836				
247	<i>Malus</i>	<i>toringo</i>	589749		3x		
248	<i>Malus</i>	<i>toringo</i>	613806		3x		
249	<i>Malus</i>	<i>toringo</i>	633814		3x		
250	<i>Malus</i>	<i>toringo</i>	633815		3x		
251	<i>Malus</i>	<i>toringoides</i>	588930		4x	Macrocarpa	
252	<i>Malus</i>	<i>toringoides</i>	589393		3x		
253	<i>Malus</i>	<i>toringoides</i>	633808		5x		
254	<i>Malus</i>	<i>transitoria</i>	633805		3x		
255	<i>Malus</i>	<i>transitoria</i>	633806		3x		
256	<i>Malus</i>	<i>trilobata</i>	589397				
257	<i>Malus</i>	× <i>platycarpa</i>	589415		4x	Hoopesii	
258	<i>Malus</i>	× <i>sublobata</i>	588922		2x	Yellow Autumn Crab	1892
Row (no.)	Country of origin	Flesh color	Flesh flavor	Flesh firmness	Flesh oxidation	Fruit ground color	Fruit overcolor
1	United States	Green	Astringent	Hard	Very oxidizing	Green	None
2	United States	Cream	Subacid	Soft	Oxidizing	Green	Red
3	China	Cream	Acid	Firm	Very oxidizing	Green	Dark red
4	China	Cream	Aromatic	Soft	Very oxidizing	Green	Dark red
5	China	White	Subacid	Semifirm	Oxidizing	Light yellow	Green
6	China	Cream	Acid	Firm	Oxidizing	Light yellow	Red
7	China	Yellow	Astringent	Firm	Very oxidizing	Orange	Red
8	Former Soviet Union	Yellow	Acid	Firm	Very oxidizing	Yellow	Red
9	United Kingdom	Yellow	Astringent	Soft	Slightly oxidizing	Yellow	Red
10	China	Yellow	Astringent	Hard	Oxidizing	Yellow	Dark red
11	Former Soviet Union	Yellow	Astringent	Hard	Very oxidizing	Yellow	Red
12	Korea	Yellow	Astringent	Hard	Very oxidizing	Light yellow	Dark red
13	United States	Orange	Acid	Firm	Very oxidizing	Yellow	Red
14	Canada	Cream	Acid	Hard	Very oxidizing	Green	None
15	United States	Green	Acid	Hard	Very oxidizing	Green	None
16	Ireland	Cream	Sweet	Semifirm	Very oxidizing	Green	Red
17	Romania	Cream	Subacid	Hard	Slightly oxidizing	Green	Red
18	Canada	Cream	Aromatic	Firm	Slightly oxidizing	Green	Red
19	Netherlands	Cream	Aromatic	Firm	Slightly oxidizing	Green	Dark red
20	United Kingdom	Cream	Sweet	Soft	Non-oxidizing	Green	Red

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Supplemental Table 1. Continued.

Row (no.)	Country of origin	Flesh color	Flesh flavor	Flesh firmness	Flesh oxidation	Fruit ground color	Fruit overcolor
21	Israel	Cream	Aromatic	Firm	Very oxidizing	Green	Dark red
22	Israel	Cream	Aromatic	Firm	Very oxidizing	Pink	Yellow
23	Former Soviet Union	Cream	Aromatic	Firm	Non-oxidizing	Green	Red
24	New Zealand	Yellow	Sweet	Firm	Very oxidizing	Green	Red
25	France	Cream	Aromatic	Firm	Slightly oxidizing	Green	Dark red
26	United States	White	Aromatic	Firm	Oxidizing	Green	Red
27	United States	Cream	Aromatic	Firm	Slightly oxidizing	Green	Brown
28	United States	Cream	Acid	Hard	Non-oxidizing	Green	Red
29	United Kingdom	White	Aromatic	Firm	Oxidizing	Green	Red
30	United States	Cream	Sweet	Soft	Very oxidizing	Green	Dark red
31	Denmark	Cream	Aromatic	Semifirm	Very oxidizing	Green	Dark red
32	Canada	White	Aromatic	Semifirm	Very oxidizing	Green	Red
33	United States	White	Sweet	Firm	Oxidizing	Green	Red
34	United States	Cream	Aromatic	Firm	Non-oxidizing	Green	Dark red
35	Japan	Cream	Aromatic	Firm		Light green	Red
36	United States	White	Acid	Hard	Oxidizing	Green	Dark red
37	Europe	Green	Astringent	Hard	Very oxidizing	Green	Orange
38	United States	Cream	Aromatic	Semifirm	Very oxidizing	Green	Dark red
39	United Kingdom	Cream	Aromatic	Firm	Slightly oxidizing	Green	Red
40	Russia	Cream	Subacid	Soft	Very oxidizing	Light green	Yellow
41	United States	Cream	Aromatic	Semifirm	Slightly oxidizing	Yellow	Red
42	Australia	Cream	Acid	Hard	Oxidizing	Green	Red
43	United States	White	Aromatic	Semifirm	Very oxidizing	Green	Dark red
44	United States	Cream	Sweet	Semifirm	Oxidizing	Green	Dark red
45	United States	Cream	Sweet	Firm	Slightly oxidizing	Light yellow	Red
46	Ukraine	Cream	Aromatic	Soft	Non-oxidizing	Orange	Green
47	United States	White	Aromatic	Firm	Slightly oxidizing	Green	Dark red
48	United States	Cream	Acid	Hard	Oxidizing	Green	Red
49	France	Cream	Acid	Hard	Oxidizing	Green	Red
50	United States	Cream	Subacid	Firm	Slightly oxidizing	Green	Red
51	United States	Cream	Aromatic	Firm	Very oxidizing	Green	Red
52	United States	Cream	Aromatic	Firm	Oxidizing	Green	Dark red
53	United States	Green	Acid	Hard	Very oxidizing	Green	None
54	United States	Cream	Aromatic	Soft	Very oxidizing	Green	Dark red
55	Germany	Cream	Acid	Semifirm	Non-oxidizing	Yellow	Red
56	United States	Cream	Aromatic	Firm	Oxidizing	Green	Red
57	Former Soviet Union	Cream	Sweet	Firm	Very oxidizing	Light green	Purple
58	Canada	White	Aromatic	Soft	Very oxidizing	Green	Red
59	Canada	Cream	Aromatic	Firm	Oxidizing	Green	Red
60	Former Soviet Union	Cream	Subacid	Firm	Non-oxidizing	Green	Red
61	United States	Cream	Subacid	Firm	Oxidizing	Green	Yellow
62	France	Cream	Aromatic	Semifirm	Non-oxidizing	Green	Red
63	United Kingdom	White	Acid	Hard	Very oxidizing	Green	Red
64	United Kingdom	Cream	Aromatic	Firm	Very oxidizing	Green	Orange
65	Canada	White	Sweet	Firm	Very oxidizing	Green	Pink
66	United States	Cream	Subacid	Semifirm	Oxidizing	Light green	Pink
67	United States	Cream	Aromatic	Soft	Oxidizing	Green	Dark red
68	United States	Green	Sweet	Firm	Non-oxidizing	Light green	Red
69	Bahamas	Yellow	Aromatic	Firm	Oxidizing	Green	Red
70	United States	White	Aromatic	Semifirm	Slightly oxidizing	Green	Orange
71	United States	Cream	Aromatic	Firm	Very oxidizing	Green	Red
72	United States	White	Aromatic	Soft	Non-oxidizing	Light green	Pink
73	United States	Cream	Aromatic	Firm	Slightly oxidizing	Green	Orange
74	United States	Cream	Sweet	Soft	Very oxidizing	Green	Dark red
75	United States	Cream	Sweet	Firm	Non-oxidizing	Green	Orange
76	United States	Cream	Aromatic	Firm	Oxidizing	Green	Red
77	Canada	Cream	Subacid	Firm	Very oxidizing	Green	Red

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Supplemental Table 1. Continued.

