Flower development and anthesis

- Differentiation of the flowers on the inflorescences starts near the time of budburst as soil and air temperatures begin to rise, which also means that the full cropping potential of the vine has been realized.

- The pollen sacs in the anthers mature shortly before capfall, as does the receptivity of the style itself. The mechanical disruption caused by the movement of the cap off the ovary and style means that grapes are mostly selfpollinated.

- Capfall has been associated with a certain number of nodes on the flower cluster's shoot, though the number seems to vary between cultivars. However ...

- When the shoots have approximately 15-17 nodes formed on them, the flowers begin to open and the calyptra fall from the rest of the flower.

Plate 8. Anthesis (cap fall) in a flower cluster. This is the first day any of the florets have opened on this flower cluster.

- The duration of flowering is also highly dependent on the environment at the time.
- Cool, overcast weather, associated with rainfall, lengthens the flowering period, whereas warm and sunny conditions hasten it.
- Thus, flowering can occur over a period of a few days to longer than a month.

- Capfall occurs mainly in the morning hours, with the highest rate occurring between 7.00 and 9.00, and the final ones falling by 12.00. This is thought to be a result of changes in turgor pressure within the cells in the calyptra’s abscission zone.


Photo source: commons.wikimedia.org

Unlike many other perennial woody crops, grapes flower long after budbreak. As it takes some time for the shoot to develop leaves that are capable of supplying the carbohydrate needs of the rest of the vine, it is critical that enough stored carbohydrate is available to support the development of shoots, roots and flower clusters. If there is not, then it is the flower clusters that suffer the most, as they can drop off the vine due to a lack of available carbohydrate.

- The flowering and fruit set process in grapes is very weather dependent.
- Pollination is mostly by wind, though insects may also contribute.
- Self-pollination, occurring as the cap comes off the ovary, is the norm
- Some studies have suggested that cross-pollination results in bigger fruit and higher seed counts.

- Airborne pollen counts have been used as a predictor for fruit set in some grape-growing areas as there is a good correlation between pollen in the air and fruit set, but this may be due to more pollen being released when the weather is warmer and dry, which is generally conducive to fruit set.

Grape pollination

- Concord and vinifera grapes are self pollinating
- Muscadines: some varieties need cross pollination
  - Scuppernong, Fry, Noble, Nesbitt, Jumbo, Hunt
- Self-fruitful: Carlos, Cowart, Dixiland, Southland

- تعدادی از ارقام انگور ماده فیزیولوژیک (ماده با پرچم واژگون) کشور:

چاوه گا، قره گندمه، قزل اوزوم ارومیه، الحقی، ساچاخ، یزندائی، خلیلی قرمز، کرلو، پرال قونقور، شرشره، سیاه سمرقندی،

- از کشت یکدست این ارقام انگور جدا خودداری شود چون بدون وجود گرده سایر ارقام قادر به تولید میوه نی□تند

Fertilization occurs 2-3 days after pollination, as the pollen tube must grow (a highly temperature-dependent process) down through the style and up into the micropyle in a 'J' shape.

Fig. 3.3. Growth of pollen tubes (lighter paths through the style) from stigmatic surface to the micropyle, shown using a fluorescent dye (image courtesy of M. Longbottom).

- **Even relatively brief spells of cool temperatures cause degeneration of embryos and decrease the chance of fruit set**, which goes some way to explaining why this is a problem in cool climate grape-growing areas.

- Typical success rates for fruit set may be in the 30-45% range.

- Flower clusters may contain from just a few to more than 1000 flowers, depending on conditions at flower cluster initiation and cultivar.

- Once viable pollen lands on a receptive stigmatic surface, a germ tube emerges from the pollen grain within a short period of time, as little as 30 min. It then begins to grow down through the style to the micropyle, following a 'J'-shaped path.

- **The speed at which the pollen tube grows is very much dependent on the temperature**, with colder temperatures resulting in drastically lower rates of elongation. (the size of the flower, and thus the length the pollen tube).

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Plate 13. Close up of grapevine flowers, showing a moist stigmatic surface on the open one. Once the tip of the ovary has dried out it is no longer receptive to pollen tube growth.

- Commonly, one or two seeds are found per berry in *V. vinifera* fruit, usually more than two on average for *V. labrusca* .

- There is considerable variation between cultivars.

- Berry size seems to be driven initially by the presence or absence of seeds, and then by the mass of seed within the berry rather than just the number of seed.

- In terms of vine yield, it is most important to have at least one viable seed.

Once fruit is set on the vine, it is unlikely that the vine will lose it. Apple and other tree fruit crops have one or more times of the year when the crop abscises naturally; however, with grape the fruit cannot be dropped, and the vine is pretty much committed to bringing it to maturity. As such, after fruit set it becomes the most important destination for the vine's carbohydrate supply, as carbon radio-tracer studies have shown.

Fruit Growth

Berry development commences after successful pollination and fertilization of ovules within a flower. Flowers with unfertilized ovules soon shrivel and die, while those remaining begin growth into berries. Many of these tiny berries, *abscise* (drop off) within the first two to three weeks. Following this drop period (called *shatter*), the retained berries generally continue to develop to maturity. Commonly, only 20–30% of flowers on a cluster develop into mature berries, but this is adequate to produce a full cluster of fruit.

Berry growth occurs in three general stages—rapid initial growth, followed by a shorter period of slow growth, and finishing with another period of rapid growth. A graph of grape berry growth thus appears as a double sigmoid pattern. Berry growth during the first stage is due to a rapid increase in cell numbers during the first three to four weeks, followed by two to three weeks of rapid cell enlargement. During this stage the berries are firm, dark green in color, and rapidly accumulating acid. Seeds have attained their full size by the end of the first growth stage.

The middle stage, called the *lag phase*, is a time of slow growth. The embryo is rapidly developing within each seed, and the seed coat becomes hardened. Berries reach their highest level of acid content and begin to accumulate sugar slowly. Toward the end of lag phase, berries undergo a reduction in chlorophyll content, causing their color to change to a lighter green.

The final stage of berry growth coincides with the beginning of fruit maturation *(ripening)*. The beginning of ripening, referred to by the French term *veraison*, is discernable by the start of color development and softening of the berry. The color change is most easily visible on dark-colored varieties, but "white" varieties continue to become lighter green, and some varieties turn a yellowish or whitish-green color by harvest. Softening of the berry and rapid sugar accumulation occur abruptly and simultaneously. Berry growth, occurring by cell enlargement, becomes rapid again in this final stage of ripening. It is thought that most of the water entering the berry after veraison comes from phloem sap, since xylem at the junction of the berry and its *pedicel* (stem) appears to become blocked at this time (Coombe, 1992).

During ripening, acid content declines and sugar content increases. It is widely believed that flavors develop in the later stages of ripening. Berries begin to accumulate sugar rapidly at the start of the ripening period, and the rate tends to remain steady until accumulation slows as the end of the maturation period is approached. Sugar is translocated as sucrose to the fruit, where it is quickly converted into glucose and fructose. Both sugars and acids primarily accumulate in cells constituting the *pulp* (flesh) of the berry, although a small amount of sugar accumulates in the skin.

The skin (epidermis) and the thin tissue layer immediately below it contain most of the color, aroma and flavor constituents, and tannins contained in the berry. Thus, all things being equal, small berries have greater color, tannins, and flavor constituents than large berries because the skin constitutes a larger percentage of the total mass of small berries. Seeds also contain tannins that can contribute to the overall astringency of wine.

The chemical composition of grape berries is complex, consisting of hundreds of compounds, many in tiny quantities, which may contribute to fruit quality attributes. The single largest component is water, followed by the sugars fructose and glucose, then the acids tartaric and malic. Other important classes of chemical compounds within grape berries include amino acids, proteins, phenolics, anthocyanins, and flavonols.

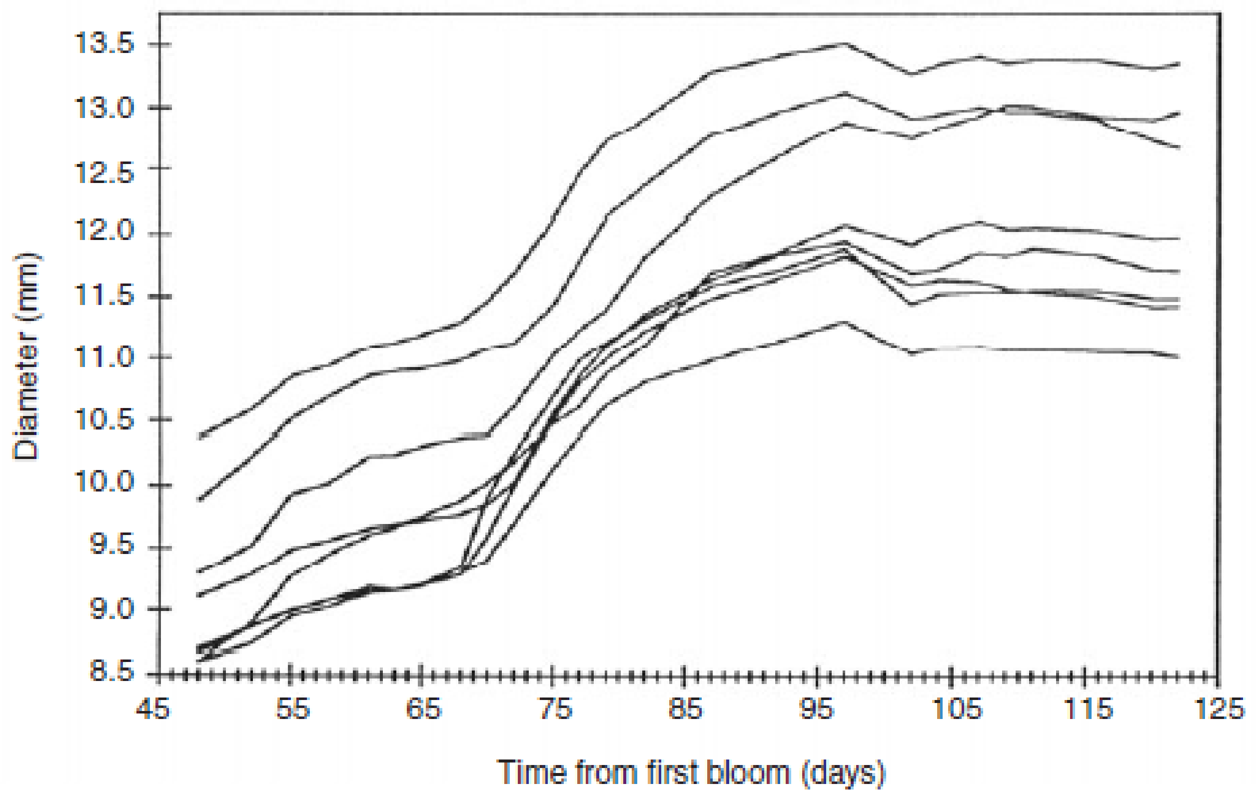


Fig. 3.4. Individual growth curves (by measurement of diameter) for eight grape berries, demonstrating the double-sigmoid shape characteristic of seeded fruit (from Creasy, 1991).

