Effect of Temperature and Day Length on Varietal Adaptation of Strawberry

(PART II)

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Central Valley and Coastal Area of California. Flower-bud initiation and fruit production patterns in the San Joaquin Valley of California are similar to those in the Southern States. Flower buds are initiated in the fall and then again in the spring, from the time growth starts, when day lengths are as short as 12 hours, until the days lengthen to about 15 hours. The harvest season begins in April and usually extends into June. Sometimes additional flower buds are initiated in the summer, but this does not occur often enough for extensive commercial production.

In the coastal area of California, in a narrow belt up to perhaps 30 miles wide, particularly from San Francisco south nearly to Los Angeles, both the day and night temperatures of midsummer are so low that flower-bud initiation continues in most ordinary varieties throughout the summer even when days are the longest. Heavy commercial shipments are made usually from April to September and October, and in some years even into November.

Varieties have been bred and selected for fruit production after the early-summer crop. They vary in their response to the low summer temperatures of this area. Some varieties are more sensitive to long days than to low temperature, and do not initiate flower buds during the summer. Others produce flower buds freely and respond like everbearing varieties. The varieties selected are those that produce more or less continuously from April to November.

Because weather conditions vary greatly from season to season and affect the extent of flower-bud formation and crop production, varieties must be tested over many seasons so that those with the most favorable responses can be selected. For example, in 1928 in central California there was a relatively short early crop and a very large summer and fall crop; and then in 1933, when there was a heavy and long early crop, this was followed by a small crop for the last of June and all of July, and then a heavy August crop. In other seasons the production might be similar to that of one or the other of these seasons, or it might differ considerably. Such differences in crop production are expressions of the effects of variations in weather on flower initiation and development.

Coastal area of Oregon and Washington. Along the coast of Oregon and Washington no selection of varieties has been made as in California. The day lengths are enough longer so that California varieties have not responded with extensive April to November production of fruit in this area. Undoubtedly varieties that would produce during these months could be bred.

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Northern Europe. In northern Europe the pattern of flower-bud initiation and fruit production in general resembles that in northern United States. Flower buds develop in the fall, beginning in September, and flowering and maturing of fruit occur in spring and early summer, respectively. Because of cooler early summers, the season of fruit production may be slightly longer than in most of northern United States. But, because of the longer days, little flower-bud initiation in most varieties seems to occur in spring and summer. In 1947 a relatively late-maturing selection at Auchincruive, Scotland, was named Climax and introduced. It is sufficiently sensitive to low temperatures, so that it initiates many flower buds in the very long days of summer in the Netherlands, England, and Scotland, and sets a heavy crop of fruit in September and October. Some other varieties—Early Cambridge (English), Victoire and Abondance (French), and Gold Mine (Danish)—also exhibit this pattern of midsummer production of flower buds and fall fruit production. In 1952, with below-normal summer temperatures, flower buds were initiated in late summer and fruit produced in the fall on many varieties in northern Europe. The everbearing varieties respond in northern Europe much as they do in the northern United States, by initiating flower buds throughout the summer.

Mexico, Central America, and Northern South America. Near the city of Irapuato, Mexico, at about 5,200-foot elevation, where most Mexican strawberries are produced, winter temperatures, like those in Florida, are high enough for growth and fruit production. During the rest of the year, the temperatures are low enough and the days short enough so that fruit is produced throughout the year. However, fruit production is greatest from February to May.

Farther south, from Guatemala to Ecuador, as the days shorten, flower buds may be initiated more continuously than in Mexico throughout the year wherever the elevation is high enough for low temperatures to occur. As Missionary is the variety that can initiate flower buds at the highest temperatures during short days, it is the best variety in the warmer areas at low elevations. Though it succeeds at sea level in Florida, Missionary produces fruit there only until the temperatures get very high, usually in April. In the Cauca River Valley of Colombia it succeeds fairly well at about 3,300-foot elevation and produces fruit the year through.

In Guatemala at about 5,600 feet the Parramos variety, which resembles the Perle de Prague of northern Europe, produces throughout the year but bears heaviest in December.

Almost directly under the equator at Ambato, Ecuador, the Ambato variety (of pure *Fragaria chiloensis* parentage) produces fruit throughout the year, but bears heavier crops in February, August, and December than at other times. Local climatic conditions, such as seasonal wind movements, variations in rainfall and air drainage, that seem to have relatively little effect on flower-bud formation when the cropping season is short, become important when flower-bud initiation takes place over a period of several months or throughout the year, as at Ambato.