Row (no.)	Country of origin	Flesh color	Flesh flavor	Flesh firmness	Flesh oxidation	Fruit ground color	Fruit overcolor
78	France	Cream	Subacid	Soft	Very oxidizing	Brown	Green
79	United States	White	Aromatic	Firm	Non-oxidizing	Light green	Red
80	Canada	Yellow	Astringent	Hard	Slightly oxidizing	Yellow	Brown
81	United Kingdom	Yellow	Astringent	Firm	Very oxidizing	Green	Red
82	Japan	Yellow	Astringent	Firm	Slightly oxidizing	Yellow	Brown
83	United States	Yellow	Subacid	Hard	Oxidizing	Green	Brown
84	United States	Yellow	Acid	Hard	Oxidizing	Green	Brown
85	United States	Green	Astringent	Hard	Non-oxidizing	Green	Brown
86	United States	Cream	Acid	Semifirm	Oxidizing	Light yellow	Brown
87	Japan						
88	United States	Yellow	Astringent	Semifirm	Oxidizing	Yellow	Purple
89	China	Cream	Astringent	Hard	Oxidizing	Yellow	Dark red
90	China	Cream	Astringent	Hard	Non-oxidizing	Light yellow	Red
91	China	Cream	Acid	Semifirm	Non-oxidizing	Light yellow	Red
92	Canada	Yellow	Astringent	Hard	Very oxidizing	Green	Yellow
93	United Kingdom	Red	Acid	Firm	Non-oxidizing	Purple	None
94	United States	White	Aromatic	Hard	Very oxidizing	Green	Red
95	Canada	Yellow	Astringent	Hard	Oxidizing	Orange	Red
96	Canada	Cream	Aromatic	Semifirm	Very oxidizing	Brown	Purple
97	Former Soviet Union	Yellow	Acid	Hard	Very oxidizing	Orange	Dark red
98	Turkey	Cream	Acid	Firm	Slightly oxidizing	Green	Red
99	United States	Yellow	Acid	Hard	Oxidizing	Red	None
100	United States	Cream	Subacid	Hard	Slightly oxidizing	Green	Dark red
101	United States	Cream	Aromatic	Soft	Oxidizing	Green	Dark red
102	United States	Cream	Sweet	Semifirm	Very oxidizing	Green	Red
103	United States	Cream	Sweet	Firm	Very oxidizing	Green	Red
104	United States	Green	Acid	Firm	Very oxidizing	Green	Purple
105	United States	Cream	Aromatic	Firm	Very oxidizing	Light green	Red
106	United States	Cream	Aromatic	Hard	Non-oxidizing	Green	Yellow
107	United States	Cream	Subacid	Soft	Very oxidizing	Light yellow	Dark red
108	United States	Cream	Acid	Semifirm	Very oxidizing	Green	Red
109	United States	Cream	Aromatic	Firm	Very oxidizing	Green	Yellow
110	United States	Cream	Aromatic	Soft	Oxidizing	Orange	Red
111	United States	Cream	Aromatic	Semifirm	Very oxidizing	Light green	Red
112	United States	White	Sweet	Firm	Oxidizing	Green	Red
113	United States	Cream	Aromatic	Firm	Oxidizing	Light green	Red
114	United States	White	Subacid	Firm	Very oxidizing	Green	Red
115	United States	Cream	Aromatic	Soft	Slightly oxidizing	Green	Red
116	United States	White	Aromatic	Firm	Non-oxidizing	Light yellow	Orange
117	United States	Red	Acid	Hard		Red	None
118	United States	Cream	Aromatic	Firm	Very oxidizing	Green	Red
119	United States	Cream	Aromatic	Soft	Slightly oxidizing	Green	Dark red
120	United States	Green	Aromatic	Semifirm	Very oxidizing	Green	Purple
121	United States	Yellow	Astringent	Semifirm	Slightly oxidizing	Yellow	Red
122	United States	Cream	Aromatic	Firm	Oxidizing	Green	Dark red
123	United States	Cream	Aromatic	Semifirm	Oxidizing	Green	Dark red
124	United States	Cream	Sweet	Soft	Slightly oxidizing	Light yellow	Dark red
125	United States	White	Subacid	Firm	Oxidizing	Green	Red
126	United States	Cream	Aromatic	Semifirm	Oxidizing	Red	None
127	United States	Cream	Aromatic	Hard		Green	Red
128	United States	White	Acid	Hard		Green	None
129	United States	White	Astringent	Hard	Very oxidizing	Green	Orange
130	United States	Cream	Astringent	Hard	Very oxidizing	Green	None
131	United States	Cream	Astringent	Hard	Very oxidizing	Green	None
132	United States	Yellow	Astringent	Firm	Slightly oxidizing	Yellow	None
133	China	Cream	Astringent	Hard	Oxidizing	Light yellow	Orange
134	United States	Yellow	Subacid	Soft	Very oxidizing	Yellow	Red

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Supplemental Table 1. Continued.

Row (no.)	Country of origin	Flesh color	Flesh flavor	Flesh firmness	Flesh oxidation	Fruit ground color	Fruit overcolor
135	United States	Cream	Subacid	Semifirm	Very oxidizing	Green	Orange
136	United States	Cream	Acid	Soft	Slightly oxidizing	Green	Orange
137	United States	Yellow	Astringent	Hard	Very oxidizing	Yellow	Red
138	United States	Yellow	Astringent	Hard	Oxidizing	Yellow	Red
139	China						
140	China	Cream	Astringent	Firm	Very oxidizing	Light yellow	Brown
141	Former Soviet Union	Cream	Acid	Semifirm	Non-oxidizing	Light green	Yellow
142	Turkey	Cream	Aromatic	Soft	Very oxidizing	Green	Yellow
143	United States	Cream	Acid	Hard	Slightly oxidizing	Green	Orange
144	China	Yellow	Astringent	Hard	Slightly oxidizing	Light yellow	
145	China						
146	United States	Cream	Acid	Hard	Oxidizing	Green	Yellow
147	United States	Cream	Subacid	Semifirm		Yellow	Orange
148	Japan	Yellow	Astringent	Semifirm	Very oxidizing	Green	None
149	Japan						
150	Ukraine	Cream	Acid	Firm	Slightly oxidizing	Green	Red
151	Japan	Yellow	Astringent	Hard	Slightly oxidizing	Yellow	Orange
152	United States	Cream	Aromatic	Soft	Slightly oxidizing	Light green	Yellow
153	Ukraine	Yellow	Acid	Soft	Slightly oxidizing	Yellow	Orange
154	Afghanistan	White	Subacid	Semifirm	Very oxidizing	Yellow	Green
155	China	Cream	Aromatic	Soft	Oxidizing	Green	Red
156	United States	Cream	Subacid	Soft	Very oxidizing	Green	Yellow
157	Former Soviet Union	Cream	Subacid	Soft	Very oxidizing	Green	Yellow
158	Kazakhstan	Cream	Subacid	Soft	Very oxidizing	Red	Green
159	Uzbekistan	Cream	Aromatic	Semifirm	Very oxidizing	Green	None
160	Tajikistan						
161	Kazakhstan	Cream	Acid	Soft	Slightly oxidizing	Green	Pink
162	Kazakhstan	White	Sweet	Soft	Slightly oxidizing	Green	Red
163	Kazakhstan	Cream	Subacid	Semifirm	Oxidizing	Light green	Red
164	Kazakhstan	Cream	Aromatic	Firm		Green	Pink
165	Kyrgyzstan	Cream	Acid	Soft	Very oxidizing	Green	Pink
166	United States	Yellow	Astringent	Firm	Slightly oxidizing	Green	Brown
167	United States	Yellow	Astringent	Firm	Oxidizing	Yellow	Red
168	China	Yellow	Astringent	Semifirm	Very oxidizing	Yellow	Brown
169	Macedonia	White	Acid	Firm	Very oxidizing	Green	Brown
170	United Kingdom	Green	Acid	Semifirm	Very oxidizing	Light yellow	Green
171	Macedonia	Cream	Aromatic	Semifirm	Non-oxidizing	Green	
172	Germany	Cream	Astringent	Firm	Non-oxidizing	Light green	Yellow
173	Germany	Yellow	Subacid	Firm	Non-oxidizing	Green	Red
174	Germany	Cream	Astringent	Semifirm	Very oxidizing	Green	Orange
175	Germany						
176	United States	Yellow	Astringent	Hard	Non-oxidizing	Light yellow	Brown
177	United States	Yellow	Astringent	Firm	Very oxidizing	Light yellow	Red
178	Latvia	Cream	Astringent	Hard	Oxidizing	Green	Yellow
179	China						
180	United Kingdom	Yellow	Astringent	Hard	Oxidizing	Yellow	Red
181	United States	Yellow	Astringent	Hard	Slightly oxidizing	Green	Red
182	United Kingdom	Green	Astringent	Firm	Very oxidizing	Green	Red
183	United States	Yellow	Astringent	Hard	Very oxidizing	Yellow	Brown
184	United States	Yellow	Astringent	Hard	Oxidizing	Green	Red
185	France	Cream	Acid	Semifirm	Very oxidizing	Green	Orange
186	United States	Yellow	Acid	Hard	Very oxidizing	Green	Red
187	Germany	Yellow	Astringent	Hard	Slightly oxidizing	Light yellow	Dark red
188	Canada	Yellow	Astringent	Semifirm	Very oxidizing	Green	Orange
189	United States	Yellow	Astringent	Hard	Very oxidizing	Yellow	Red
190	United Kingdom	Cream	Acid	Hard	Very oxidizing	Light yellow	Dark red
191	United Kingdom	White	Acid	Hard	Very oxidizing	Green	Brown

Continued next page

Supplemental Table 1. Continued.