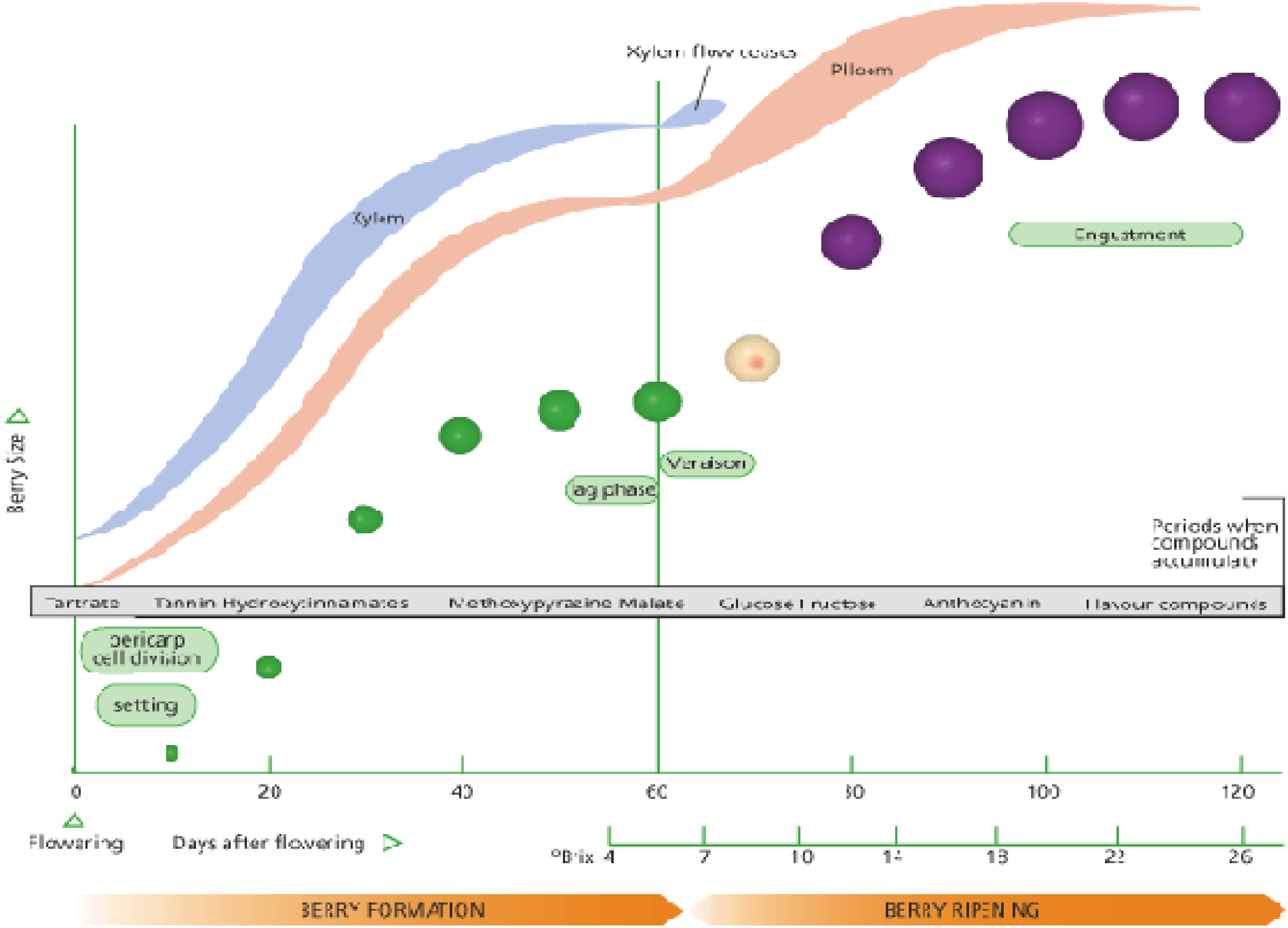
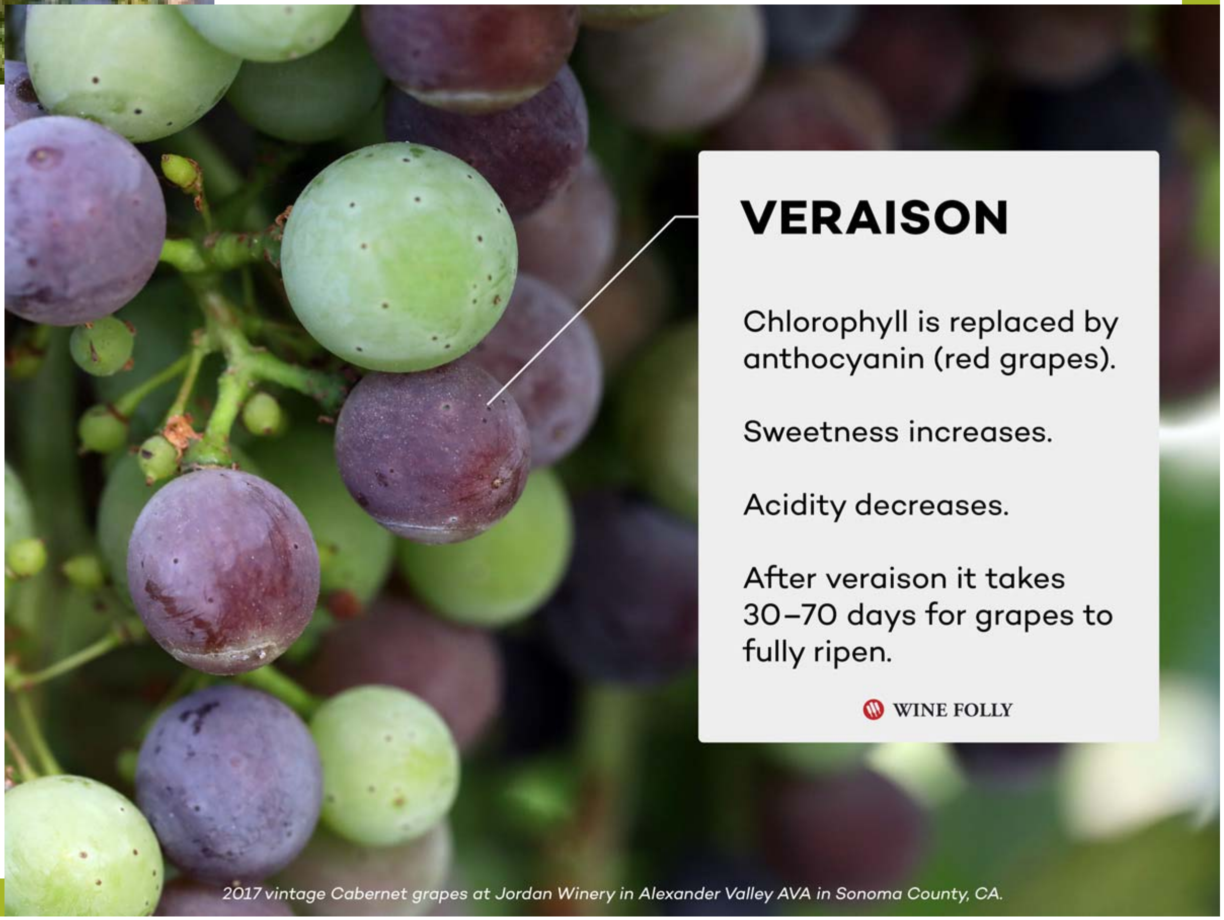


Figure 2: Diagram showing relative size and colour of berries at 10-day intervals after flowering, passing through major developmental events (rounded boxes). Also shown are the periods when compounds accumulate, the levels of juice °brix, and an indication of the rate of inflow of xylem and phloem vascular saps into the berry. Illustration by Jordan Koutroumanidis, Winetitles.



2017 vintage Cabernet grapes at Jordan Winery in Alexander Valley AVA in Sonoma County, CA.

- In Phase 1 of growth there is no significant accumulation of sugars in the berry, as much of the photoassimilate is used for cell division and expansion.
- However, there is an accumulation of organic acids, primarily malic and tartaric, the latter of which is relatively unusual in fruit crops.
- The duration of Phase I seems to be similar for most grape cultivars, while that for Stage II can vary considerably depending on cultivar, management and environment.
- Many characteristics in the grape change in the period leading up to maturity

The chemical composition of grape berries is complex, consisting of hundreds of compounds, many in tiny quantities, which may contribute to fruit quality attributes. The single largest component is water, followed by the sugars fructose and glucose, then the acids tartaric and malic. Other important classes of chemical compounds within grape berries include amino acids, proteins, phenolics, anthocyanins, and flavonols.

- The primary component of mature grapes is water, making up about 75-85% of their weight
- Approximately 15-25% is in the form of sugar, a higher percentage than in many other fresh fruits.
- The organic acids tartaric, malic and citric make up 0.5-1.0% of the fruit,
- pectin about 0.25% and there is a long list of other nutritional components.

Ripeness factors of the fruit that are typically considered when scheduling harvest are sugar content, acid content, pH, color, and flavor. The combination of these factors determines the *fruit quality* of the harvest. Ripening processes in the fruit cease upon harvest, but while fruit is on the vine ripening is a continuous process. So there is usually a short time, influenced by weather, during which the fruit remains within the desired ripeness parameters. Berries can become *overripe* if harvest is delayed until the fruit has developed beyond the desired range of ripeness. Consider also that ripeness parameters can vary considerably depending on the intended use.

Fruit ripening can be delayed, and the attainment of desired ripeness parameters inhibited, by an excessive *crop load* (amount of fruit per vine). A vine that is allowed to produce more fruit than it can develop to the desired level of ripeness is considered to be *overcropped*. Severe overcropping can negatively impact vine health as well as fruit quality

- **There are several measurable parameters in grapes that relate in some way to quality factors**
- measure of sugar concentration (°Brix)
- Specific gravity (density of a Solution)
- the amount of acid (titrating a sample of juice)
- ratio of sugar to acid (usually °Brix:TA)
- concentration of hydrogen ions (H+) in a solution (pH)

(is important for the biological stability of grape juice and wine as well as having an effect on the ionic forms of some molecules, such as anthocyanins, affecting their colour)

- Other factors, such as physical damage, presence of disease or non-grape materials (leaves, stems, insects, sand, etc.). These can often be measured objectively. For example, the level of botrytis infection in grapes can be estimated by measuring the amount (or activity) of the enzyme laccase in the juice.

Baumé?

Oechsle?

- Evolutionarily speaking, the seeds within the fruit are the most important part of the vine: the vine produces seed to propagate and spread the offspring.

- So how have seedless berries come about?
- Random mutations can cause a vine to arise that has seedless berries. In addition, some crosses of plants can result in sterile offspring, so a seeded cultivar pollinating another seeded cultivar may result in a seedless offspring.

- In most cases seedless cultivars are not, in fact, really seedless.

- Many of the popular seedless table grapes are stenospermocarpic. The flowers are pollinated and the embryos fertilized, but soon after the embryo aborts;

- however, in the time that the fertilized embryo is developing, it produces enough plant growth regulators to encourage growth of a large berry.

- In some cases there may be something that looks like a viable seed, but is in fact the lignified shell of a seed with no embryo within.

- Parthenocarpy, a process that requires pollination but not fertilization to set fruit, does occur with cultivars like 'Black Corinth' (syn. 'Zante Current)',

Fig. 3.6. Seed remnants within a seedless table grape ('Perlette').

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Plate 14. A Black Corinth / Zante Current cluster showing the small size of the parthenocarpic berries.

Factors influencing fruit set

- There are many factors that will affect the percentage fruit set in grapevine.
- Among the most important are:
- **availability of light,**
- **moderate temperatures**
- **dry weather**.

- The grapevine grows in the wild, as the vine is vegetative until it has grown up the tree trunks and emerged into the higher light levels in the canopy above.
- Older vines (having more permanent wood than younger vines) perform better. (stored carbohydrates are more important).
- As flowering occurs early in the season, water is usually available in the soil profile, and stress must be actively avoided in only the driest of regions, or in those areas with soils of very low water-holding capacity.

- Deficiencies in certain nutrients can also reduce fruit set, chief among them being zinc and boron.

One physiological disorder that is probably connected to a lack of available carbohydrate is early bunchstem necrosis (syn. inflorescence necrosis). This fruit set problem results in the loss of individual flowers, branches of flower clusters or even entire flower clusters in the weeks leading up to and including the fruit set period (Jackson and Coombe, 1988; Ibacache, 1990; Plate 15). It is thought that this problem is a result of a build-up of toxic ammonium in the flower cluster tissues because of an inability of those tissues to convert ammonium to the amino acid glutamate – a process that requires carbohydrates (Jordan *et al*., 1993). Its appearance is sporadic and difficult to predict, but can have a significant effect on yields.

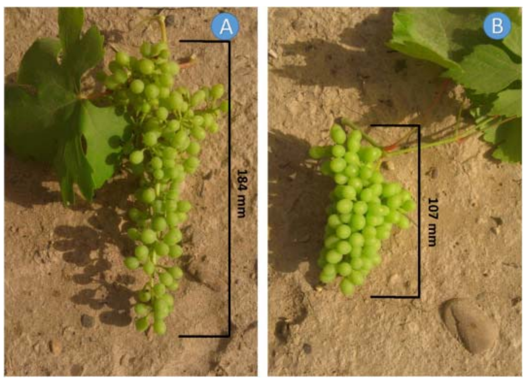
Girdling

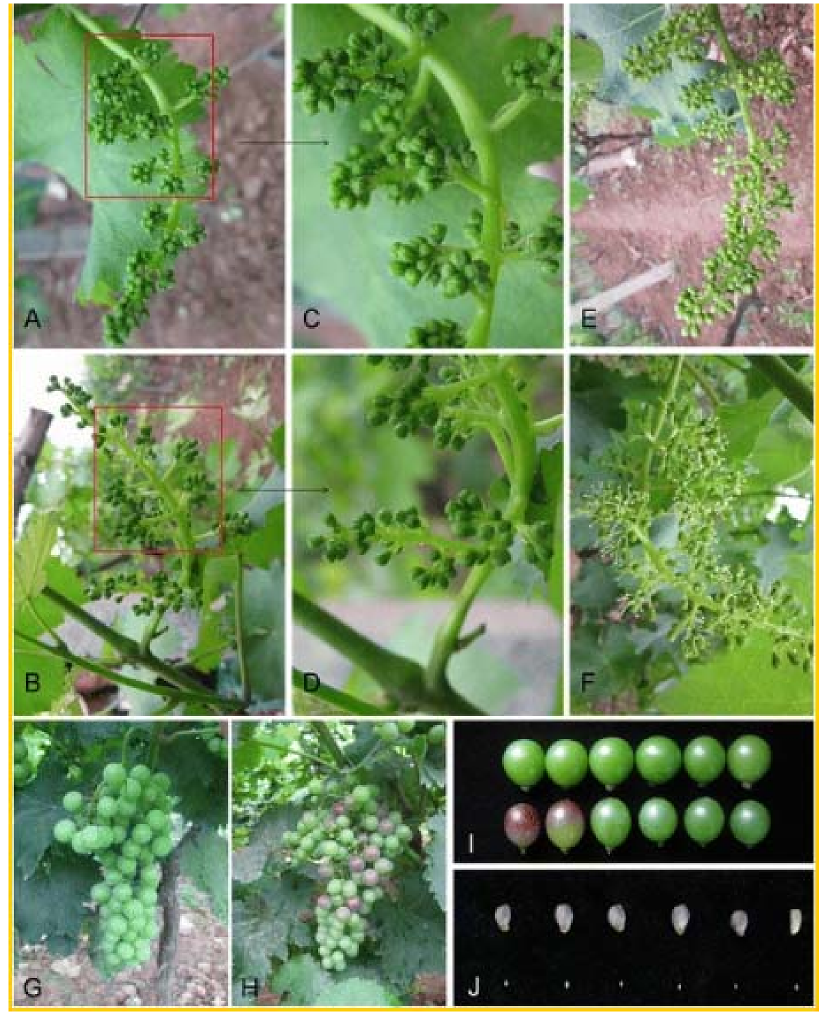
Topping and tipping

Zinc application

Pre-bloom is time for micronutrients primarily. This is the best and usually the only time that micronutrients are applied and the application method is usually foliar. Commonly, boron and zinc are applied at this time, but some vineyards have benefitted from an application of molybdenum as well

- Plant growth regulators





- **Inflorescences, clusters, berries and seeds from grape cv. 'Kyoho' following GA_3 application. (A and B)** Inflorescences from untreated control **(A)** and GA_3-treated **(B)** plants 72 h after treatment; **(C** and **D)** Magnification of the portions of **(A)** and **(B)** enclosed in a red frame, respectively; **(E and F)** Inflorescences from untreated control **(E)** and GA_3-treated **(F)** plants 8 d after treatment. **(G and H)** Clusters from untreated control **(G)** and GA_3-treated **(H)** plants 57 d after treatment (45 d after full bloom, DAF); **(I)** Berries from untreated control (top-row) and GA_3-treated (bottom-row) plants 57 d after treatment (45 DAF); **(J)** Seeds from untreated control (top-row) and GA_3-treated (bottom-row) plants at maturity.

Factors influencing fruit quality

Crop load regulation

- Winter pruning
- Shoot thining
- Fruit/cluster thining

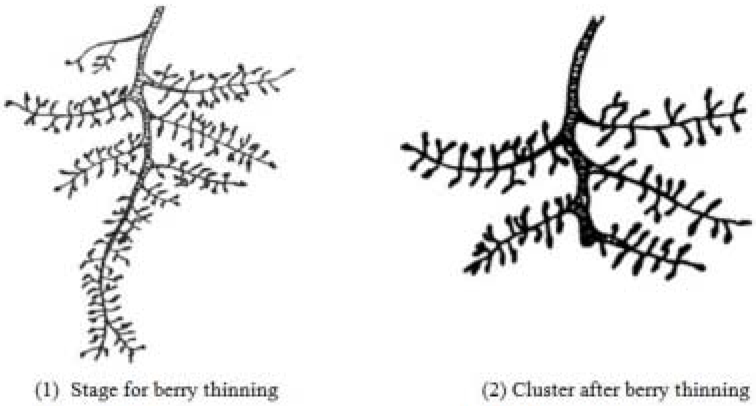


Fig. 1: cluster before and after berry thinning according to HERRERA (2002).

a Control (no thinning);
b Flower-cluster thinning or brushing, prior to anthesis;
c Berry-cluster thinning, when berries were 3–6 mm in diameter;
d Berry-cluster thinning, when berries were 7–10 mm in diameter;
e Berry-cluster thinning, when berries were 11–15 mm in diameter; and
f Berry-cluster thinning, when berries were 16–18 mm in diameter.

