Variation in floral development and spring bloom date among 1,000 apple cultivars and hybrids

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The USDA-ARS Malus germplasm collection in Geneva, NY is a living catalog of over 2,000 distinct apple cultivars, species, and hybrids, and represents a valuable source of genetic alleles for breeding of novel apple varieties suited for 21st century production.

The Applocalypse of 2011, in which extended periods of abnormally high spring temperatures led to early bloom and subsequent freezes and catastophic loss of apple and other fruit crops in the Midwestern U.S., highlights the critical need for better control of bloom timing. Although breeding and introduction of later-blooming cultivars is an obvious solution, this trait has not been prioritized in breeding programs. The first step for this goal is to find genetic alleles that control this trait, which may not exist in domestic apple (*Malus x domestica*), but in wild apple species. In this project, I developed a floral development rating scale and used this to assess variability in floral development and spring bloom date for over 1,000 apple cultivars, hybrids, and wild apple species maintained at a large apple germplasm collection. I found an incredible range in floral development early in the season, ranging from plants that had barely initiated bud break to those that were already in full bloom. Very early blooming accessions included representatives of *M. kirgisorum*, *M. orientalis*, *M. sieversii*, and *M. sylvestris*. Very late blooming accessions included representatives of *M. coronaria*, *M. angustifolia*, *M. ioensis*, *M. florentina*, and *M. yunnanensis*. Of nearly 1,000 cultivars of *M. x domestica* studied, none were classified as very late blooming, and only one bloomed late enough to likely escape future freezes similar to 2012. Interestingly, *M. x domestica* cultivars were underrepresented among populations of late blooming or very early blooming types, suggesting that bloom time has already been subjected to selection. The *Malus* species that is adapted to the Midwestern U.S., *M. ioensis*, was substantially delayed relative to all *M. x domestica*, suggesting that delayed bloom is advantageous for apple in nature. This study suggests that *M. ioensis* or other members of this interspecies group (*M. angustifolia* and *M. coronaria*) are good sources of genetic alleles conferring delayed flowering.