Row (no.)	Country of origin	Flesh color	Flesh flavor	Flesh firmness	Flesh oxidation	Fruit ground color	Fruit overcolor
192	United States	Yellow	Astringent	Firm	Oxidizing	Red	None
193	United States	Cream	Astringent	Firm	Slightly oxidizing	Red	None
194	China	Green	Acid	Hard	Very oxidizing	Green	Brown
195	United Kingdom	Yellow	Acid	Firm	Very oxidizing	Green	Brown
196	China	Yellow	Astringent	Hard	Very oxidizing	Yellow	Red
197	China	Yellow	Acid	Semifirm	Very oxidizing	Pink	Dark red
198	China						
199	United States	Green	Astringent	Hard	Very oxidizing	Green	Orange
200	Former Soviet Union	Cream	Subacid	Firm	Slightly oxidizing	Green	Orange
201	United States	Cream	Aromatic	Semifirm	Oxidizing	Green	Red
202	United States	Cream	Sweet	Soft	Non-oxidizing	Light yellow	
203	Taiwan						
204	China	Yellow	Astringent	Hard	Very oxidizing	Light yellow	Red
205	China	Yellow	Astringent	Semifirm	Very oxidizing	Orange	Pink
206	China	Orange	Astringent	Semifirm	Very oxidizing	Orange	Purple
207	China	Yellow	Astringent	Firm	Very oxidizing	Orange	Purple
208	China	Green	Astringent	Firm	Very oxidizing	Light yellow	Red
209	United States	White	Sweet	Semifirm	Very oxidizing	Green	Red
210	United States	Cream	Aromatic	Semifirm	Slightly oxidizing	Light yellow	Red
211	United States	Green	Astringent	Hard	Very oxidizing	Green	Brown
212	China	Cream	Astringent	Hard	Non-oxidizing	Pink	Brown
213	China						
214	United States	Yellow	Acid	Hard	Oxidizing	Yellow	Orange
215	Former Soviet Union	Cream	Astringent	Semifirm	Very oxidizing	Light green	Yellow
216	Former Soviet Union	White	Astringent	Firm	Non-oxidizing	Light green	Brown
217	Former Soviet Union	Cream	Astringent	Firm	Very oxidizing	Green	Yellow
218	Former Soviet Union	White	Astringent	Semifirm	Non-oxidizing	Green	Orange
219	Former Soviet Union						
220	Turkey						
221	Turkey						
222	Turkey	White	Astringent	Semifirm	Non-oxidizing	Green	Red
223	Turkey	White	Astringent	Firm	Non-oxidizing	Green	Yellow
224	Turkey	Cream	Acid	Firm	Very oxidizing	Green	Yellow
225	United States	Yellow	Astringent	Hard	Non-oxidizing	Red	Dark red
226	Kazakhstan	White	Subacid	Semifirm	Very oxidizing	Green	Red
227	Kazakhstan	Cream			Very oxidizing	Light green	Pink
228	Kazakhstan	Cream	Acid	Soft	Oxidizing	Green	Yellow
229	Kazakhstan	Cream	Subacid	Semifirm	Very oxidizing	Light green	Brown
230	Kazakhstan	Cream	Subacid	Semifirm	Slightly oxidizing	Light green	Pink
231	Kazakhstan	Cream	Subacid	Semifirm	Very oxidizing		Red
232	Kazakhstan	White	Astringent	Semifirm	Very oxidizing	Light green	Red
233	Kazakhstan	Cream	Astringent	Semifirm	Very oxidizing	Green	Red
234	Kazakhstan	Cream		Firm	Oxidizing	Green	Red
235	Kazakhstan	Cream	Subacid	Semifirm	Very oxidizing	Light green	Pink
236	Kazakhstan	Green	Subacid	Semifirm	Very oxidizing	Green	Red
237	Kazakhstan	Red	Astringent	Semifirm	Slightly oxidizing	Red	None
238	Kazakhstan	Cream	Subacid	Semifirm	Very oxidizing	Light yellow	Red
239	Kazakhstan	Cream	Astringent	Semifirm	Very oxidizing	Green	Red
240	Kazakhstan	Cream	Sweet	Firm	Very oxidizing	Green	Red
241	Kazakhstan	White	Subacid	Soft	Very oxidizing	Light green	Red
242	Kazakhstan	White	Astringent	Firm	Very oxidizing	Light green	Yellow
243	Kazakhstan						
244	United Kingdom	Yellow	Astringent	Hard	Very oxidizing	Green	Dark red
245	United States	Yellow	Astringent	Firm	Very oxidizing	Yellow	Red
246	China						
247	United States	Yellow	Astringent	Hard	Slightly oxidizing	Red	None
248	United States	Cream	Astringent	Semifirm	Very oxidizing	Orange	Red

Continued next page

Supplemental Table 1. Continued.

Row (no.)	Country of origin	Flesh color	Flesh flavor	Flesh firmness	Flesh oxidation	Fruit ground color	Fruit overcolor
249	China	Yellow	Astringent	Soft	Very oxidizing	Red	Red
250	China	Green	Astringent	Hard	Non-oxidizing	Orange	Red
251	United States	Yellow	Astringent	Firm	Very oxidizing	Yellow	Orange
252	United Kingdom	Yellow	Astringent	Firm	Very oxidizing	Light yellow	Red
253	China	Orange	Acid	Firm	Oxidizing	Orange	Red
254	China						
255	China						
256	United Kingdom						
257	United States	White	Acid	Hard	Very oxidizing	Green	Orange
258	Japan	Yellow	Acid	Firm	Very oxidizing	Green	Orange
Row (no.)	Fruit surface with russet (%)	Fruit wt (g)	Fruit juiciness	Fruit shape	Overcolor on fruit (%)	Fruit overcolor pattern	Soluble solids (%)
1	0–11	<200–2500	very juicy	Flat			12.2–15.9
2	0–11	<200–2500		Globose	66–77	Splashed	8.4–12.2
3		<200–2500		Globose	77–88	Blush	
4	0–11	>400		Flat	66–77	Blush	8.4–12.2
5	0–11	<200–2500		Globose	66–77	Blush	8.4–12.2
6	0–11	<200–2500	Very juicy	Ellipsoid	88–99	Striped	8.4–12.2
7		<200–2500		Flat	66–77	Blush	
8		<200–2500		Flat	77–88	Striped	19.7–23.5
9		<200–2500		Ellipsoid	55–66	Blush	
10		<200–2500		Globose	88–99	Blush	
11	0–11	<200–2500		Globose	88–99	Splashed	15.9–19.7
12		<200–2500		Flat	77–88	Blush	
13		<200–2500		Flat	55–66	Blush	19.7–23.5
14	0–11	<200–2500		Flat	0–11	None	12.2–15.9
15	0–11	<200–2500		Flat			12.2–15.9
16		200–2500–100		Conical	66–77	Splashed	15.9–19.7
17	0–11	1200–2500–200		Globose	44–55	Blush	12.2–15.9
18	0–11	100–1200–2500		Globose	88–99	Splashed	15.9–19.7
19	0–11	1200–2500–200		Conical	77–88	Blush	8.4–12.2
20		>400		Globose	66–77	Blush	8.4–12.2
21		>400		Conical	66–77	Splashed	8.4–12.2
22	0–11	>400		Conical	88–99	Blush	8.4–12.2
23	0–11	100–1200–2500		Globose	33–44	Blush	12.2–15.9
24	0–11	<200–2500		Conical	66–77	Splashed	12.2–15.9
25	0–11	>400		Conical	88–99	Splashed	12.2–15.9
26	0–11	>400		Globose	77–88	Splashed	8.4–12.2
27	0–11	>400		Globose	22–33	Blush	12.2–15.9
28	0–11	>400		Globose	77–88	Blush	12.2–15.9
29	0–11	>400		Globose	66–77	Splashed	8.4–12.2
30		>400		Globose	88–99	Blush	8.4–12.2
31	0–11	>400		Conical	88–99	Blush	12.2–15.9
32		100–1200–2500		Globose	88–99	Blush	12.2–15.9
33	0–11	>400		Globose	77–88	Splashed	8.4–12.2
34		>400		Globose	88–99	Blush	12.2–15.9
35		>400		Globose	44–55	Striped	12.2–15.9
36		>400		Globose	77–88	Blush	12.2–15.9
37	0–11	<200–2500		Flat	0–11	Blush	12.2–15.9
38	0–11	>400		Globose	88–99	Blush	8.4–12.2
39	0–11	>400		Globose	55–66	Splashed	8.4–12.2
40	0–11	<200–2500		Globose	66–77	Blush	8.4–12.2
41	0–11	200–250		Conical	77–88	Splashed	12.2–15.9
42		>400		Globose	33–44	Blush	8.4–12.2
43		>400		Globose	88–99	Blush	12.2–15.9
44	0–11	250–300		Conical	88–99	Splashed	12.2–15.9
45		>400		Conical	77–88	Splashed	12.2–15.9

Continued next page

Supplemental Table 1. Continued.