To aid in understanding, the main parts of a grape bunch are illustrated in Fig. 1 (Dokoozlian, 2000).

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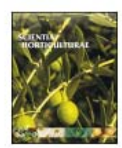


Berry-cluster thinning to prevent bunch compactness of 'BRS Vitoria', a new black seedless grape

CrossMark

Sergio Ruffo Roberto[a,*], Wellington Fernando Silva Borges[a], Ronan Carlos Colombo[a], Renata Koyama[a], Ibrar Hussain[a], Reginaldo Teodoro de Souza[b]

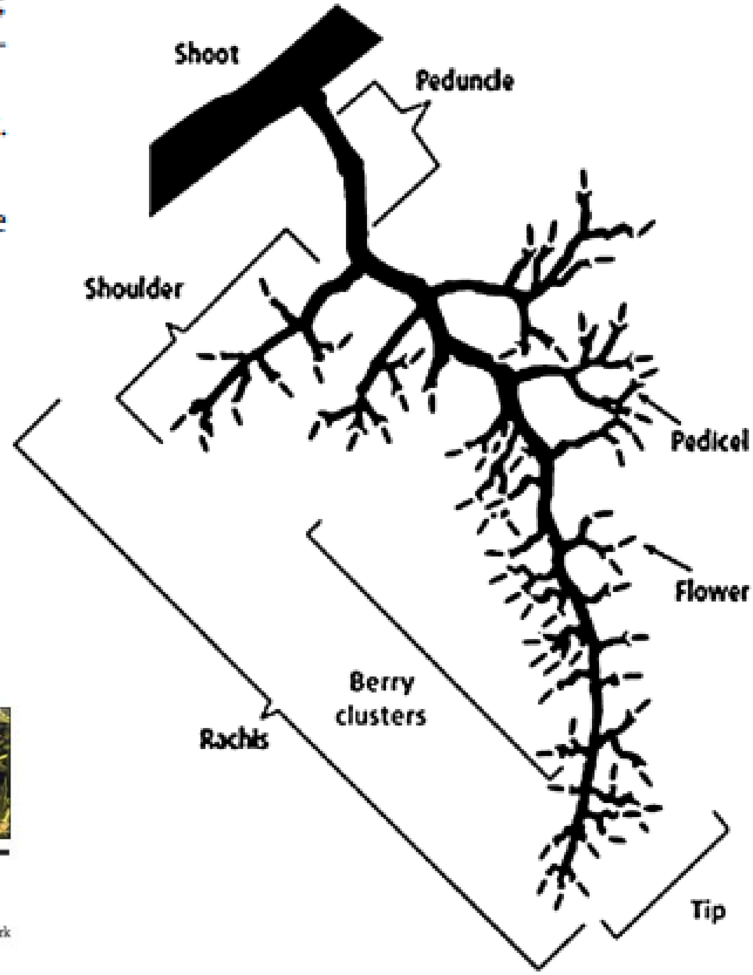


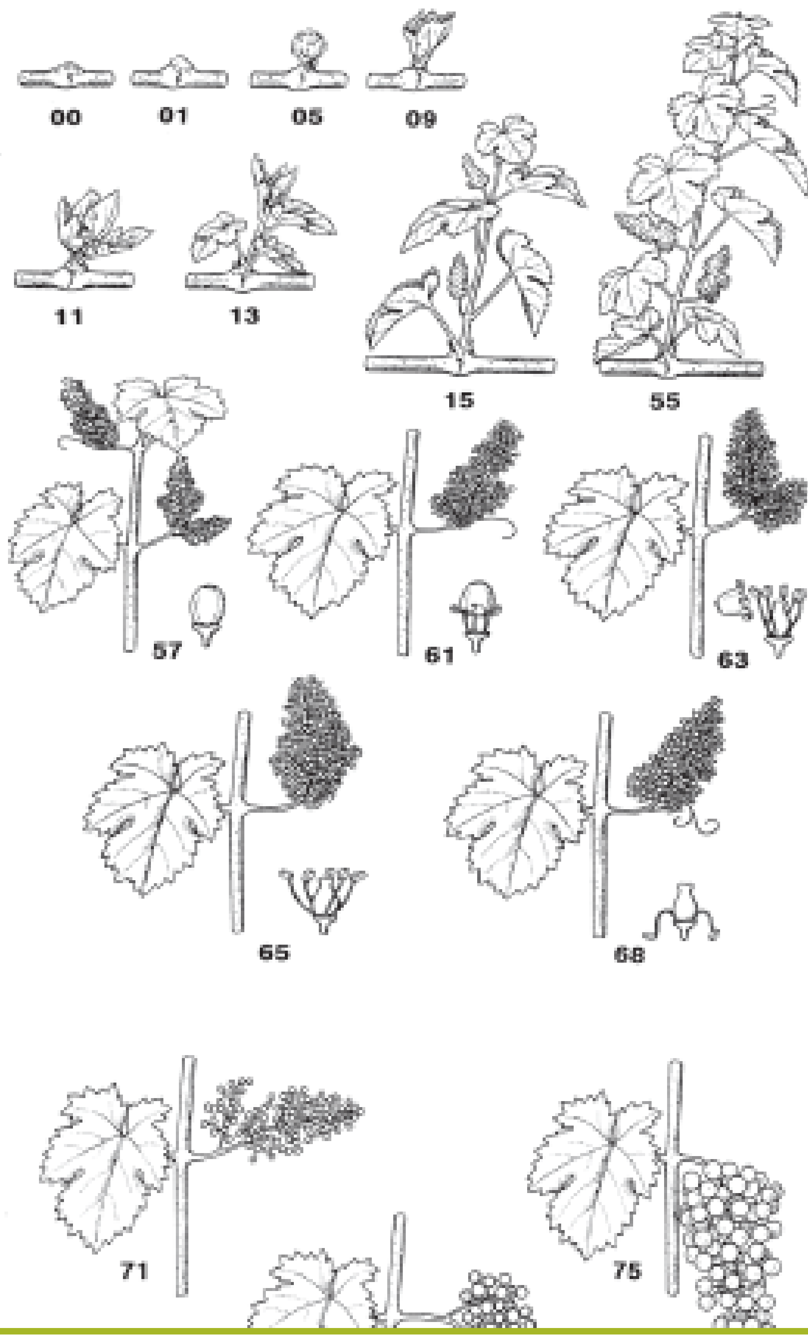
Fig. 1. The main parts of a grape bunch.

- Leaf removal

- Ethylene/ABA application

- Plant growth regulators (PGRs), such as gibberellic acid (GA_3) or forchlorfenuron (CPPU), to increase berry size, may further suppress color. Therefore, to ensure timely and uniform color development, it is often necessary to apply other PGRs.
- The most widely used PGR for improving grape berry color is ethephon (Ethrel). The degradation of ethephon releases ethylene, a plant hormone that stimulates pigment accumulation in grapes. One or two pints of Ethrel® is applied at veraison (5%-30% berry color) in a spray volume that is sufficient to achieve thorough fruit coverage. Late or excessive applications of ethephon can result in soft berries, which decreases their post-harvest shelf life.
- Recently, another active ingredient, abscisic acid (ABA), has become available as an agrochemical (ProTone™, Valent BioSciences, Libertyville, IL). Like ethephon, the application of ABA accelerates and improves the coloring of grapes (Figure 1). Abscisic acid is generally applied at veraison, when about 50% of the berries have softened, but post-veraison applications also may be effective. Typical applications range from 75 to 250 grams of active ingredient (g/a.i.) per acre, in a spray volume that is sufficient to ensure thorough coverage of the clusters. Suboptimal coverage may result in unsatisfactory results.
- **Caution**: Plant growth regulators (PGRs), including ethephon and abscisic acid, are classified as pesticides and are subject to the same rigorous regulatory framework. Plant growth regulators may not be approved for grapes in certain regions, or for particular cultivars of grapes.

Figure 1. 'Crimson Seedless' grapes that received no PGRs for color improvement (left column), or increasing concentration of ABA (middle and right columns). *Photo by Cecilia Peppi, University of California.*



Principal growth stage 0: Sprouting/Bud development

00 Dormancy: buds pointed to round, light or dark brown according to variety; bud scales more or less closed according to variety

01 Beginning of bud swelling: buds begin to expand inside the bud scales

03 End of bud swelling: buds swollen, but not green

05 "Wool Stage": brown wool clearly visible

07 Beginning of bud burst: green shoot tips just visible

08 Bud burst: green shoot tips clearly visible

Principal growth stage 1: Leaf development

11 First leaf unfolded and spread away from shoot

12 2nd leaves unfolded

13 3rd leaves unfolded

14 Stages continuous until...

19 9 or more leaves unfolded

Principal growth stage 5: Inflorescence emerge

53 Inflorescences clearly visible

55 Inflorescences swelling, flowers closely pressed together

57 Inflorescences fully developed; flowers separating

Principal growth stage 6: Flowering

60 First caps detached from the receptacle

61 Beginning of flowering: 10% of caps fallen

62 20% of caps fallen

63 Early flowering: 30% of caps fallen

64 40% of caps fallen

65 Full flowering: 50% of caps fallen

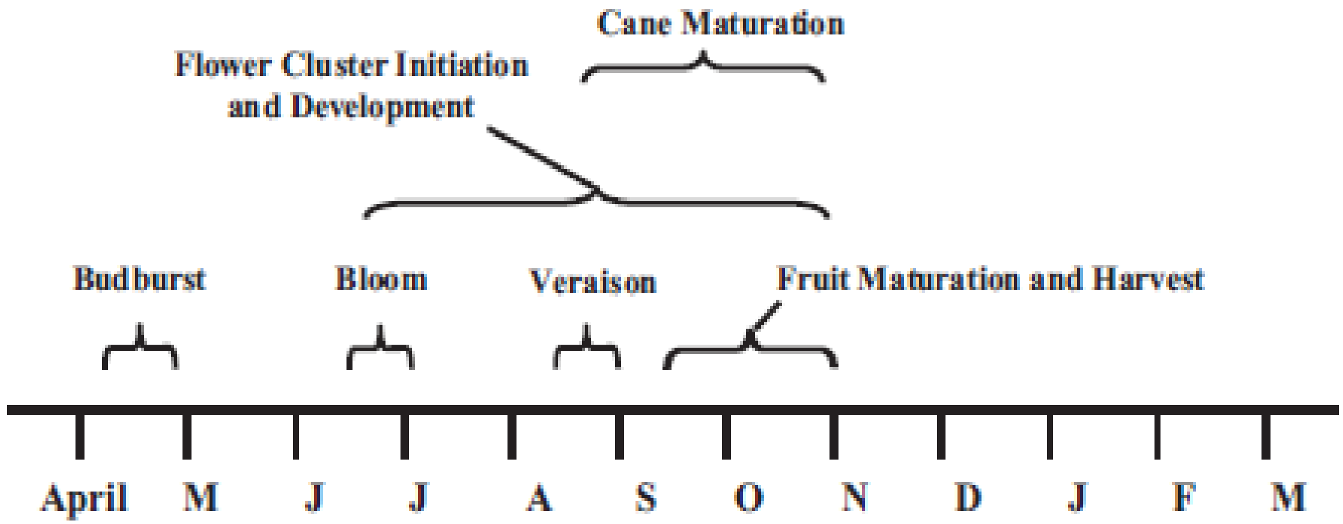
66 60% of caps fallen

67 70% of caps fallen

68 80% of caps fallen

69 End of flowering

Figure 8. Annual cycle of grapevine growth.Figure by Ed Hellman.



Dormancy, Acclimation and Cold Hardiness

- در پاییز، Vine وارد دوره رکود dormancy می‌شود.
- مقابله با آسیب توسط سرما
- توانایی تاک خواب برای تحمل دمای سرد Cold hardiness گفته می-شود.
- مقاومت به سرما در انگور شدیدا دینامیک و تحت تأثیر شرایط محیطی و رشد، ارقام، بافتهای مختلف و زمان است. (نمی‌توان به صورت مطلق بیان کرد که مثلاً واریته X تا 20- درجه سانتی گراد به سرما مقاوم است)

سه مرحله فصل رکود عبارتند از:

-acclimation: دوره انتقال از شرایط غیر مقاوم (non-hardy) به شرایط مقاومت کامل Full hardy .

- midwinter : دوره شدیدترین سرما و بیشترین مقاومت به سرما

-deacclimation: دوره انتقال از مقاومت کامل به شرایط غیر مقاوم و رشد فعال.

- Acclimation یک فرایند تدریجی است که بعد از پایان یافتن رشد Shoot شروع می‌شود و در تمام پاییز و اوایل زمستان ادامه می‌یابد.
- ترکیب روز کوتاه و کاهش دما در پاییز فاکتورهای مهمی هستند که بر خوگیری و مقاومت به سرما اثر می‌گذارند.
- فرایند خوگیری در انگور در برگیرنده تعداد زیادی فعالیت همزمان است که در مجموع باعث افزایش مقاومت به سرما می‌شوند. مقدار آب برخی بافت‌ها کاهش می‌یابد در حالی‌که مقدار مواد جامد حل شونده Soluteها افزایش می‌یابد، در نفوذپذیری غشا و ثبات دمایی thermal stability تعدادی آنزیم‌ها هم افزایش دیده می‌شود و در نتیجه تمام این فرایندها مقاومت به دماهای زیر صفر زمستان است.

Supercooling vs. **Tolerate ice and increased solutes**

Because of the different mechanisms involved, tissues vary in tolerance to freezing temperatures. Woody tissues of the trunk, cordon, and canes generally have greater cold hardiness than dormant buds and roots. In comparisons of grapevine woody tissues, the vascular cambium is thought to be the last tissue to be damaged by cold temperatures, followed in sequence by younger xylem, older xylem, and phloem (Wample et al., 2000). Within dormant buds, primary buds are typically less cold hardy than secondary buds, and tertiary buds are the most hardy.

Poor management practices or growing conditions can inhibit the acclimation process, resulting in reduced cold hardiness.

Acclimation is promoted by exposure of shoots and leaves to sunlight and is associated with periderm development and low relative water content.