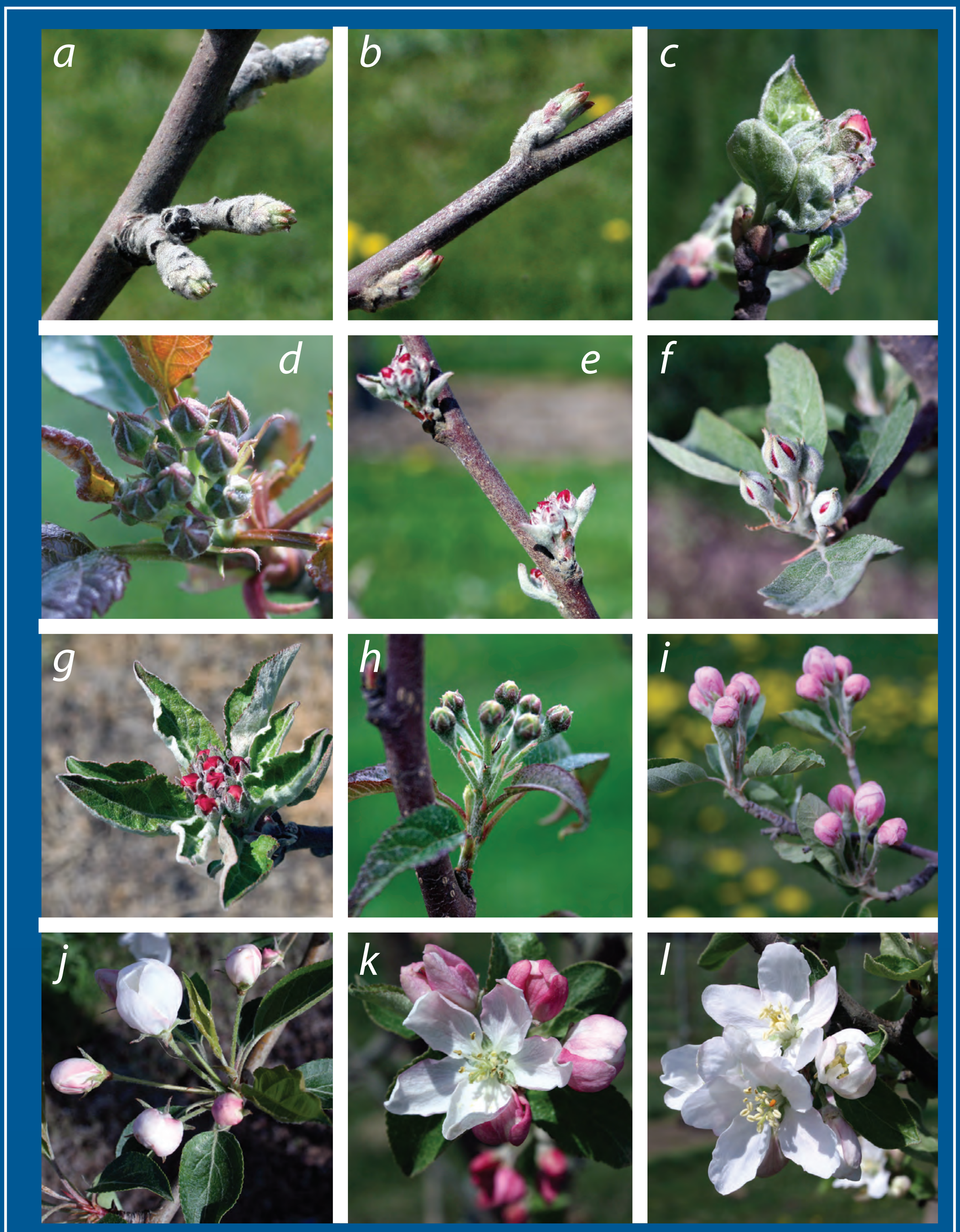

Figure 1. Stages of floral development in apple as designated in this study. (a) At the earliest stage (Stage 0), plants had just broken dormancy, with vegetative or mixed vegetative/floral shoots apparent. Inflorescences were visible only upon macroscopic dissection of shoots. (b) At Stage 1, the inflorescence was macroscopically visible within the shoot without dissection (M. x domestica) (c,d) By Stage 2, individual flowers were easily apparent as a tight cluster [e.g., in M. x domestica, (c)] or loose cluster [e.g., M. fusca (d)]. At this stage, in M. x domestica, petals were visible in the dominant 'King' flower (c). (e,f) By Stage 3, most flowers within the inflorescence showed petals (f, M. ioensis). (g,h) By Stage 4, petals were apparent in all flowers (g,; h, M. fusca). (i) Petals became dominant over sepals on the bud in Stage 5 (M. ioensis). (j) In Stage 6, petals of one or more flowers failed to totally enclose the flower. (k) One or more flowers was fully open at Stage 7. (l) By Stage 8 essentially all flowers in an inflorescence were open.