Row (no.)	Fruit surface with russet (%)	Fruit wt (g)	Fruit juiciness	Fruit shape	Overcolor on fruit (%)	Fruit overcolor pattern	Soluble solids (%)
46	0-11	>400		Globose	77-88	Blush	12.2-15.9
47		>400		Globose	88-99	Blush	12.2-15.9
48	0-11	350-400		Conical	77-88	Blush	12.2-15.9
49	0-11	<200-2500		Flat	55-66	Splashed	12.2-15.9
50	0-11	200-250		Flat	66-77	Blush	12.2-15.9
51	0-11	>400		Globose	77-88	Splashed	8.4-12.2
52		1200-2500-200		Conical	88-99	Blush	12.2-15.9
53	0-11	<200-2500		Flat			8.4-12.2
54		>400		Globose	88-99	Blush	12.2-15.9
55	0-11	>400		Globose	66-77	Splashed	12.2-15.9
56	0-11	>400		Globose	88-99	Striped	12.2-15.9
57	0-11	<200-2500		Globose	55-66	Blush	12.2-15.9
58		>400		Globose	88-99	Blush	12.2-15.9
59	0-11	>400		Conical	88-99	Splashed	15.9-19.7
60	0-11	100-1200-2500		Globose	44-55	Splashed	8.4-12.2
61		1200-2500-200		Conical	33-44	Blush	12.2-15.9
62	11-22	1200-2500-200		Conical	22-33	Blush	12.2-15.9
63	0-11	>400		Globose	44-55	Blush	8.4-12.2
64	11-22	>400		Conical	33-44	Blush	12.2-15.9
65	0-11	200-250	Dry	Oblong	66-77	Blush	8.4-12.2
66	0-11	100-1200-2500	Medium	Oblong	44-55	Striped	8.4-12.2
67	0-11	1200-2500-200		Globose	88-99	Blush	12.2-15.9
68	0-11	>400		Globose	77-88	Splashed	12.2-15.9
69	0-11	200-2500-100		Conical	55-66	Blush	12.2-15.9
70	0-11	>400		Conical	55-66	Blush	8.4-12.2
71		>400		Globose	88-99	Splashed	8.4-12.2
72	0-11	>400		Globose	55-66	Striped	12.2-15.9
73	0-11	250-300		Conical	88-99	Splashed	15.9-19.7
74	0-11	>400		Globose	88-99	Blush	8.4-12.2
75	11-22	>400		Globose	22-33	Splashed	12.2-15.9
76	0-11	>400		Globose	88-99	Blush	12.2-15.9
77	0-11	200-2500-100		Globose	44-55	Blush	12.2-15.9
78	11-22	<200-2500		Globose	66-77	Blush	12.2-15.9
79		>400		Globose	77-88	Blush	8.4-12.2
80	0-11	<200-2500		Globose	22-33	Blush	23.5-27.2
81		<200-2500		Ellipsoid	33-44	Blush	27.2-31.0
82	11-22	<200-2500		Globose	11-22	Blush	23.5-27.2
83		<200-2500		Ellipsoid	55-66	Blush	12.2-15.9
84		<200-2500		Ellipsoid	66-77	Blush	15.9-19.7
85	0-11	<200-2500		Oblong	55-66	Blush	15.9-19.7
86		<200-2500		Oblong	44-55	Blush	15.9-19.7
87							
88	0-11	<200-2500	Very juicy	Flat	88-99	Blush	19.7-23.5
89		<200-2500		Globose	66-77	Blush	
90		<200-2500		Flat	77-88	Blush	19.7-23.5
91		<200-2500		Globose	88-99	Blush	
92		<200-2500		Flat	33-44	Blush	19.7-23.5
93	0-11	200-2500-100		Globose	0-11		12.2-15.9
94	0-11	>400		Globose	55-66	Splashed	8.4-12.2
95		<200-2500		Ellipsoid	77-88	Blush	19.7-23.5
96	0-11	>400		Flat	77-88	Striped	8.4-12.2
97	0-11	<200-2500		Globose	77-88	Blush	15.9-19.7
98		200-2500-100		Globose	55-66	Blush	12.2-15.9
99	0-11	<200-2500		Flat	0-11	None	19.7-23.5
100	0-11	100-1200-2500		Globose	88-99	Blush	15.9-19.7
101		>400		Globose	66-77	Blush	12.2-15.9

Continued next page

Supplemental Table 1. Continued.

Row (no.)	Fruit surface with russet (%)	Fruit wt (g)	Fruit juiciness	Fruit shape	Overcolor on fruit (%)	Fruit overcolor pattern	Soluble solids (%)
102	0–11	>400		Conical	77–88	Blush	8.4–12.2
103		>400		Conical	66–77	Splashed	8.4–12.2
104	0–11	>400		Conical	66–77	Splashed	8.4–12.2
105		>400		Globose	33–44	Blush	12.2–15.9
106	0–11	>400		Globose	77–88	Blush	12.2–15.9
107	0–11	<200–2500		Flat	88–99	Blush	
108	0–11	>400		Globose	55–66	Striped	8.4–12.2
109		>400		Conical	33–44	Blush	8.4–12.2
110		>400		Globose	66–77	Blush	12.2–15.9
111	0–11	>400		Globose	66–77	Splashed	12.2–15.9
112	0–11	>400		Conical	66–77	Blush	8.4–12.2
113		>400		Globose	88–99	Blush	12.2–15.9
114	0–11	100–1200–2500		Globose	66–77	Blush	12.2–15.9
115		>400		Globose	88–99	Blush	8.4–12.2
116	0–11	>400		Globose	33–44	Splashed	8.4–12.2
117		<200–2500		Flat	0–11	None	23.5–27.2
118	0–11	>400		Globose	88–99	Splashed	8.4–12.2
119	0–11	>400		Globose	88–99	Blush	12.2–15.9
120		>400		Globose	77–88	Splashed	8.4–12.2
121	0–11	<200–2500		Globose	77–88	Blush	27.2–31.0
122	0–11	>400		Globose	88–99	Blush	12.2–15.9
123		100–1200–2500		Globose	88–99	Blush	12.2–15.9
124		>400		Globose	88–99	Splashed	8.4–12.2
125	0–11	>400		Globose	77–88	Blush	8.4–12.2
126		>400		Conical	0–11	None	12.2–15.9
127		>400		Globose	88–99	Splashed	8.4–12.2
128				Flat			
129		<200–2500		Flat	33–44	Blush	12.2–15.9
130		<200–2500		Flat			12.2–15.9
131		<200–2500		Globose			12.2–15.9
132	0–11	<200–2500		Globose	0–11	None	
133		<200–2500		Ellipsoid	22–33	Blush	15.9–19.7
134	0–11	<200–2500		Flat	77–88	Splashed	
135		<200–2500		Flat	33–44	Blush	15.9–19.7
136		<200–2500		Flat	11–22	Blush	15.9–19.7
137		<200–2500		Flat	66–77	Blush	27.2–31.0
138		<200–2500		Flat	88–99	Blush	
139							
140	0–11	<200–2500	Very juicy	Ellipsoid	77–88	Blush	19.7–23.5
141		<200–2500		Globose	88–99	Blush	8.4–12.2
142		<200–2500		Globose	66–77	Blush	
143	0–11	<200–2500		Globose	33–44	Blush	
144	55–66	<200–2500	Very juicy	Globose	88–99	Blush	19.7–23.5
145							
146		<200–2500		Globose	88–99	Blush	15.9–19.7
147		<200–2500		Globose	33–44	Blush	
148		<200–2500		Globose	0–11	Blush	12.2–15.9
149							
150	0–11	<200–2500		Globose	66–77	Blush	12.2–15.9
151	0–11	200–2500–100		Globose	11–22	Blush	
152	0–11	<200–2500		Flat	88–99	Blush	
153	0–11	<200–2500		Globose	44–55	Splashed	15.9–19.7
154		<200–2500		Flat	77–88	Blush	8.4–12.2
155		>400		Conical	66–77	Splashed	
156	0–11	<200–2500		Globose	77–88	Blush	8.4–12.2
157	0–11	<200–2500		Globose	66–77	Blush	

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Supplemental Table 1. Continued.