Reduced hardiness has been associated with large, dense (shaded) canopies, canes with either long internodes or large internode diameter, and canes with large persistent lateral canes.

Additionally, heavy fruit loads or defoliation (early leaf fall due to stress, disease, or pest activity) inhibit acclimation, probably through reduced availability of photosynthates.

neither nitrogen fertilization nor irrigation practices reduce grapevine cold hardiness, unless nonstandard practices are used that encourage continued late-season growth, which inhibits acclimation

Cold hardiness of buds is fairly stable through the winter months, but sharp increases in temperature can cause buds to deacclimate and lose hardiness, and the extent of deacclimation can vary by variety or species. Bud hardiness has been correlated with air temperature of the preceding five-day period. Cold hardiness decreases as the grapevine rapidly de-acclimates in response to warm temperatures in the spring. Deacclimation is much less gradual than cold acclimation in the fall, and the rate of deacclimation accelerates through the dormant season.

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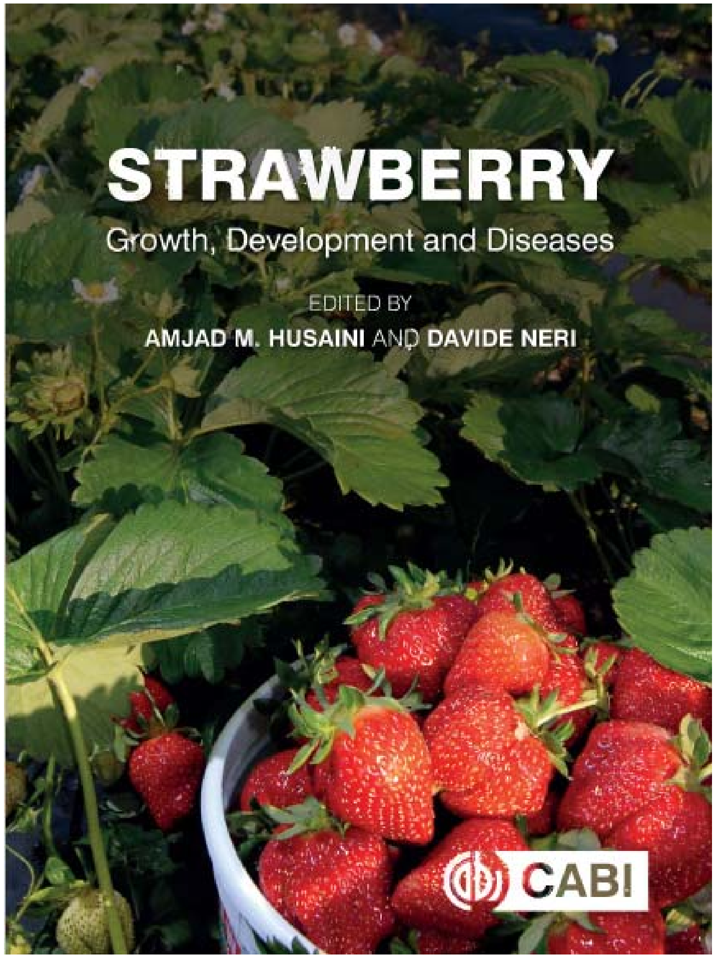
20

Plate 19. Spring frost-affected grapevine shoots. One (centre), however, seemed to escape damage and is pushing forth.

Plate 20. Yellowing of leaves caused by early season sub-lethal cold temperatures while the leaf tissues were developing in the bud.

26 فروردین 97


Strawberry



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Ch. 1 Strawberries: a General Account

1-1 Origin and History of strawberry cultivation

- The genus *Fragaria*
- Family Rosaceae.
- Recorded history of the *Fragas* dates back to 23–79 ad.

Northern Europe, including France, cultivated the woodland strawberry, *Fragaria vesca* (L.), as early as 1300. It was appreciated as much for its flowers as for the fruit.

North America cultivated the native strawberry, *Fragaria virginiana*, which was a hardy plant with the ability to withstand cold temperature and drought. In the early 1600s, *F. virginiana* was imported to Europe.

In the 1700s, explorers found a wild strawberry in Chile, *Fragaria chiloensis*, which grew large fruit but was not well suited to a wide range of climates.

Additionally, musky strawberries, *Fragaria moschata*, were also cultivated in Europe and Russia for centuries. Musky strawberries are light red to purple, and have a strong vinous flavour like Muscat grapes.

Fragaria chiloensis

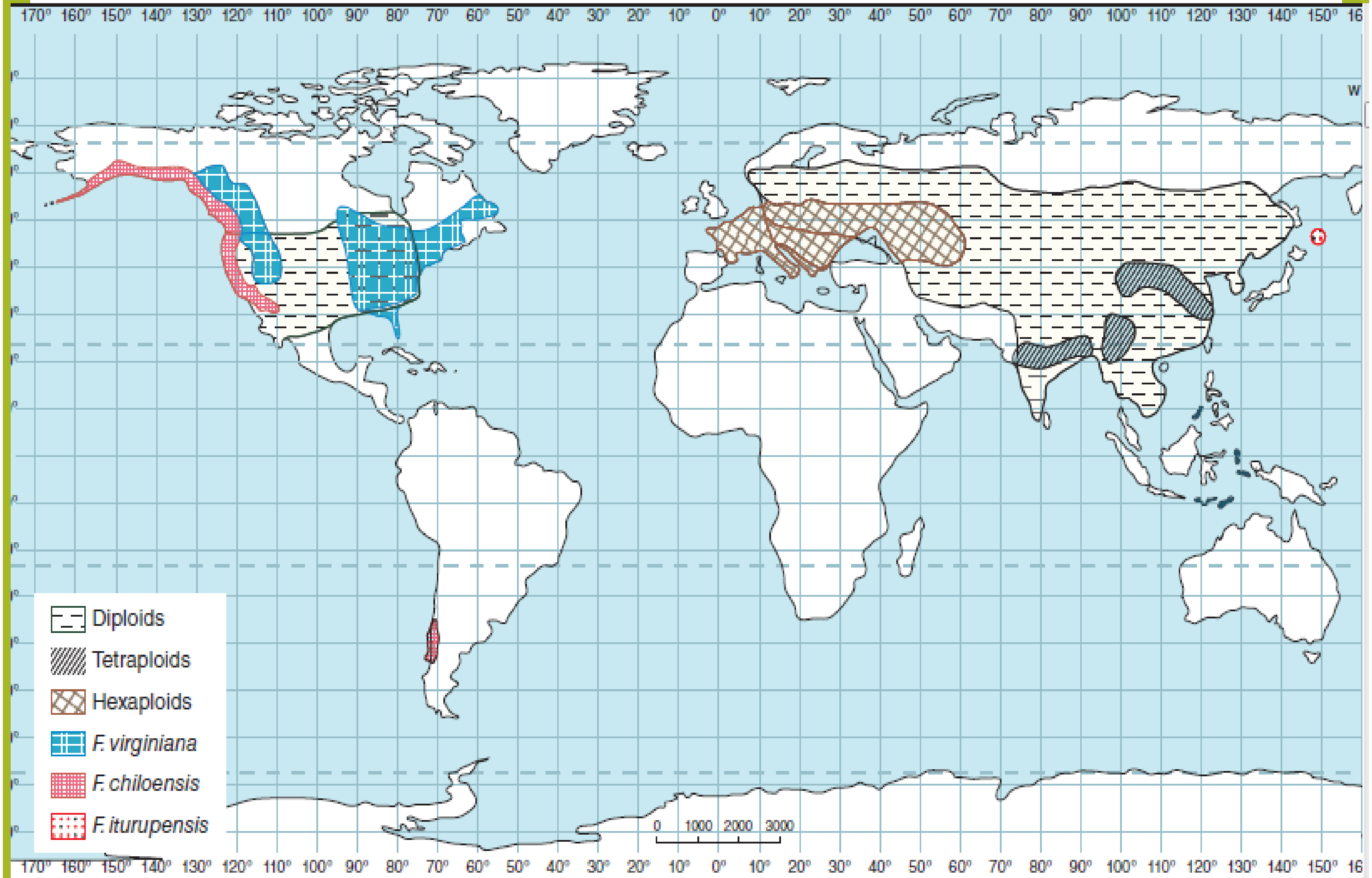
Fragaria vesca L.

Fragaria moschata

Fragaria virginiana

- In 1714, the most important event in the history of the modern strawberry took place.

- Amedee-Francois Frezier, a member of the French army, ...



g. 2.1. World distribution of *Fragaria* spp.

1.2. Taxonomy and Biology

The French botanist Antoine Nicolas Duchesne is credited with identification of the natural hybrid *Fragaria* × *ananassa*.

The cultivated strawberry *F.* . *ananassa* Duch. is a member of the family Rosaceae, subfamily Rosoideae, along with blackberries and raspberries.

There are about 34 species of *Fragaria* found in Asia, America (North and South) and Europe, of which two are cultivated commercially for their fruit:

F. moschata, the musky or Hautboy strawberry,
F. vesca, the woodland or alpine strawberry.

These species were cultivated for centuries, but there is very little production of them today, due to the success of *F.* . *ananassa*.

Strawberries can be diploid, tetraploid, hexaploid, octoploid and even decaploid.

2X: The woodland strawberry, *F. vesca*, and most of the native species around the world are diploid. (They range from dioecious to hermaphroditic and self-fertile to self-incompatible).

3X: *Fragaria moupinensis*, *Fragaria orientalis*, and *Fragaria corymbosa*.

6X: *F. moschata* is a hexaploid strawberry and is known for its musky flavour.

F. chiloensis and *F. virginiana* are both ?,

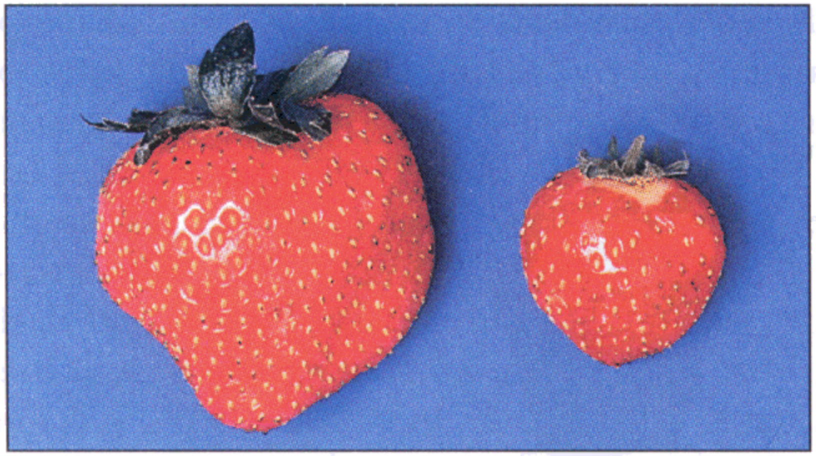
Fragaria moupinensis

Fragaria moupinensis - WikiVisually

This polyploidy of the *Fragaria* spp. makes selection of desirable traits via traditional breeding using cross-pollinationof the flowering plants **tedious and time consuming.**

Due to the difficulties imposed by the complicated octoploid genome on conventional breeding strategies, manipulation through recombinant DNA technology, Golden Gate cloning and CRISPR (clustered regularly interspaced short palindromic repeats)/Cas systems are favourable options in strawberry improvement.

The problem of strawberry fruit softening is a classic example of this kind of intervention by biotechnological tools. Genetic transformation has also improved strawberries for many traits that confer adaptive advantage to these plants such as the challenges imposed by climate change



8*x* 2x

1.3. Area, Production and Yield

Strawberry is a highly popular crop and is in great demand for fresh markets as well as in the fruit processing industry for preparing jams and other products.

Its popularity can be judged from the fact that the production of strawberries has increased considerably in recent years (Table 1.1, Figs 1.1–1.3).

Table 1.1. Total area and production of strawberry across major regions.

	Production (t)		Area (ha)	
Region	2003	2013	2003	2013
World	5,041,331	7,739,622	320,990	361,662
Europe	1,224,692	1,484,987	162,543	162,315
Asia	2,334,869	3,845,553	113,121	143,036
USA	977,945	1,360,869	19,587	23,549
Africa	184,582	417,135	6,250	10,671

Source: http://faostat.fao.org/.

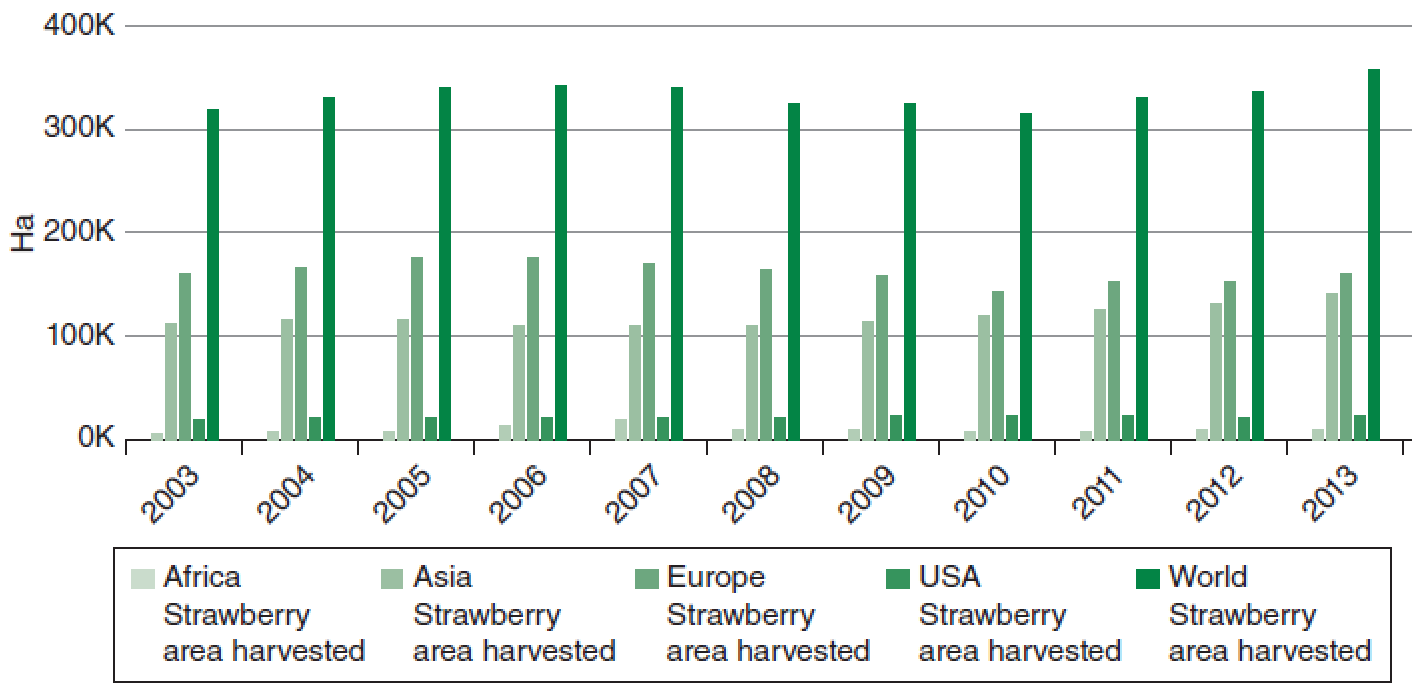


Fig. 1.1. Trend in strawberry area harvested across major regions. K, thousand.