Presumably these environmental conditions affect the everbearing varieties in northern United States much as they do the varieties that fruit continuously in the highlands of central and northern South America. So far, however, no studies have been made of the effects of various factors of the

environment on fruit production of everbearers.

Continuous flower-bud production in strawberry species

Fragaria vesca and other diploids. The so-called alpine, the everbearing type of *F. vesca,* is reported to have originated at Mont Cenis in the alpine region of northern Italy and to have been first brought into gardens in 1530. It apparently has a gene for continuous flower-bud initiation instead of a gene for runner initiation. This alpine type never produces runners and all plants come from seed. Flower buds start initiating a few months after seed germination and continue to do so under all conditions observed. No intermediate condition between late-summer and fall flower-bud formation and continuous flower-bud formation, has been observed by the writer in *F. vesca* or in other diploid species. However, in Europe a variety often called Quatre Saisons (a descriptive term properly applied only to the alpine type) is said to be a two-crop form of *F. vesca.* No everbearing type similar to the alpine has been reported in the other diploid species. Named varieties of alpines are grown in western Europe commercially and seed of the Baron Solemacher is regularly sold in the United States.

Octoploid species. Summer and fall flowering is not at all rare in the 3 octoploid species—*F. virginiana, F. ovalis,* and *F. chiloensis*—in the wild and is probably in the genetic makeup of cultivated strawberries. It has appeared in seedlings of cultivated strawberries at various times during the last century. Although most everbearing varieties selected from seedlings of ordinary varieties have not been very productive in the summer and fall, productive everbearing varieties have been bred both in Europe and in North America from them. At present the Rockhill, Gem, Red Rich, and Twentieth Century are among the best in the United States. Charles (Geant) Simmen, La Sans Rivale, Record, and St. Claude are said to be among the best in Europe.

Fig. 1. **Climax strawberry planted in March, flowering and fruiting on August 11, at Kent, England.**

A different type of everbearing seems to be shown by the western North American species *F. ovalis*. It does not normally flower and fruit in the summer and fall where it grows wild, at elevations of from 5,000 feet to 10,000 feet, from Colorado to Oregon. However, many selections of it collected from the wild have flowered and fruited throughout the hot summers at Glenn Dale and Beltsville, Maryland. This response to climate seems quite different from that of cultivated everbearing varieties which flower and fruit freely only in northern states where the weather is relatively cool.

Conclusions

The foregoing review of flower-bud formation and fruit production is a background from which to look at the strawberry industry, the genetic makeup of our varieties, and our research programs.

In 1955 fresh strawberries were available in the large markets of the United States every month of the year. Of course, the greatest quantity was available in late spring and early summer at the time of usual fruit production. However, during July, August, and September large quantities of strawberries were shipped from the coastal areas of California. This summer and fall supply has become increasingly important since 1945. In northern states everbearing varieties also supply some berries to the markets throughout the summer and fall. Though many other fruits are abundant in the summer and fall in California, large quantities of strawberries have been sold fresh during this period for many years in this area. It seems probable that eastern markets would take large quantities also, and the large shipments of the last few years from California to eastern markets seem to bear this out.

Perhaps the most important additions to the fresh-fruit markets could be made if ways could be found to make the production of everbearing varieties less risky and that of two-crop and of summer- and fall-crop varieties possible in certain areas, especially in western Washington and Oregon. For the coast of Oregon and Washington a new group of varieties might be bred that would fruit in the summer and fall much as the Shasta, Lassen, and other varieties do in coastal California. A second group might be bred for the area east of the coastal mountain range to give a second crop in fall. Second cropping in the autumn may be possible in some areas of our eastern states.

New varieties with different fruiting seasons are needed, and there seems to be abundant parental material. The gene for summer fruiting of *F. ovalis*, the wild strawberry of western North America, has not been integrated with genes for other desirable characters into cultivated varieties, and may be useful in giving flower-bud formation in hot weather. Selections of *F. chiloensis* and *F. virginiana* may have useful genes for out-of-season flowering and fruiting. The usefulness of the two-crop varieties of Europe in breeding for second-crop production also needs exploring. Though high yields have been obtained by mulching everbearing varieties throughout the year, severe losses of plants occur under such mulching. Research to control such losses is needed to determine whether two-crop varieties are worth breeding. Clear appraisal of the strawberry situation in each region should indicate the research lines most needed for modern production practices.