Row (no.)	Fruit surface with russet (%)	Fruit wt (g)	Fruit juiciness	Fruit shape	Overcolor on fruit (%)	Fruit overcolor pattern	Soluble solids (%)
158	0-11	<200-2500		Globose	66-77	Blush	12.2-15.9
159	0-11	200-2500-100	Medium	Flat			8.4-12.2
160							
161	0-11	<200-2500	Dry	Ellipsoid	0-11	Blush	8.4-12.2
162	0-11	200-2500-100	Very dry	Flat	88-99	Blush	8.4-12.2
163	0-11	200-2500-100	Very dry	Globose	55-66	Striped	12.2-15.9
164				Globose	33-44	Blush	
165	0-11	<200-2500	Very dry	Globose	0-11	Striped	8.4-12.2
166		<200-2500		Globose	88-99	Blush	
167		<200-2500		Flat	88-99	Blush	27.2-31.0
168		<200-2500		Globose	55-66	Blush	23.5-27.2
169		<200-2500		Flat	0-11	Blush	8.4-12.2
170	11-22	>400		Globose	88-99	Blush	
171							
172	0-11	<200-2500	Medium	Flat	77-88	Blush	12.2-15.9
173	0-11	<200-2500	Mod. Juicy	Flat	11-22	Blush	12.2-15.9
174	0-11	<200-2500	Dry	Flat	11-22	Splashed	8.4-12.2
175							
176	0-11	<200-2500	Very juicy	Globose	66-77	Blush	
177		<200-2500		Globose	88-99	Blush	
178		<200-2500		Flat	44-55	Blush	
179							
180		<200-2500		Globose	55-66	Blush	
181		<200-2500		Globose	77-88	Blush	
182	0-11	<200-2500	Very juicy	Flat	44-55	Blush	23.5-27.2
183	0-11	<200-2500		Globose	44-55	Blush	27.2-31.0
184	0-11	<200-2500		Globose	66-77	Blush	19.7-23.5
185	0-11	<200-2500		Ellipsoid	33-44	Blush	8.4-12.2
186		<200-2500		Globose	66-77	Splashed	23.5-27.2
187		<200-2500		Flat	88-99	Blush	
188		<200-2500	Very juicy	Ellipsoid	22-33	Blush	
189	0-11	<200-2500		Flat	55-66	Blush	23.5-27.2
190		<200-2500		Globose	88-99	Blush	19.7-23.5
191		<200-2500		Globose	0-11	Blush	8.4-12.2
192		<200-2500		Flat	0-11	None	23.5-27.2
193		<200-2500		Globose	0-11	None	
194	0-11	<200-2500		Oblong	88-99	Blush	19.7-23.5
195	0-11	<200-2500		Globose	33-44	Blush	23.5-27.2
196	0-11	<200-2500		Flat	66-77	Blush	23.5-27.2
197	0-11	<200-2500	Very juicy	Flat	77-88	Blush	23.5-27.2
198							
199		<200-2500		Flat	33-44	Blush	12.2-15.9
200		100-1200-2500		Globose	11-22	Blush	12.2-15.9
201		>400		Globose	77-88	Splashed	8.4-12.2
202	0-11	100-1200-2500	Very dry	Flat		Blush	8.4-12.2
203							
204		<200-2500		Flat	88-99	Blush	27.2-31.0
205	0-11	<200-2500		Globose	55-66	Blush	27.2-31.0
206	0-11	<200-2500	Very juicy	Flat	88-99	Blush	0.9-4.7
207	0-11	<200-2500	Very juicy	Flat	66-77	Blush	27.2-31.0
208	0-11	<200-2500	Medium	Flat	33-44	Blush	27.2-31.0
209		>400		Globose	66-77	Splashed	12.2-15.9
210	0-11	1200-2500-200	Mod. Juicy	Globose	77-88	Blush	12.2-15.9
211	0-11	<200-2500	Very juicy	Flat	22-33	Blush	12.2-15.9
212	0-11	<200-2500	Very juicy	Oblong	22-33	Blush	23.5-27.2
213							

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Supplemental Table 1. Continued.

Row (no.)	Fruit surface with russet (%)	Fruit wt (g)	Fruit juiciness	Fruit shape	Overcolor on fruit (%)	Fruit overcolor pattern	Soluble solids (%)
214	0–11	<200–2500		Flat	0–11	Blush	
215	0–11	<200–2500	Dry	Flat	77–88	Blush	8.4–12.2
216	44–55	<200–2500	Mod. Juicy	Flat	22–33	Splashed	12.2–15.9
217	0–11	<200–2500	Medium	Flat	22–33	Blush	4.7–8.4
218	0–11	<200–2500	Medium	Flat	11–22	Splashed	12.2–15.9
219							
220							
221							
222	0–11	<200–2500	Mod. Juicy	Flat	22–33	Splashed	8.4–12.2
223	0–11	<200–2500	Dry	Flat	88–99	Blush	8.4–12.2
224	0–11	<200–2500	Dry	Flat	55–66	Splashed	8.4–12.2
225	0–11	<200–2500	Very juicy	Oblong	77–88	Blush	
226	0–11	100–1200–2500	Dry	Globose	22–33	Striped	8.4–12.2
227	11–22	200–2500–100	Dry	Flat	11–22	Blush	8.4–12.2
228	0–11	<200–2500	Medium	Flat	33–44	Blush	8.4–12.2
229	0–11	1200–2500–200	Medium	Globose	22–33	Striped	8.4–12.2
230	11–22	100–1200–2500	Medium	Conical	44–55	Striped	12.2–15.9
231	0–11	<200–2500	Medium	Globose	55–66	Splashed	12.2–15.9
232	0–11	<200–2500	Medium	Globose	0–11	Blush	8.4–12.2
233	0–11	<200–2500	Medium	Globose	22–33	Striped	8.4–12.2
234	0–11	200–2500–100	Medium	Globose	33–44	Striped	12.2–15.9
235	0–11	200–2500–100	Medium	Flat	0–11	Striped	12.2–15.9
236	0–11	<200–2500	Medium	Flat	33–44	Striped	8.4–12.2
237	0–11	<200–2500	Dry	Globose	0–11	None	8.4–12.2
238	0–11	200–2500–100	Dry	Globose	55–66	Striped	8.4–12.2
239	0–11	100–1200–2500	Dry	Globose	66–77	Striped	12.2–15.9
240	0–11	200–2500–100	Mod. Juicy	Ellipsoid	44–55	Striped	12.2–15.9
241	11–22	200–2500–100	Dry	Conical	22–33	Striped	12.2–15.9
242	0–11	<200–2500	Medium	Flat	44–55	Blush	8.4–12.2
243							
244	0–11	<200–2500		Ellipsoid	88–99	Blush	
245	0–11	<200–2500		Globose	77–88	Blush	
246							
247		<200–2500		Flat	0–11		27.2–31.0
248	0–11	<200–2500	Very juicy	Flat	66–77	Blush	
249	0–11	<200–2500	Medium	Flat	88–99	Blush	23.5–27.2
250	0–11	<200–2500	Medium	Globose	88–99	Blush	23.5–27.2
251	0–11	<200–2500		Flat	77–88	Blush	15.9–19.7
252		<200–2500		Ellipsoid	77–88	Blush	27.2–31.0
253	0–11	<200–2500	Very juicy	Flat	0–110	Blush	23.5–27.2
254							
255							
256							
257		<200–2500		Globose	33–44	Blush	12.2–15.9
258		<200–2500		Flat	88–99	Blush	15.9–19.7

^aIndividuals highlighted in gray were identified as duplicates by Gross et al. (2012b). Trait data are from the Genetic Resources Information Network [GRIN (U.S. Department of Agriculture, 2012)].

Supplemental Table 2. Ten independently identified 265-sample amended cores generated by the MSTRAT program (Gouesnard et al., 2001).^z