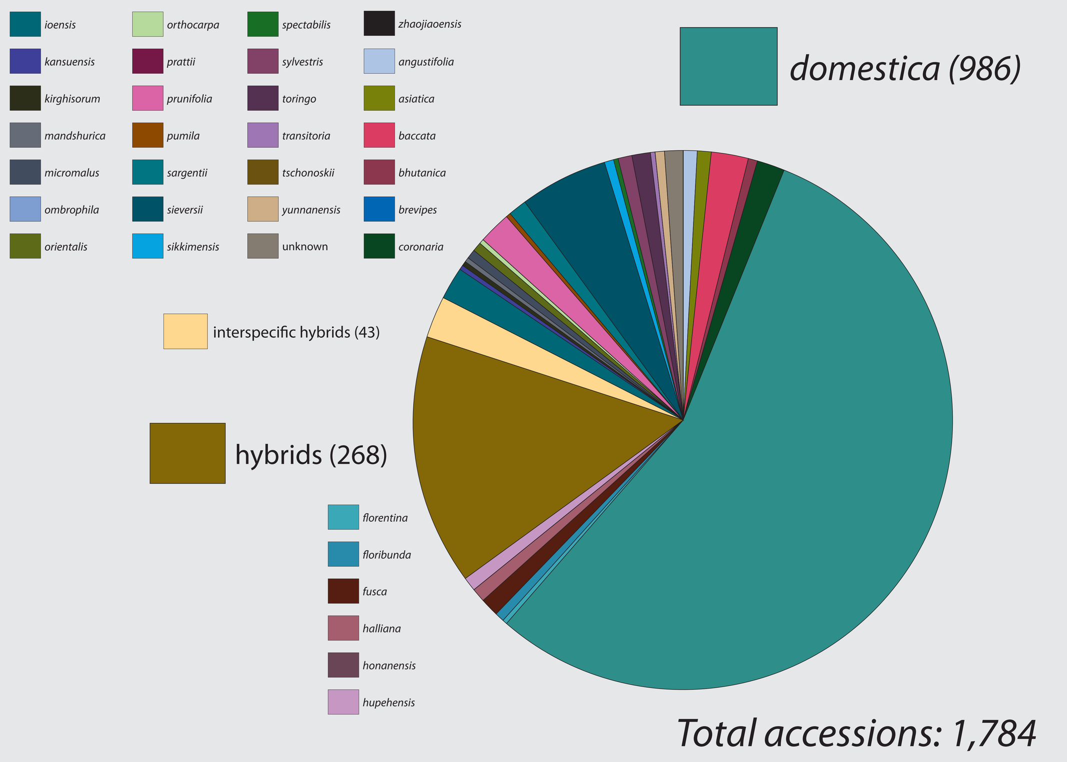

Figure 2. Species and numbers of species representatives analyzed in this study.

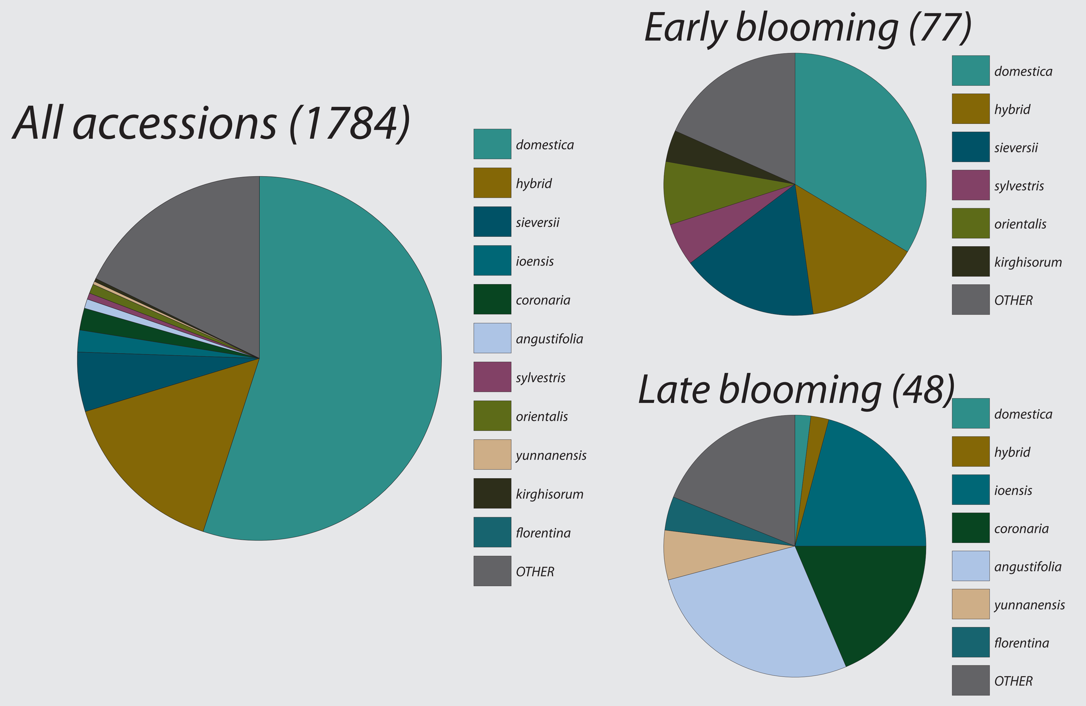

Figure 3. Proportional analysis of accessions in relation to early or late blooming. The composition of the entire population for 11 species groups is shown at left. Composition of the subsets of early or late blooming accessions is shown at right. Only significant differences are shown (p<1E10-3, Fisher's Exact Test)

Table 1. Extremes of floral development in *M. x domestica*

Late blooming	Extreme early blooming
Koningszuur	Novosibirski Sweet
	Redspur Delicious
	Shinibalt 1
	Anna
	Ottawa No. 322
	Crimson Beauty