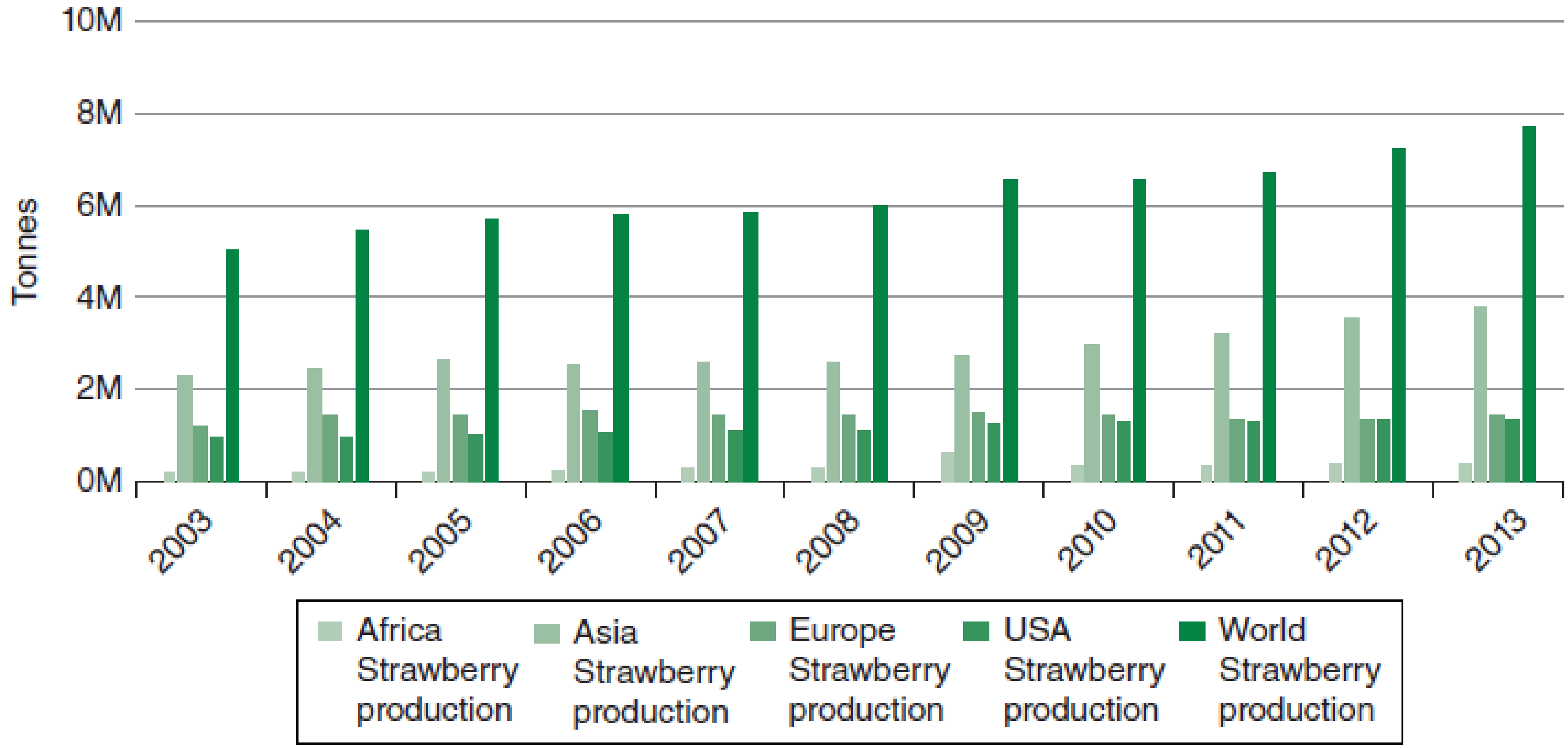


Fig. 1.3. Trend in strawberry production across major regions. M, million.

2013

China, mainland	**2997504**
United States of America	**1382096**
Mexico	**379464**
Turkey	**372498**
Spain	**312466**
Egypt	**262432**
Republic of Korea	**216803**
Poland	**192647**
Russian Federation	**188000**
Japan	**165600**
23. Iran (Islamic Republic of)	**39296**

1	Area	2017	Unit	Value
2	China, mainland		tonnes	3717283
3	United States of America		tonnes	1449280
4	Mexico		tonnes	658436
5	Egypt		tonnes	407240
6	Turkey		tonnes	400167
7	Spain		tonnes	360416
8	Republic of Korea		tonnes	210304
9	Poland		tonnes	177921
10	Russian Federation		tonnes	175652
11	Morocco		tonnes	161793
12	Japan		tonnes	158702
13	Germany		tonnes	135283
14	United Kingdom		tonnes	127623
15	Italy		tonnes	125335
16	Belarus		tonnes	79778
17	Netherlands		tonnes	66100
18	France		tonnes	59260
19	Greece		tonnes	58900
20	Colombia		tonnes	58751
21	Iran (Islamic Republic of)		tonnes	55621

1.4. Health-promoting Properties

In the past few years, the antioxidant power of fruit has been considered an indicator of the beneficial bioactive compounds present in foodstuffs and therefore of their healthfulness.

Indeed, strawberry **phenolics** are best known for their antioxidant and anti-inflammatory action, and possess direct and indirect antimicrobial, anti-allergy, and anti-hypertensive properties, as well as the capacity for inhibiting the activities of some physiological enzymes and receptors, preventing oxidative stress-related diseases.

The major class of strawberry polyphenols is flavonoids, mainly anthocyanins.

There is consolidated evidence to classify strawberries as a functional food with several preventive and therapeutic health benefits.

Strawberry phenolics are able to:

(i) detoxify free radicals, blocking their production;
(ii) modulate the expression of genes involved in metabolism, cell proliferation and antioxidant defence; and
(iii) protect and repair DNA damage

Of its many positive characteristics, the nutritional value of strawberries is nearly perfect (Table 1.2).

Eight medium strawberries contain more vitamin C than an orange, 20% of the recommended daily allowance for folic acid, no fat and no cholesterol, and are considered high in fibre.

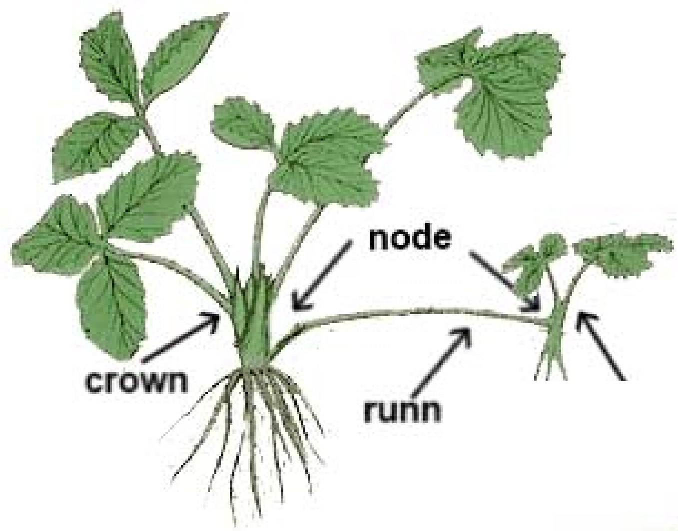
Another significant nutritional feature is the concentration of folate (24 μg per 100 g of fresh fruit): among fruit, strawberries are one of the richest natural sources of this indispensable micronutrient, which represents an essential factor in health promotion and disease prevention

Table 1.2. Nutritional composition of strawberry (*Fragaria* × *ananassa* Duch.). (From US Department of Agriculture: http://ndb.nal.usda.gov/ndb/search/list?qlookup=09316&format=Full.)

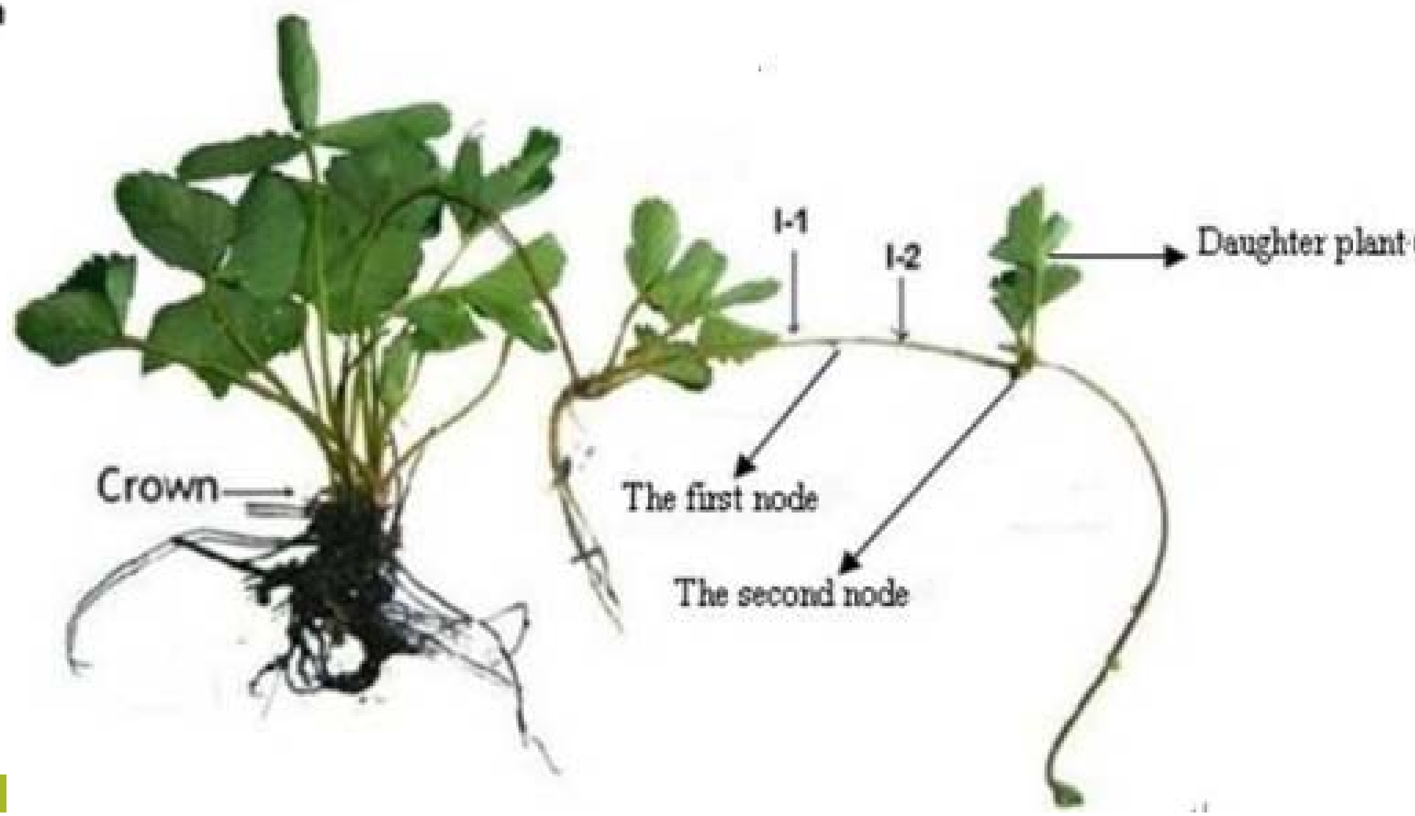
Component	Per 100 g	Standard error	Component	Per 100 g	Standard error
Nutrient			Lipids		
Water (g)	90.95	0.214	Fatty acids, total saturated (g)	0.015	–
Energy (kcal)	32	–	16:00 (g)	0.012	–
Energy (kJ)	136	–	18:00 (g)	0.003	–
Protein (g)	0.67	0.026	Fatty acids, total monounsaturated (g)	0.043	–
Total lipid (fat) (g)	0.3	0.047	16:1 undifferentiated (g)	0.001	–
Ash (g)	0.4	0.021	18:1 undifferentiated (g)	0.042	–
Carbohydrate, by difference (g)	7.68	–	Fatty acids, total polyunsaturated (g)	0.155	–
Fibre, total dietary (g)	2	0.152	18:2 undifferentiated (g)	0.09	–
Sugars, total (g)	4.89	–	18:3 undifferentiated (g)	0.065	–
Sucrose (g)	0.47	0.328	18:4 (g)	0	–
Glucose (dextrose) (g)	1.99	0.194	20:4 undifferentiated (g)	0	–
Fructose (g)	2.44	0.198	20:5 *n*-3 (EPA) (g)	0	–
Lactose (g)	0	0	22:5 *n*-3 (DPA) (g)	0	–
Maltose (g)	0	0	22:6 *n*-3 (DHA) (g)	0	–
Galactose (g)	0	0	Cholesterol (mg)	0	–
Starch (g)	0.04	0.029	Phytosterols (mg)	12	–
Vitamins			Amino acids		
Vitamin C, total ascorbic acid (mg)	58.8	2.473	Tryptophan (g)	0.008	–
Thiamin (mg)	0.024	0.003	Threonine (g)	0.02	–
Riboflavin (mg)	0.022	0.008	Isoleucine (g)	0.016	–
Niacin (mg)	0.386	0.037	Leucine (g)	0.034	–
Pantothenic acid (mg)	0.125	0.003	Lysine (g)	0.026	–
Vitamin B-6 (mg)	0.047	0.012	Methionine (g)	0.002	–
Folate, total (µg)	24	5.465	Cystine (g)	0.006	–
Folic acid (µg)	0	–	Phenylalanine (g)	0.019	–
Folate, food (µg)	24	5.465	Tyrosine (g)	0.022	–
Folate, DFE (µg)	24	–	Valine (g)	0.019	–
Choline, total (mg)	5.7	–	Arginine (g)	0.028	–
Betaine (mg)	0.2	–	Histidine (g)	0.012	–
Vitamin B-12 (µg)	0	–	Alanine (g)	0.033	–
Vitamin B-12, added (µg)	0	–	Aspartic acid (g)	0.149	–
Vitamin A, RAE (µg)	1	0.031	Glutamic acid (g)	0.098	–