In core	Run 1 PI no.	In core	Run 2 PI no.	In core	Run 3 PI no.	In core	Run 4 PI no.	In core	Run 5 PI no.	In core	Run 6 PI no.	In core	Run 7 PI no.	In core	Run 8 PI no.	In core	Run 9 PI no.	In core	Run 10 PI no.
x	104727	x	104727	x	104727	x	104727	x	104727	x	104727	x	104727	x	104727	x	104727	x	104727
x	107196	x	107196	x	107196	x	107196	x	107196	x	107196	x	107196	x	107196	x	107196	x	107196
x	123989	x	123989	x	123989	x	123989	x	123989	x	123989	x	123989	x	123989	x	123989	x	123989
x	188517	x	188517	x	188517	x	188517	x	188517	x	188517	x	188517	x	188517	x	188517	x	188517
x	246464	x	246464	x	246464	x	246464	x	246464	x	246464	x	246464	x	246464	x	246464	x	246464
x	271831	x	271831	x	271831	x	271831	x	271831	x	271831	x	271831	x	271831	x	271831	x	271831
x	280400	x	280400	x	280400	x	280400	x	280400	x	280400	x	280400	x	280400	x	280400	x	280400
x	280401	x	280401	x	280401	x	280401	x	280401	x	280401	x	280401	x	280401	x	280401	x	280401
x	286599	x	286599	x	286599	x	286599	x	286599	x	286599	x	286599	x	286599	x	286599	x	286599
x	322713	x	322713	x	322713	x	322713	x	322713	x	322713	x	322713	x	322713	x	322713	x	322713
x	323617	x	323617	x	323617	x	323617	x	323617	x	323617	x	323617	x	323617	x	323617	x	323617
x	369855	x	369855	x	369855	x	369855	x	369855	x	369855	x	369855	x	369855	x	369855	x	369855
x	383515	x	383515	x	383515	x	383515	x	383515	x	383515	x	383515	x	383515	x	383515	x	383515
x	392303	x	392303	x	392303	x	392303	x	392303	x	392303	x	392303	x	392303	x	392303	x	392303
x	437055	x	437055	x	437055	x	437055	x	437055	x	437055	x	437055	x	437055	x	437055	x	437055
x	437057	x	437057	x	437057	x	437057	x	437057	x	437057	x	437057	x	437057	x	437057	x	437057
x	483254	x	483254	x	483254	x	483254	x	483254	x	483254	x	483254	x	483254	x	483254	x	483254
x	537000	x	537000	x	537000	x	537000	x	537000	x	537000	x	537000	x	537000	x	537000	x	537000
x	588753	x	588753	x	588753	x	588753	x	588753	x	588753	x	588753	x	588753	x	588753	x	588753
x	588757	x	588757	x	588757	x	588757	x	588757	x	588757	x	588757	x	588757	x	588757	x	588757
x	588772	x	588772	x	588772	x	588772	x	588772	x	588772	x	588772	x	588772	x	588772	x	588772
x	588778	x	588778	x	588778	x	588778	x	588778	x	588778	x	588778	x	588778	x	588778	x	588778
x	588785	x	588785	x	588785	x	588785	x	588785	x	588785	x	588785	x	588785	x	588785	x	588785
x	588804	x	588804	x	588804	x	588804	x	588804	x	588804	x	588804	x	588804	x	588804	x	588804
x	588806	x	588806	x	588806	x	588806	x	588806	x	588806	x	588806	x	588806	x	588806	x	588806
x	588824	x	588824	x	588824	x	588824	x	588824	x	588824	x	588824	x	588824	x	588824	x	588824
x	588825	x	588825	x	588825	x	588825	x	588825	x	588825	x	588825	x	588825	x	588825	x	588825
x	588835	x	588835	x	588835	x	588835	x	588835	x	588835	x	588835	x	588835	x	588835	x	588835
x	588837	x	588837	x	588837	x	588837	x	588837	x	588837	x	588837	x	588837	x	588837	x	588837
x	588838	x	588838	x	588838	x	588838	x	588838	x	588838	x	588838	x	588838	x	588838	x	588838
x	588841	x	588841	x	588841	x	588841	x	588841	x	588841	x	588841	x	588841	x	588841	x	588841
x	588842	x	588842	x	588842	x	588842	x	588842	x	588842	x	588842	x	588842	x	588842	x	588842
x	588844	x	588844	x	588844	x	588844	x	588844	x	588844	x	588844	x	588844	x	588844	x	588844
x	588848	x	588848	x	588848	x	588848	x	588848	x	588848	x	588848	x	588848	x	588848	x	588848
x	588849	x	588849	x	588849	x	588849	x	588849	x	588849	x	588849	x	588849	x	588849	x	588849
x	588850	x	588850	x	588850	x	588850	x	588850	x	588850	x	588850	x	588850	x	588850	x	588850
x	588853	x	588853	x	588853	x	588853	x	588853	x	588853	x	588853	x	588853	x	588853	x	588853
x	588859	x	588859	x	588859	x	588859	x	588859	x	588859	x	588859	x	588859	x	588859	x	588859
x	588866	x	588866	x	588866	x	588866	x	588866	x	588866	x	588866	x	588866	x	588866	x	588866
x	588868	x	588868	x	588868	x	588868	x	588868	x	588868	x	588868	x	588868	x	588868	x	588868
x	588870	x	588870	x	588870	x	588870	x	588870	x	588870	x	588870	x	588870	x	588870	x	588870
x	588872	x	588872	x	588872	x	588872	x	588872	x	588872	x	588872	x	588872	x	588872	x	588872

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Supplemental Table 2. Continued.

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Supplemental Table 2. Continued.

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Supplemental Table 2. Continued.

In core	Run 1 PI no.	In core	Run 2 PI no.	In core	Run 3 PI no.	In core	Run 4 PI no.	In core	Run 5 PI no.	In core	Run 6 PI no.	In core	Run 7 PI no.	In core	Run 8 PI no.	In core	Run 9 PI no.	In core	Run 10 PI no.
x	594105	x	594104	x	594104	x	594104	x	594104	x	594104	x	594104	x	594104	x	594104	x	594105
x	594106	x	594105	x	594105	x	594105	x	594105	x	594105	x	594105	x	594105	x	594105	x	594106
x	594107	x	594106	x	594106	x	594106	x	594106	x	594106	x	594106	x	594106	x	594106	x	594107
x	594108	x	594107	x	594107	x	594107	x	594107	x	594107	x	594107	x	594107	x	594107	x	594108
x	594109	x	594108	x	594108	x	594108	x	594108	x	594108	x	594108	x	594108	x	594108	x	594109
x	594110	x	594109	x	594109	x	594109	x	594109	x	594109	x	594109	x	594109	x	594109	x	594110
x	594111	x	594110	x	594110	x	594110	x	594110	x	594110	x	594110	x	594110	x	594110	x	594111
x	594112	x	594111	x	594111	x	594111	x	594111	x	594111	x	594111	x	594111	x	594111	x	594112
x	594113	x	594112	x	594112	x	594112	x	594112	x	594112	x	594112	x	594112	x	594112	x	594113
x	596278	x	594113	x	594113	x	594113	x	594113	x	594113	x	594113	x	594113	x	594113	x	594113
x	596280	x	596278	x	596278	x	596278	x	596278	x	596278	x	596278	x	596278	x	596278	x	596278
x	596281	x	596280	x	596280	x	596280	x	596280	x	596280	x	596280	x	596280	x	596280	x	596280
x	596282	x	596281	x	596281	x	596281	x	596281	x	596281	x	596281	x	596281	x	596281	x	596281
x	596283	x	596282	x	596282	x	596282	x	596282	x	596282	x	596282	x	596282	x	596282	x	596282
x	613835	x	596283	x	596283	x	596283	x	596283	x	596283	x	596283	x	596283	x	596283	x	596283
x	613845	x	613835	x	613835	x	613835	x	613835	x	613835	x	613835	x	613835	x	613835	x	613835
x	613880	x	613845	x	613845	x	613845	x	613845	x	613845	x	613845	x	613845	x	613845	x	613845
x	613969	x	613969	x	613969	x	613969	x	613969	x	613969	x	613969	x	613969	x	613969	x	613969
x	613976	x	613976	x	613976	x	613976	x	613976	x	613976	x	613976	x	613976	x	613976	x	613976
x	613998	x	613998	x	613998	x	613998	x	613998	x	613998	x	613998	x	613998	x	613998	x	613998
x	619168	x	619168	x	619168	x	619168	x	619168	x	619168	x	619168	x	619168	x	619168	x	619168
x	633798	x	633798	x	633798	x	633798	x	633798	x	633798	x	633798	x	633798	x	633798	x	633798
x	633804	x	633804	x	633804	x	633804	x	633804	x	633804	x	633804	x	633804	x	633804	x	633804
x	633811	x	633811	x	633811	x	633811	x	633811	x	633811	x	633811	x	633811	x	633811	x	633811
x	633813	x	633813	x	633813	x	633813	x	633813	x	633813	x	633813	x	633813	x	633813	x	633813
x	633816	x	633816	x	633816	x	633816	x	633816	x	633816	x	633816	x	633816	x	633816	x	633816
x	633817	x	633817	x	633817	x	633817	x	633817	x	633817	x	633817	x	633817	x	633817	x	633817
x	633824	x	633824	x	633824	x	633824	x	633824	x	633824	x	633824	x	633824	x	633824	x	633824
x	633826	x	633826	x	633826	x	633826	x	633826	x	633826	x	633826	x	633826	x	633826	x	633826
x	633827	x	633827	x	633827	x	633827	x	633827	x	633827	x	633827	x	633827	x	633827	x	633827
	104034		104034		123733		123733		123733		104034		123733		123733		104034		123733
	123733		123733		127686		134668		134668		123733		134668		127686		123733		134668
	134668		127686		134668		134672		136604		127686		141362		134668		134668		161838
	141362		141362		141362		141362		141362		134668		162062		141362		141362		162062
	148478		141362		162062		162062		160387		141362		162545		162062		162062		245048
	162062		162062		205460		245048		162062		162062		245048		245048		245048		264689
	245048		199419		245048		247314		245048		188525		259453		247314		247314		264693
	247314		245048		247314		264689		264689		245048		264689		264689		264689		292931
	264689		247314		264689		264693		264693		247314		264693		264693		264693		296775
	264693		264689		264693		279323		296775		249925		296775		296775		296775		306321
	296775		264693		296775		293885		322714		264689		306321		322714		306321		322714
	306321		296775		306321		296775		392301		264693		322714		392301		322714		392301

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Supplemental Table 2. Continued.