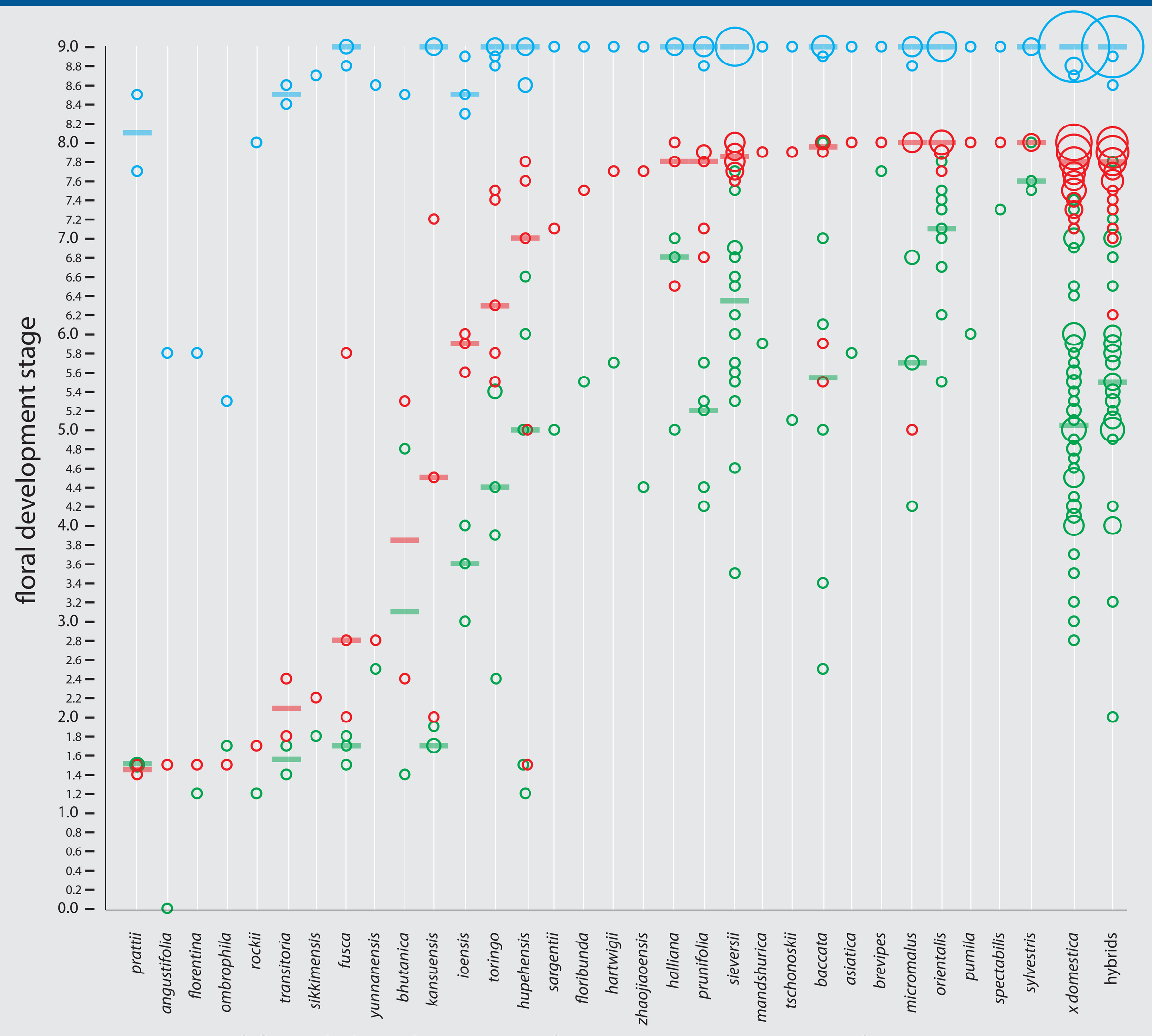

Figure 4. Stage of floral development for representatives of species groups. Chart depicts individual observations for 189 accessions of the core Malus diversity collection on three dates representing early (green), mid (red), and late (blue) development for the population in general. The number of accessions evaluated within each species group is indicated by size of the circle; here the smallest circle represents one accession. Medians of observations are shown as a short horizontal bar.

In 2012, excessive early-season temperatures led to bloom of domestic apple (left) weeks before normal. Subsequent hard freezes damaged flowers and led to extensive crop loss. Later blooming cultivars and species, such as the native apple M. ioensis (right) were not subject to damage because flowers had not developed extensively.

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