Retinol (µg)	0	–	Glycine (g)	0.026	–
Carotene, β (µg)	7	0.22	Proline (g)	0.02	–
Carotene, α (µg)	0	0	Serine (g)	0.025	–
Cryptoxanthin, β (µg)	0	0	Minerals		
Vitamin A, (IU)	12	0.625	Calcium (Ca) (mg)	16	0.562
Lycopene (µg)	0	0	Iron (Fe) (mg)	0.41	0.026
Lutein + zeaxanthin (µg)	26	8.04	Magnesium (Mg) (mg)	13	0.222
Vitamin E (α-tocopherol) (µg)	0.29	0.024	Phosphorus (P) (mg)	24	0.72
Vitamin E, added (mg)	0	–	Potassium (K) (mg)	153	4.073
Tocopherol, β (mg)	0.01	0.002	Sodium (Na) (mg)	1	0.1
Tocopherol, γ (mg)	0.08	0.01	Zinc (Zn) (mg)	0.14	0.013
Tocopherol, δ (mg)	0.01	0.005	Copper (Cu) (mg)	0.048	0.004
Vitamin D (D2 + D3) (µg)	0	–	Manganese (Mn) (mg)	0.386	0.018
Vitamin D (IU)	0	–	Selenium (Se) (µg)	0.4	–
Vitamin K (phylloquinone) (µg)	2.2	0.29	Fluoride (F) (µg)	4.4	0.4
Anthocyanidins			Flavonols		
Petunidin (mg)	0.1	0.1	Isorhamnetin (mg)	0	–
Delphinidin (mg)	0.3	0.28	Kaempferol (mg)	0.5	0.01
Malvidin (mg)	0	0.01	Myricetin (mg)	0	0.04
Pelargonidin (mg)	24.8	0.69	Quercetin (mg)	1.1	0.04
Peonidin (mg)	0	0.05	Isoflavones		
Cyanidin (mg)	1.7	0.05	Daidzein (mg)	0	0
Flavan-3-ols			Genistein (mg)	0	0
(+)-Catechin (mg)	3.1	0.19	Glycitein (mg)	0	–
(–)-Epigallocatechin (mg)	0.8	0.35	Total isoflavones (mg)	0	0.005
(–)-Epicatechin (mg)	0.4	0.13	Formononetin (mg)	0	–
(–)-Epicatechin 3-gallate (mg)	0.2	0.02	Coumestrol (mg)	0	–
(–)-Epigallocatechin 3-gallate (mg)	0.1	0.06	Proanthocyanidin		
(+)-Gallocatechin (mg)	0	0.005	Proanthocyanidin monomers (mg)	3.7	0.8
Flavanones			Proanthocyanidin dimers (mg)	5.3	1.89
Hesperetin (mg)	0	0	Proanthocyanidin trimers (mg)	4.9	2.27
Naringenin (mg)	0.2	0.25	Proanthocyanidin 4–6mers (mg)	28.1	6.47
Flavones			Proanthocyanidin 7–10mers (mg)	23.9	3.47
Apigenin (mg)	0	0	Proanthocyanidin polymers (>10mers) (mg)	75.8	13.36
Luteolin (mg)	0	0.001			

Strawberry plants



Perennial
herb
crown (compact stem in the center)
runner (doughter plant)
leaves (triplet denticulated)
flowers and fruits

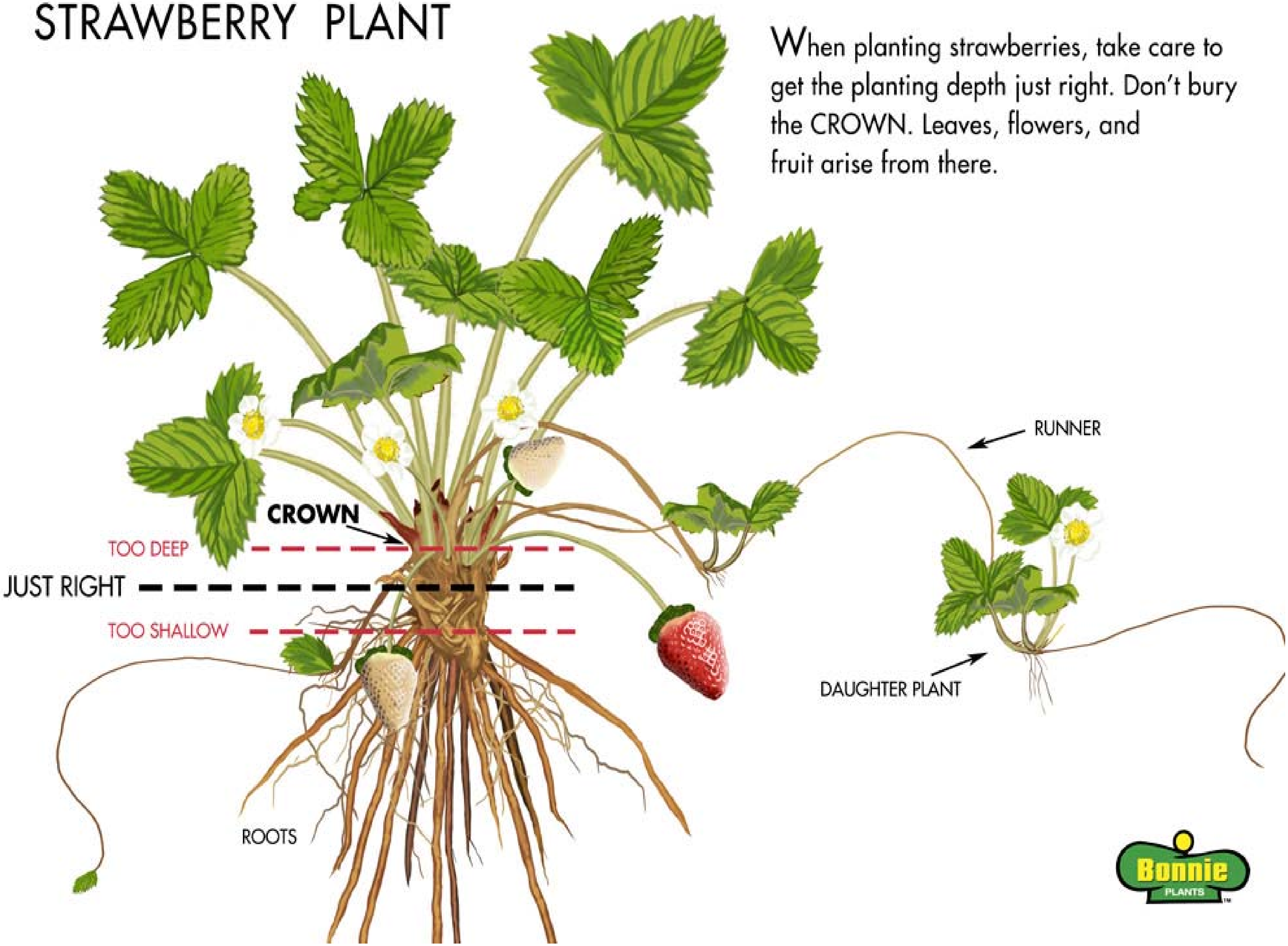


Modified Stems

- A **stolon** is a horizontal stem that is fleshy or semi-woody and lies along the top of the ground.
- A runner is a type of stolon. Strawberry
- It is a specialized stem that grows on the soil surface and forms a new plant at one or more of its nodes.
- The leaves on strawberry runners are small but are located at the nodes which are easy to see.

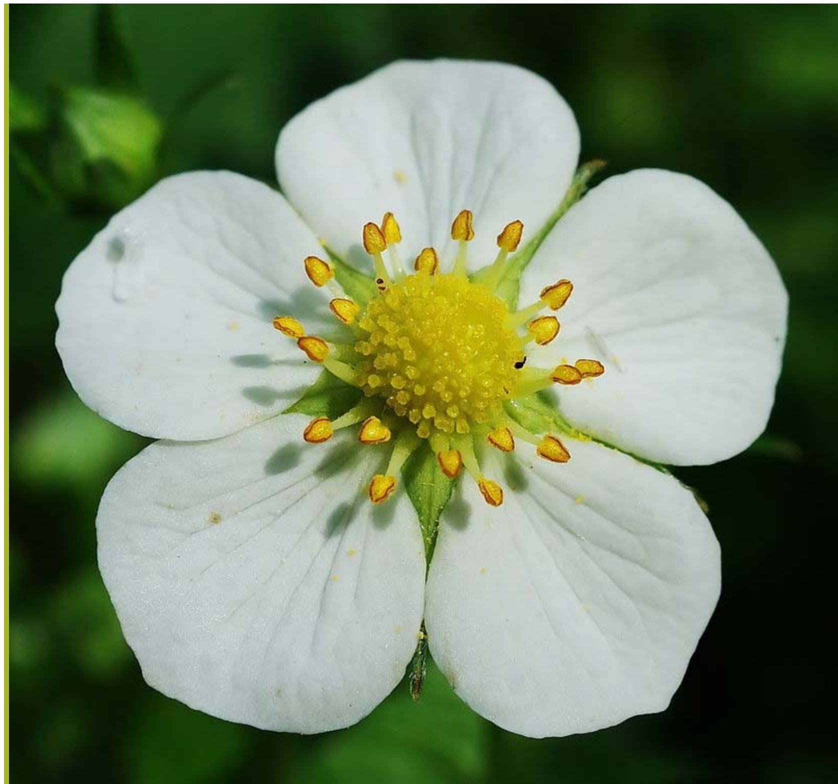
STRAWBERRY PLANT

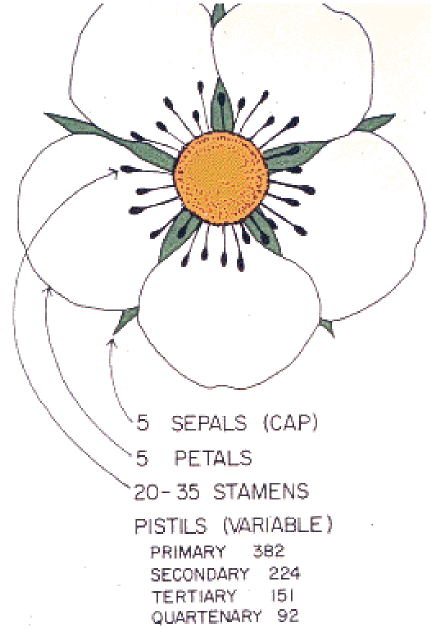
When planting strawberries, take care to get the planting depth just right. Don't bury the CROWN. Leaves, flowers, and fruit arise from there.



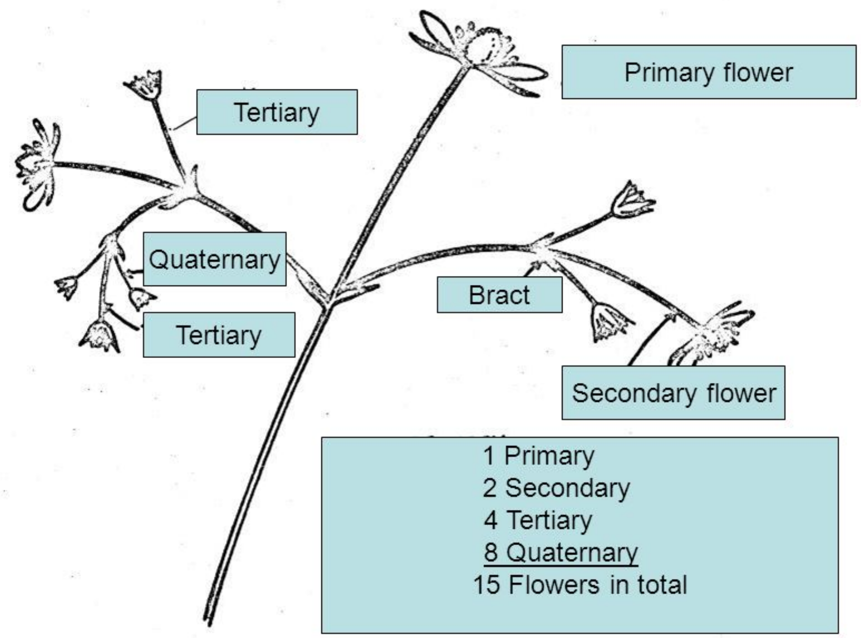
The Crown

- The crown is a short stem.
- New leaves develop with a bud in the axil of each leaf (auxiliary buds).
- The auxiliary buds will either remain undeveloped, grow and form runners or grow to form a side or branch crown.
- Environmental factors like day length and temperature influence the development of auxiliary buds.
- for example: The buds of June bearers develop into runners during the summers long 14 to 16 hour days. Once the days grow shorter in August and September, the buds no longer form runners. Instead they form branch crowns and flower buds.
- The more branch crowns that are formed, the greater the potential for fruit production during the next year since each crown can produce one flower stalk on which fruit is borne.





cyme inflorescence



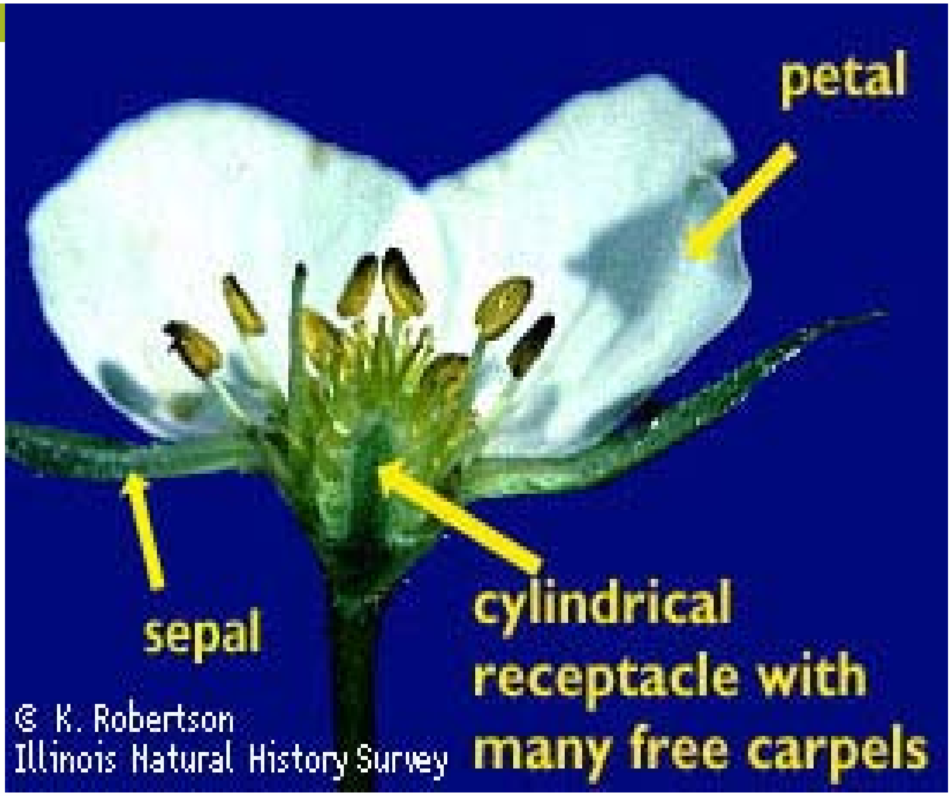
1 Primary
2 Secondary
4 Tertiary
8 Quaternary
15 Flowers in total