In core	Run 1 PI no.	In core	Run 2 PI no.	In core	Run 3 PI no.	In core	Run 4 PI no.	In core	Run 5 PI no.	In core	Run 6 PI no.	In core	Run 7 PI no.	In core	Run 8 PI no.	In core	Run 9 PI no.	In core	Run 10 PI no.
	322714		306321		322714		322714		58887		296775		337434		58887		392301		58887
	337434		322714		383526		337434		588907		306321		392301		588907		58887		588907
	383513		392301		392301		392301		588915		307501		58887		588915		588907		588915
	392301		58887		58887		58887		588984		322714		588907		588984		588915		588984
	58887		588907		588907		588907		589016		392301		588915		589016		588984		589016
	588907		588915		588915		588908		589018		58887		588984		589018		589015		589058
	588915		588984		588984		588915		589058		588907		589018		589058		589016		589080
	588984		589018		589018		588931		589080		588915		589058		589072		589018		589099
	589016		589058		589018		588984		589099		588984		589080		589080		589058		589122
	589018		589080		589028		589016		589162		589018		589099		589099		589080		589162
	589058		589099		589058		589018		589196		589058		589162		589162		589099		589196
	589080		589162		589080		589058		589233		589080		589196		589196		589162		589241
	589099		589242		589099		589080		589241		589099		589241		589233		589196		589282
	589162		589243		589162		589099		589242		589162		589242		589241		589241		589289
	589196		589282		589196		589162		589282		589241		589282		589242		589242		589378
	589241		589418		589242		589196		589423		589242		589378		589282		589282		589423
	589242		589423		589282		589423		589456		589282		589423		589423		589289		589456
	589282		589456		589423		589456		589575		589378		589456		589456		589314		589459
	589406		589531		589425		589258		589657		589423		589459		589459		589423		589522
	589423		589629		589456		589282		589748		589456		589593		589629		589425		589575
	589456		589748		589459		589289		589755		589459		589601		589657		589456		589629
	589629		589755		589624		589351		589769		589515		589629		589748		589459		589657
	589657		589866		589748		589423		589770		589531		589748		589755		589629		589739
	589748		590004		589755		589459		589818		589629		589755		589769		589641		589748
	589755		590006		589769		589629		589866		589691		589770		589770		589657		589769
	589769		590057		589839		589755		589909		589748		590004		589771		589748		589991
	589770		590067		589960		589990		589974		589755		590036		589818		590004		590004
	589866		590091		590004		590004		589990		589987		590057		589974		590006		590057
	589909		590096		590006		590014		590004		590057		590067		590004		590036		590067
	590004		590101		590057		590057		590006		590067		590091		590006		590057		590091
	590036		590113		590067		590067		590057		590090		590096		590057		590067		590096
	590057		590136		590091		590091		590067		590096		590101		590067		590091		590101
	590067		590157		590096		590096		590091		590101		590113		590091		590096		590113
	590091		590175		590101		590101		590096		590113		590136		590096		590101		590136
	590096		590181		590113		590113		590101		590136		590157		590101		590113		590157
	590101		613799		590136		590136		590113		590157		590181		590113		590136		590181
	590113		613814		590157		590175		590136		613799		613799		590136		590157		613799
	590136		613841		590175		590181		590157		613814		613814		590157		590181		613802
	590157		613860		590181		613799		590181		613847		613841		590181		613799		613814
	590181		613865		613799		613814		590198		613860		613860		613799		613802		613860
	613799		613870		613814		613860		613799		613865		613865		613814		613814		613865
	613814		613879		613860		613865		613814		613870		613870		613841		613860		613870

Continued next page

Supplemental Table 2. Continued.

In core	Run 1 PI no.	In core	Run 2 PI no.	In core	Run 3 PI no.	In core	Run 4 PI no.	In core	Run 5 PI no.	In core	Run 6 PI no.	In core	Run 7 PI no.	In core	Run 8 PI no.	In core	Run 9 PI no.	In core	Run 10 PI no.
x	613860	x	613880	x	613865	x	613870	x	613860	x	613879	x	613879	x	613860	x	613865	x	613892
x	613865	x	613892	x	613870	x	613879	x	613865	x	613880	x	613892	x	613865	x	613870	x	613925
x	613870	x	613925	x	613892	x	613892	x	613870	x	613925	x	613925	x	613870	x	613878	x	613989
x	613879	x	613989	x	613925	x	613925	x	613892	x	613989	x	613989	x	613892	x	613892	x	629309
x	613892	x	629305	x	613989	x	613989	x	613925	x	629301	x	629305	x	613925	x	613925	x	629314
x	613925	x	629309	x	629305	x	629314	x	613989	x	629305	x	629316	x	613989	x	613989	x	629316
x	613989	x	629314	x	629316	x	629316	x	629305	x	629314	x	629319	x	629305	x	629305	x	629319
x	629305	x	629316	x	629316	x	629319	x	629316	x	629316	x	644191	x	629316	x	629307	x	644253
x	629316	x	629319	x	629319	x	644253	x	629319	x	629319	x	644253	x	629319	x	629316	x	657018
x	629319	x	644253	x	644253	x	657018	x	657018	x	644183	x	657018	x	644253	x	644183	x	657063
x	657018	x	657017	x	657018	x	657066	x	657072	x	644253	x	657041	x	657018	x	644253	x	657086
x	657041	x	657018	x	657107	x	657107	x	657107	x	657018	x	657107	x	657107	x	657018	x	657107
x	657107	x	657107	x	657118	x	657118	x	657118	x	657107	x	657118	x	657118	x	657107	x	657118

²Samples that are already in the original *Malus* core are marked as "In core." Samples that are not in the original core but are present in all 10 of the MSTRAT runs are listed in Table 2.

Supplemental Table 3. Ten independently identified 100-sample core collections were generated by the M+ program (Reeves et al., 2012) based on genotypic data.^z

In core	Run 1 PI no.	In core	Run 2 PI no.	In core	Run 3 PI no.	In core	Run 4 PI no.	In core	Run 5 PI no.	In core	Run 6 PI no.	In core	Run 7 PI no.	In core	Run 8 PI no.	In core	Run 9 PI no.	In core	Run 10 PI no.	PI no. of accessions in 10 of 10 modified MSTRAT runs
x	271831	x	271831	x	271831	x	271831	x	271831	x	188517	x	107196	x	271831	x	104727	x	271831	104034
x	369855	x	286599	x	369855	x	280400	x	369855	x	271831	x	271831	x	369855	x	271831	x	369855	123733
x	383515	x	369855	x	437055	x	280401	x	588868	x	280401	x	369855	x	437055	x	369855	x	437057	134668
x	437055	x	588806	x	588944	x	369855	x	589246	x	369855	x	588806	x	588933	x	589382	x	588804	245048
x	588992	x	589384	x	589384	x	588868	x	589253	x	588868	x	589384	x	588944	x	589384	x	588868	264689
x	589384	x	589399	x	589399	x	588944	x	589384	x	589384	x	589399	x	588960	x	589399	x	589246	264693
x	589399	x	589422	x	589422	x	589384	x	589399	x	589399	x	589422	x	589384	x	589422	x	589384	271831
x	589422	x	589727	x	589596	x	589399	x	589422	x	589422	x	589727	x	589399	x	589727	x	589399	279323
x	589727	x	589758	x	589727	x	589422	x	589727	x	589727	x	589758	x	589422	x	589758	x	589422	369855
x	589758	x	589812	x	589753	x	589727	x	589758	x	589763	x	589758	x	589727	x	5894093	x	589727	392301
x	594093	x	594093	x	589758	x	589758	x	594093	x	589827	x	594096	x	589758	x	594096	x	589758	588907
x	594096	x	594096	x	589763	x	589869	x	594094	x	589930	x	594097	x	589763	x	594097	x	594093	589058
x	594097	x	594104	x	594093	x	594093	x	594096	x	594093	x	594104	x	589869	x	594104	x	594096	589080
x	594104	x	104034	x	594096	x	594096	x	594097	x	594096	x	633804	x	589879	x	633804	x	594097	589099

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In core	Run 1	In core	Run 2	In core	Run 3	In core	Run 4	In core	Run 5	In core	Run 6	In core	Run 7	In core	Run 8	In core	Run 9	In core	Run 10	PI no. of accessions in 10 of 10 modified MSTRAT runs
x	594108		105498		594104	x	633804	x	594104	x	594097		78170	x	594093		104034	x	594104	589196
x	596281	x	105505	x	596281	x	104034	x	596281	x	594104		104034	x	594094		123733		104034	589384
	104034		123733		104034		104790		78170		594107		105498	x	594096		123735		105505	589399
	105498		125223		105498		105498		104034		104034		105505	x	594104		123960		123733	589422
	105505		131215		105505		105505		105498		104781		123733		102537		123967		123735	589632
	105528		134668		122620		123733		105505		105132		123960		104034		125746		126998	589727
	123729		134807		123733		123960		123733		105498		129820		105498		129820		127009	589909
	123733		135999		123960		131010		123751		105505		131823		105505		134668		127015	590004
	125746		136243		125746		131964		123960		123733		132272		123733		135999		127022	590067
	131823		136604		133750		134668		123967		131215		134668		123960		136001		129820	590096
	132759		141213		134668		135999		127004		134668		134672		128362		136604		131975	590136
	134668		148496		136604		136604		132758		135499		136604		129820		141362		134668	594093
	141362		157731		157734		148496		134668		136604		148496		134668		148496		141240	594096
	148703		162721		161840		148710		136604		148478		157734		136001		154165		148496	613865
	157734		162722		161843		162062		137090		148496		173983		136604		161758		157734	613870
	161758		162732		162503		173983		158736		162062		187062		148496		162062		162549	613989
	161838		162735		162545		173986		161765		176379		194096		157734		162716		162723	629315
	162062		173978		162712		175548		162712		187062		199532		161846		162732		162735	
	175533		176379		176379		176379		175551		188523		199533		162549		176379		176379	
	188525		187062		199692		205462		176379		206029		209939		173983		188516		188515	
	205460		199419		240817		224611		232661		206033		240817		175552		188525		240817	
	206029		224610		245048		245048		240817		245048		241965		176379		199418		241965	
	240817		245048		247314		262969		245048		255898		245048		200780		206033		245048	
	245048		247314		255899		264689		247314		264557		247023		237702		240817		264689	
	247026		264689		262970		264693		264689		264559		264689		240817		244724		264693	
	247314		264693		264689		279323		264693		264689		264693		245048		245048		279323	
	259449		279323		264693		279447		279323		264693		279323		264689		259447		296775	
	264689		292136		265301		293888		306321		279323		280028		264693		264689		344552	
	264693		306321		279323		392301		320871		306321		306321		279323		264693		383509	
	279323		392301		280018		392304		383513		307503		307500		306321		279323		392301	
	307518		588765		292135		392306		392301		392301		307506		322032		306321		437042	
	316482		588780		306321		437043		588745		392305		383513		383513		307380		588765	
	383509		588817		307383		437048		588771		483259		392301		392301		392301		588874	
	383510		588864		307500		588745		588817		588745		483261		483259		506361		588907	
	383513		588905		320871		588765		588885		588890		588745		588745		588745		588944	
	392301		588907		341068		588771		588907		588907		588860		588765		588771		589015	
	588754		589058		392301		588834		588957		588927		588907		588907		588780		589016	
	588834		589080		588905		588891		588989		588929		588927		588964		588907		589058	