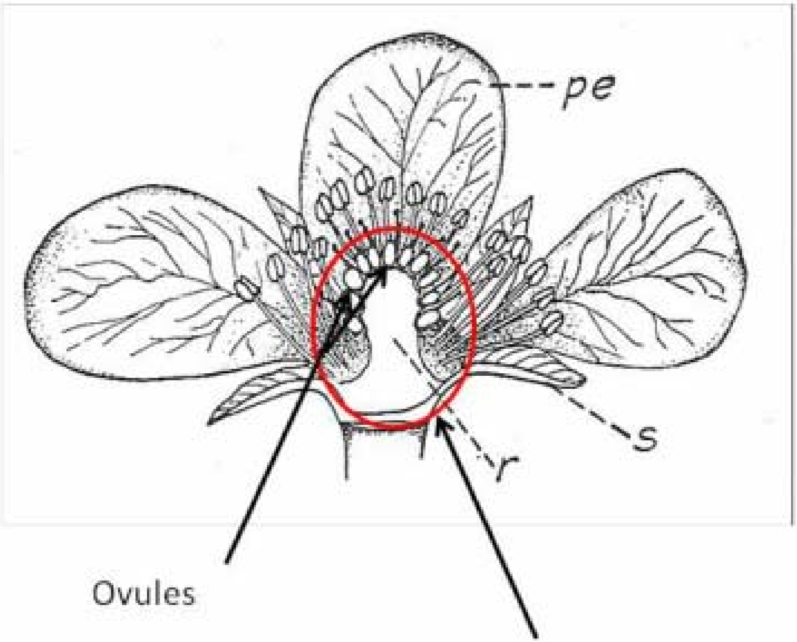
White
2.5 cm
50-500 pistils on a pulvinate yellow receptacle

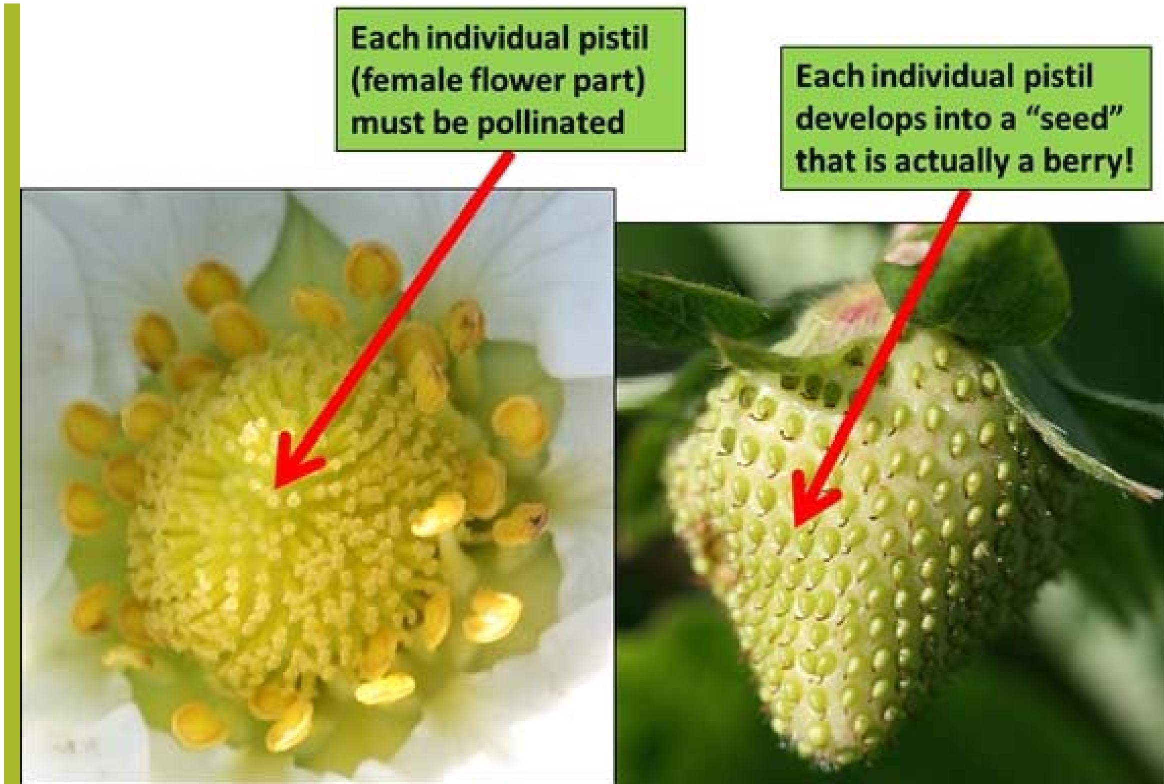
Strawberry inflorescence

The inflorescence develops a central or primary flower that opens first. This is followed by smaller secondary, tertiary and quaternary flowers opening up in sequence. The large primary flower develops into the largest berry, known as the "king" berry.

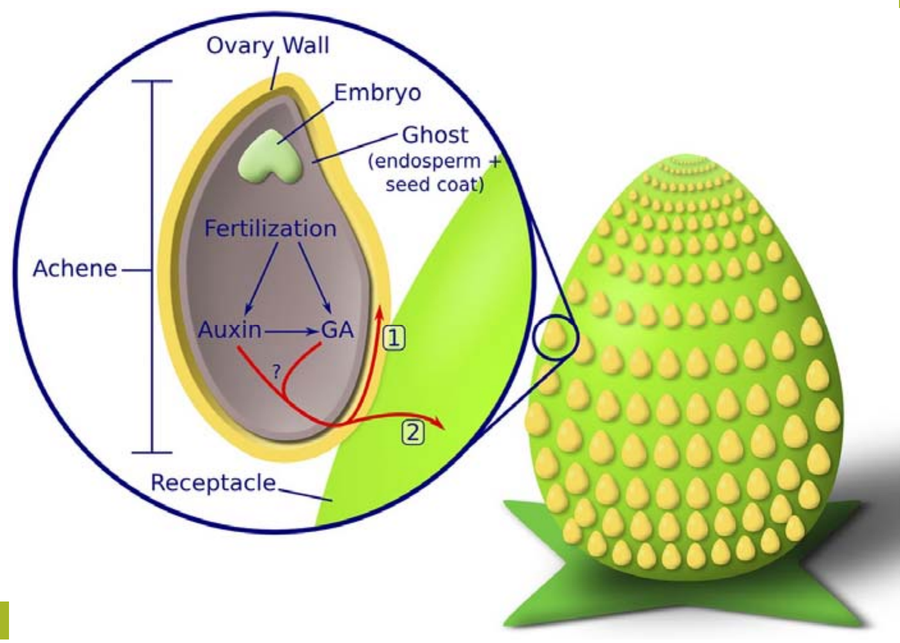
It usually takes about 30 days for flowers of June bearers to develop into fruit. This period may be reduced to 18 days with good growing conditions and high temperatures. Adverse conditions like cool weather could extend development to 40 days or more.



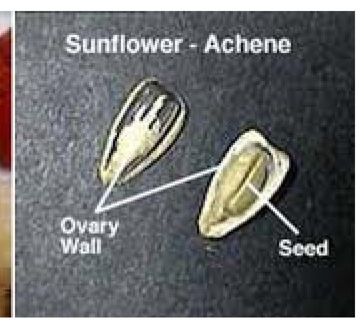




Self fruit full
preferably bee




Cross-pollination by insects
vs.
Self & Wind pollination


Sunflower - Achene
Ovary Wall
Seed

The Root

The strawberry plant is shallow rooted. Most of its roots are contained in the top 6 in (15 cm) of soil.
Day neutral plants have a shallower root system with most roots in the top 3 to 4 in (8 to 10 cm).

Strawberries

- Types of strawberries
  - Junebearing
  - Day neutral
  - Alpine
  - Ornamental

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June-Bearing Strawberries

The primary type of strawberry is the June-bearing strawberry. These cultivars are sometimes referred to as short-day strawberries because they initiate flower buds the previous summer/fall as the days become shorter. This type of strawberry is commonly grown in perennial matted rows, where runners are encouraged to root within the row each year to establish productive crowns for the following year.

Day-Neutral Strawberries

In the 1970s, day-neutral (remontant) strawberries were developed at the University of California. Day-neutral strawberries flower throughout the growing season as long as temperatures are below 90°F. Periods of hot weather will cause a temporary gap in fruit production. Day-neutral strawberries do not produce as many runners as the other types, so they are usually grown commercially with plastic mulch in a hill system, where runners are removed to maintain individual plants. This type of strawberry can be grown in annual or perennial production systems.

Everbearing Strawberries

As people noticed that some types of strawberries bore small fall crops in addition to a spring crop, breeders and hobbyists began selecting for this trait. The result was everbearing strawberries, such as 'Ft. Laramie', 'Gem', 'Ogallala', 'Ozark Beauty', 'Quinault', and 'Rockhill'. Everbearing strawberries tend to have large spring and fall crops, with little fruit in between.

Distinguishing between everbearing and day-neutral cultivars can be confusing for the home gardener. Day-neutral cultivars are "everbearing," whereas the old everbearing cultivars produce two distinct crops—one in the spring and one in the fall. Furthermore, both day-neutral and everbearing cultivars are usually sold as "everbearing" in retail nurseries.

روز بلند (همیشه بارده)	روز خنثی(همیشه بارده)	روز کوتاه
Gem	Selva	Kordestan
Ogallala	Albion	Camarosa
Ozark Beauty	Seascape	Chandler
Quinault	Aromas	Gaviota
Ft. Laramie	Portola	Cavendish
Rockhill'		

Strawberries

- Self fruitful
- Cultivars
  - Junebearing
    - Early season: 'Earliglow', 'Annapolis'
    - Midseason: 'Honeoye', 'Allstar', 'Redchief', 'Guardian', 'Darselect'
    - Late season: 'Lateglow', 'Winona'
  - Day Neutral: 'Albion', 'Seascape', 'San Andreas'
  - Alpine: 'Alexandria', 'Alpine Yellow', 'Reugen'
  - Ornamental: 'Pink Panda'

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Strawberry Breeding

- The first breeding activities were carried out in the UK in the 19th century.
- in 1821, strawberry cultivar -'Keens' Seedling'- released, which was then grown successfully for about a century.

- In the 20th century, strawberry breeding activity expanded further around the world.

- The programmes have become so numerous that a recent survey.

- registered that more than 900 new cultivars were obtained from 1982 to 2008 worldwide.
- The USA topped the list, with more than 190 cultivars, followed by Italy (74), France (70), Japan (65), the UK (56), Canada (51) and other countries (33).

Most of the cultivars that have been introduced belong to the octoploid species *F.* × *ananassa*, but there also exist cultivars with diploid (*Fragaria vesca*), hexaploid (*Fragaria moschata*) and decaploid (*Fragaria* × *vescana*) chromosomes. (?)

Some *Fragaria* × *Potentilla* intergeneric hybrids have also been obtained.

Potentillla fruticosa

Strawberry 'Pink Panda'

Table 3.1. Results obtained in the breeding programmes carried out in California, USA, and Po Valley, Italy. (From Shaw and Larson, 2008.)

Location		Yield (g per plant)	Fruit size (g)	Firmness (N)
California[a]	1945–1966	595	14.9	0.245
	1993–2004	1.429	24.9	0.456
Italy[b]	1970–1980	768	16.5	0.389
	2000–2010	1.390	26.1	0.572

[a]Average data from the two cultural techniques of winter planting and summer planting of the reference varieties.
[b]Average data from the five best advanced selections (summer planting).

1. Yield

Yield depends on the combination of a series of characteristics including:
the number of flowers, and consequently of fruits,
their size,
the plant crown number,
hardiness and resistance to disease.

Problem: increase plant yield further, has a negative effect on fruit sugar content.

However, in some areas (especially those with temperate climate and fresh summers) the day-neutrality characteristic was used to increase the plant yield.

This trait allows an extended harvest calendar (3–4 months or more) and allows the production of a larger number of inflorescences per plant.

2. Harvesting time and fruiting habit

Most breeding programmes aim to extend the harvest calendar of the June-bearing (short-day) cultivars.

This has becoming increasingly important to eliminate culture seasonalization and provide better management of farm labour.

Earliness is a very important characteristic in breeding programmes carried out in warm winter, searching for genotypes with low winter chilling requirements;

using bare-root plants (winter (autumn) planting system), the harvest time is further extended compared with cold-stored plants (summer (spring) planting).

In areas with particularly warm winters (subtropical areas), low winter chilling requirement cultivars are able to fruit in winter time.

Late flowering time and thus harvest time is particularly important in countries with colder temperatures, especially in winter (#frost).

Many programmes aim to extend harvest time using the 'ever-bearing' characteristic.

- The first day-neutral cultivars, which were introduced commercially in 1979 ('Aptos', 'Brighton' and 'Hecker'), were derived from the third generation of backcrosses.