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Supplemental Table 3. Continued.

In core	Run 1	In core	Run 2	In core	Run 3	In core	Run 4	In core	Run 5	In core	Run 6	In core	Run 7	In core	Run 8	In core	Run 9	In core	Run 10	PI no. of accessions in 10 of 10 modified MSTRAT runs
588860	589099	588907	588905	589018	588939	589058	589020	589080	589058	589058	589058	589058	589058	589058	589058	589058	589058	589058	589075	
588907	589192	588951	588907	589058	588907	589058	588907	589058	588907	589058	588907	589058	588907	589058	588907	589058	588907	589058	589080	
589016	589196	589016	588931	589080	589054	589080	588931	589080	589054	589080	589054	589080	588931	589080	589054	589080	589054	589080	589099	
589058	589241	589018	589058	589099	589058	589099	589058	589099	589058	589099	589058	589099	589058	589099	589058	589099	589058	589099	589155	
589063	589242	589058	589078	589117	589080	589117	589078	589117	589080	589117	589080	589117	589078	589117	589080	589117	589080	589117	589178	
589080	589281	589080	589080	589176	589083	589176	589080	589176	589083	589176	589083	589176	589080	589176	589083	589176	589083	589176	589196	
589099	589314	589099	589099	589196	589099	589196	589099	589196	589099	589196	589099	589196	589099	589196	589099	589196	589099	589196	589220	
589107	589377	589174	589174	589232	589190	589232	589174	589232	589190	589232	589190	589232	589174	589232	589190	589232	589190	589232	589233	
589161	589378	589196	589196	589242	589196	589242	589196	589242	589196	589242	589196	589242	589196	589242	589196	589242	589196	589242	589281	
589196	589585	589223	589233	589301	589242	589301	589233	589301	589242	589301	589242	589301	589233	589301	589242	589301	589242	589301	589314	
589233	589594	589281	589242	589314	589249	589314	589242	589314	589249	589314	589249	589314	589242	589314	589249	589314	589249	589314	589322	
589281	589632	589402	589281	589365	589281	589365	589281	589365	589281	589365	589281	589365	589281	589365	589281	589365	589281	589365	589325	
589319	589677	589423	589286	589377	589314	589377	589286	589314	589377	589314	589377	589314	589286	589314	589377	589314	589377	589314	589347	
589377	589700	589456	589330	589378	589377	589378	589330	589378	589377	589378	589377	589378	589330	589378	589377	589378	589377	589378	589377	
589423	589745	589565	589377	589423	589378	589423	589377	589423	589378	589423	589378	589423	589377	589423	589378	589423	589378	589423	589423	
589426	589765	589593	589378	589498	589409	589498	589378	589498	589409	589498	589409	589498	589378	589498	589409	589498	589409	589498	589602	
589632	589769	589628	589569	589632	589423	589632	589569	589632	589423	589632	589423	589632	589569	589632	589423	589632	589569	589632	589608	
589662	589772	589632	589588	589667	589588	589667	589588	589667	589588	589667	589588	589667	589588	589667	589588	589667	589588	589667	589632	
589688	589839	589739	589601	589677	589632	589677	589601	589677	589632	589677	589632	589677	589601	589677	589632	589677	589601	589677	589686	
589691	589876	589765	589632	589738	589689	589738	589632	589738	589689	589738	589689	589738	589632	589738	589689	589738	589689	589738	589755	
589765	589877	589839	589647	589765	589765	589765	589647	589765	589765	589765	589765	589765	589647	589765	589765	589765	589765	589765	589760	
589772	589902	589876	589739	589767	589767	589767	589739	589767	589767	589767	589767	589767	589739	589767	589767	589767	589767	589767	589766	
589839	589909	589901	589748	589772	589772	589772	589748	589772	589772	589772	589772	589772	589748	589772	589772	589772	589772	589772	589767	
589909	589927	589909	589761	589839	589839	589839	589761	589839	589839	589839	589839	589839	589761	589839	589839	589839	589839	589839	589772	
590004	589935	589935	589764	589874	589870	589874	589764	589874	589870	589874	589870	589874	589764	589874	589870	589874	589870	589874	589839	
590011	590004	589982	589772	589909	589871	589909	589772	589909	589871	589909	589871	589909	589772	589909	589871	589909	589871	589909	589860	
590028	590014	589992	589839	589988	589909	589988	589839	589988	589909	589988	589909	589988	589839	589988	589909	589988	589909	589988	589876	
590031	590028	590004	589909	590004	590004	590004	589909	590004	590004	590004	590004	590004	589909	590004	590004	590004	590004	590004	589909	
590065	590034	590028	589987	590036	590028	590036	589987	590036	590028	590036	590028	590036	589987	590036	590028	590036	590028	590036	589920	
590067	590053	590067	590004	590067	590067	590067	590004	590067	590067	590067	590067	590067	590004	590067	590067	590067	590067	590067	590004	
590096	590067	590096	590028	590096	590088	590096	590028	590096	590088	590096	590088	590096	590028	590096	590088	590096	590088	590096	590067	
590111	590095	590113	590057	590101	590096	590101	590057	590101	590096	590101	590096	590101	590057	590101	590096	590101	590096	590101	590096	
590112	590096	590128	590067	590113	590096	590113	590067	590113	590096	590113	590096	590113	590067	590113	590096	590113	590096	590113	590113	
590136	590112	590130	590096	590136	590131	590136	590096	590136	590131	590136	590131	590136	590096	590136	590131	590136	590131	590136	590136	
590175	590136	590136	590113	590143	590136	590143	590113	590143	590136	590143	590136	590143	590113	590143	590136	590143	590136	590143	590175	
590181	590176	590175	590136	590175	590175	590175	590136	590175	590175	590175	590175	590175	590136	590175	590175	590175	590175	590175	590175	
613826	590181	613799	590175	590175	590175	590175	590175	590175	590175	590175	590175	590175	590175	590175	590175	590175	590175	590175	613809	
613844	613814	613814	590181	613799	613802	613799	590181	613799	613802	613799	613802	613799	590181	613799	613802	613799	613802	613799	613814	

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Supplemental Table 3. Continued.

In core	Run 1 PI no.	In core	Run 2 PI no.	In core	Run 3 PI no.	In core	Run 4 PI no.	In core	Run 5 PI no.	In core	Run 6 PI no.	In core	Run 7 PI no.	In core	Run 8 PI no.	In core	Run 9 PI no.	In core	Run 10 PI no.	PI no. of accessions in 10 of 10 modified MSTRAT runs
	613865		613819		613844		613814		613814		613814		613814		613814		613843		613826	
	613870		613826		613865		613865		613826		613818		613846		613833		613860		613842	
	613878		613865		613870		613870		613843		613843		613865		613865		613865		613865	
	613922		613870		613892		613892		613860		613865		613867		613867		613870		613870	
	613927		613892		613925		613925		613865		613870		613870		613870		613900		613892	
	613989		613922		613989		613989		613870		613892		613892		613892		613989		613989	
	619162		613925		629315		629315		613892		613922		613910		613989		629315		629298	
	629315		613989		629319		629319		613989		613989		613989		629315		629319		629315	
	629319		629315		644187		644253		629301		629315		629315		629319		644253		644253	
	644176		644253		644253		657011		629315		644253		657040		644164		657018		657018	

^aSamples that are already in the original Malus core are marked as "In core." Accessions present in all 10 of the M+ runs are listed in the right-most column.