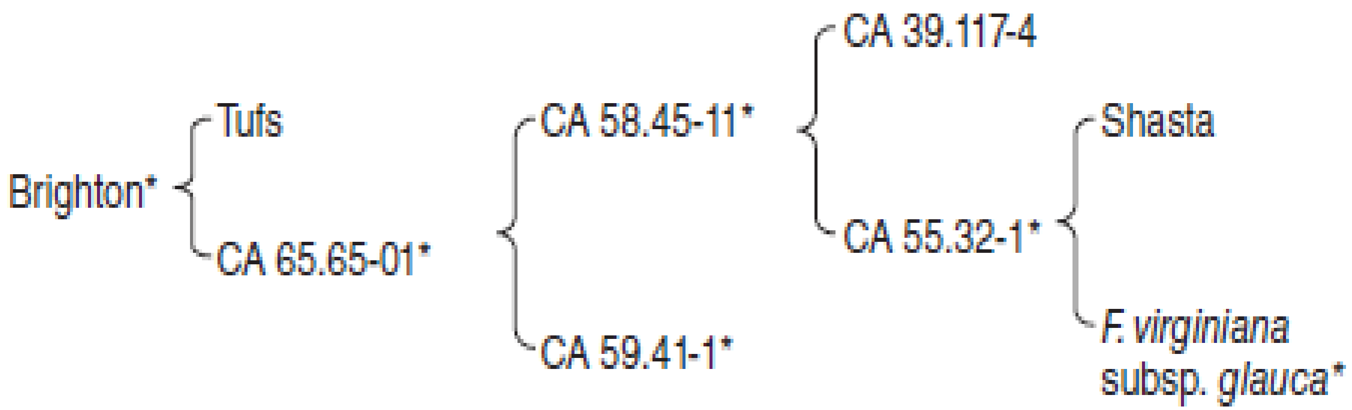


Fig. 3.1. Pedigree of the Californian ever-bearing day-neutral cultivar 'Brighton'. *, Day-neutral genotype.

the new ever-bearing cultivars will play an increasingly important role, especially in the strawberry industry of temperate climate (fairly cool summer) and the harvest could last four or five summer/autumn months using cold-stored plants planted from the middle of March to early April.

Ever-bearing is polygenic control (Shaw and Famula, 2005).
There exists great variability in the expression of this characteristic depending on both genotype and environmental factors, especially temperature.

Some June-bearing cultivars, in specific environmental conditions, can have a second flowering after the main bloom caused by a second period of differentiation, taking place in spring when there are the right temperature and photoperiod conditions (before the end of March in the northern hemisphere).

This trait is common in southern areas, but happens occasionally in northern areas, most frequently only in protected culture.

3. Average fruit weight

- improve plant production
- and reduce harvest costs.

a 1 g increase in average fruit weight allowed savings of 1 million Lire (about 500 Euros) per hectare

In order to reduce picking costs, long fruit stems (pedicels) is a sought-after characteristic, particularly in southern areas where fresh plants (winter planting system) are used, as they have limited plant development during the coldest months.

4. Organoleptic quality of fruit

Combining high yield and high fruit quality has always been a main objective in breeding programmes but is difficult to achieve. In some programmes, the fruit quality has been considered for a long time as a 'secondary objective', with the preference being to obtain large fruits to improve the yield

The negative correlation between **yield** and **sugar** level

The levels of **aromatic substances and of flesh firmness** are also negatively correlated with increased **size**
trend to improve flesh **firmness** results in a progressive loss in fruit **aroma**

The nutritional parameters (antioxidant compounds and phenolic content) seem to be the most innovative characteristics on which research is focusing its attention due to their benefits on human health.

The variability between the existing germplasms is remarkable, and these can be used to improve these parameters in specific breeding programmes.

Some specific breeding programmes have already been started, aiming to improve these characteristics using clones of wild species (in particular of *F. virginiana* subsp. *glauca*) as parents.

5. Pest and disease resistance

The pathogens causing problems to strawberries have different levels of importance in different cultural areas. For this reason, breeding programmes focus on different pathogens depending on their importance in the area where the programme is carried out.


Selva
Albion
Diamante
Seascape
Aromas


CAMAROSA

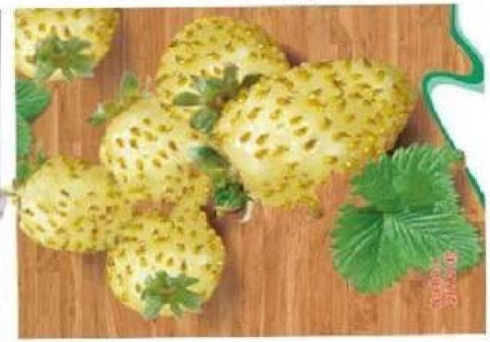
Fig. 4.1. (a) White strawberry culture in Contulmo, Región del Bio-Bio, Chile. (b) Infected plant. (c) Commercialization of white and red strawberry at the Putu market, Región del Maule, Chile. (a, b) From Rudi Montenegro (Universidad Austral de Chile, Chile); (c) from Cristina Theoduloz (Universidad de Talca, Chile).

NO.1 Green Strawberry 50 seeds

NO.2 Black Strawberry 50 seeds

NO.3 Red Climbing Strawberry 50 seeds

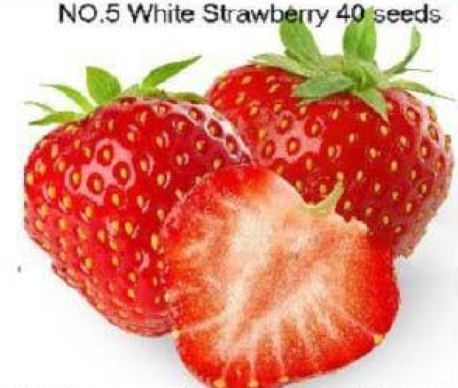
NO.4 Pineberry 80 seeds



NO.5 White Strawberry 40 seeds

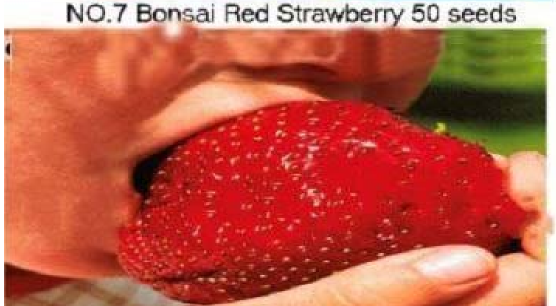
NO.6 Normal Red Strawberry 50 seeds

NO.7 Bonsai Red Strawberry 50 seeds



NO.8 Cream Red Strawberry 50 seeds

NO.9 Perennial Red Strawberry 40 seeds



No.10 Giant Strawberry 50 Seeds

NO.11 Mini Red Strawberry 50 seeds

NO.12 African Blue Strawberry 50 seeds

7 Plant Architecture in Different Cultivation Systems

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1. Introduction

Plant architecture represents the morphological expression of a genotype in a certain period.

معماری و ساختار گیاه نشان دهنده چگونگی مورفولوژی یک ژنوتیپ در یک دوره خاص است و با شاخصهای مختلفی تعریف میشود. مانند نوع رشد، مدل شاخه دهی، موقعیت اندام های زایشی و عادت رشد و گلدهی

Strawberry plant architecture shows some constant features related to its **determined** growth pattern.

Growth always stops with a terminal inflorescence.

further growth only from lateral branches (sympodial growth)

Showing the same fractal organization.

The vegetative shoots develop as runners.

Variability of **plant architecture** is related to the:

distribution and position of the vegetative and reproductive structures along its short axis (rosette plant).

These features of the growth habit change according to:
genotype,
plant age,
growing environment
Cultivation technique,

… due to the plasticity of the species.

In fact, the reproductive and vegetative behavior (phenotype) of the strawberry plants is sensitive to environmental and agronomic and nutritional factors

Plants can be part of a programmed production system in the nursery to produce in **predicted periods** under **different cultivation systems** and, **using specific propagation techniques**, they can bear a **different number and distribution of shoots**, inflorescences or **flowers** and **runners**.

2. Flower Induction and Environmental Control

Flower induction in strawberry is sensitive to **thermophotoperiod.** According to plant genotypes, which are classified into:

Remontant or recurrent (**ever-bearing or long day** and **day-neutral** plants)

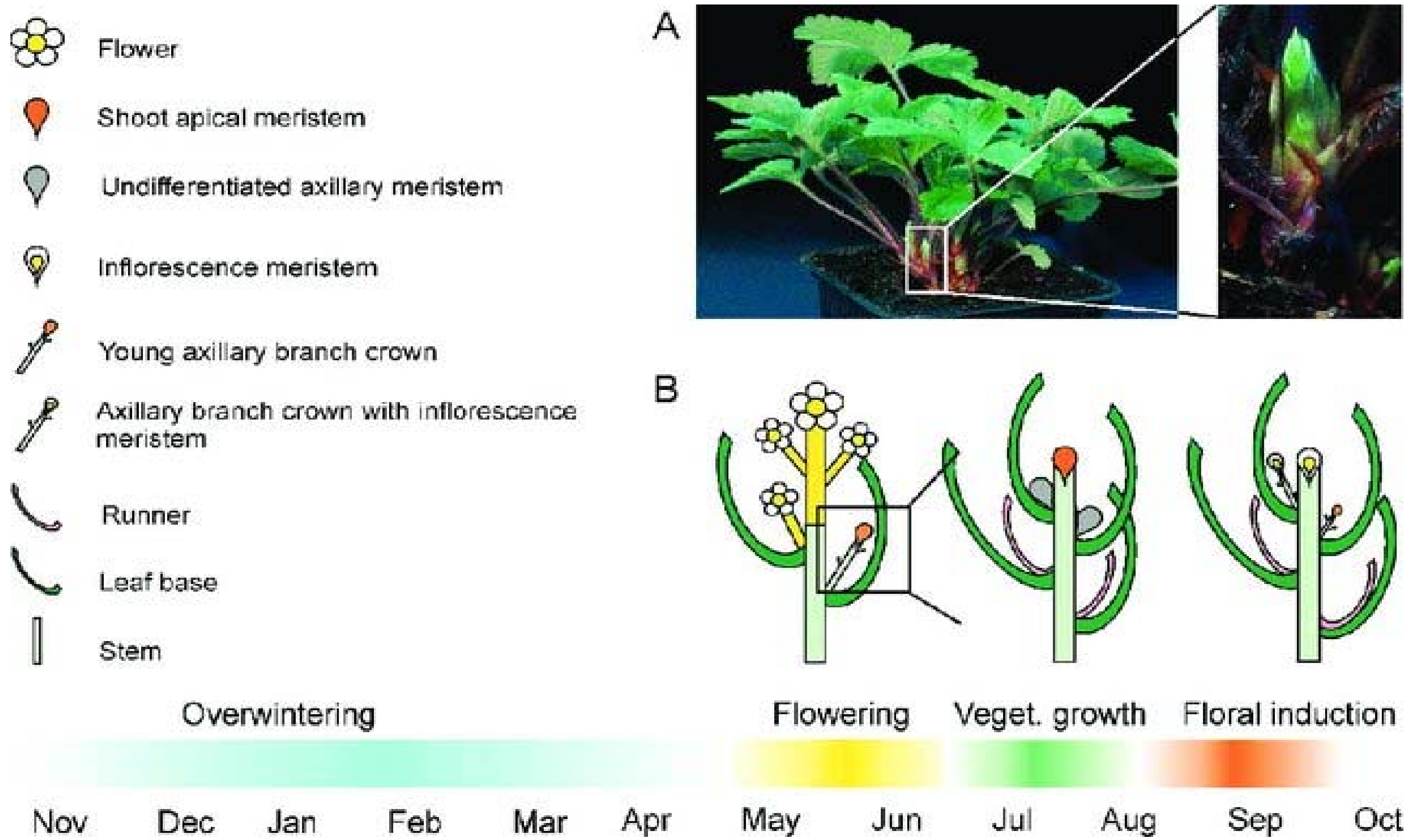
Non-remontant (seasonal flowering, short day or June-bearing) types.

- Non-remontant cultivars provide only one harvest in spring–summer, as a result of flower induction that took place in the preceding late summer–autumn, when their thermophotoperiodic requirements for flower initiation were satisfied by short days (less than 11–16 h) or low temperatures (9–21°C, optimal below 15–18°C).

- A minimum number (7–14) of short-day cycles is required for flower induction, according to cultivar, temperature and day length.
- Under long-day conditions, the terminal apex of the crown remains vegetative and many runners develop from the axillary buds,

as vegetative and reproductive growth have contrasting responses and requirements

- ✓ Remontant cultivars produce fruits more times per year, due to their different sensitivity to day length in relation to the temperature for flower induction.
- ✓ Flower initiation is possible when day length is longer than 12 h (long-day cultivars) or irrespective of photoperiod (day-neutral cultivars).
- ✓ Thus, a rigid classification of cultivars is not adequate to explain all the possible complex responses to day length.
- ✓ At low temperature, most genotypes show a day-neutral behaviour but can be distinguished according to their response to photoperiod at higher temperatures
- ✓ Thus, temperature affects the behaviour of both short-day and day-neutral cultivars in relation to photoperiod.
- ✓ Furthermore, prolonged warm temperatures (above 26–30°C) totally or partially inhibit flower formation, whatever the photoperiod.
- ✓ Therefore, in warm latitudes (tropical and equatorial), the profitable cultivation of strawberry is possible only where temperatures are lower in the highlands or where there is an eventual chill season.



Plant structure and seasonal growth cycles in strawberry. A) A LD-grown vegetative strawberry plant with several branch crowns. Runners have been removed. Magnification illustrates a single axillary branch crown; B) Typical seasonal growth cycle of woodland strawberry grown in temperate zone. Flowering occurs in late spring. Vegetative growth is continued from young branch crowns that were not induced in autumn. The axillary meristems of these branch crowns produce runners during the summer months, and new branch crowns towards autumn. In autumn, the main shoot apical meristem and the apical meristems of the oldest axillary branch crowns develop into inflorescence meristems, which complete their development the following spring.

The thermophotoperiodic conditions inducing flowering in short-day plants are normally effective only in summer–autumn,

suggesting that:

other factors are involved in the control of plant physiology, such as the chilling that prevents flower induction in spring.

Furthermore, plant meristems are sensitive to flower-inducing factors according to their physiological condition:

they are more receptive when the growth of the apex is reduced.

Therefore, the behavior of the plant (reproductive or vegetative) can be determined by the modulation of many factors interacting with the plant growth, involving:

abiotic, agronomic, nutritional and environmental factors or the presence of stress, and we can assume that these factors determine a main indirect effect modifying the vigour of the whole plant (not directly on meristem).

After flower induction, …

during the differentiation process, the formation of flowers in the floral apex is enhanced by mild temperatures (18°C).
(affect on the final crop load).

Yield and fruit **quality** can be **improved** by modifying one or more effective factors **during the growing cycles**, starting from plant production in the nursery, in order to anticipate or delay flower induction and to determine the number of flowers and inflorescences.

3. Growing Cycles – Plant Plasticity for Harvest Seasons

Management of plant architecture in **nursery**
Management of plant architecture in **field**

Nursery techniques provide many plant types allowing the application of different planning strategies for cultivation.

Different plant types have different architectures, each suitable for integrating in specific growing cycles.

9.2. Plant Production Systems

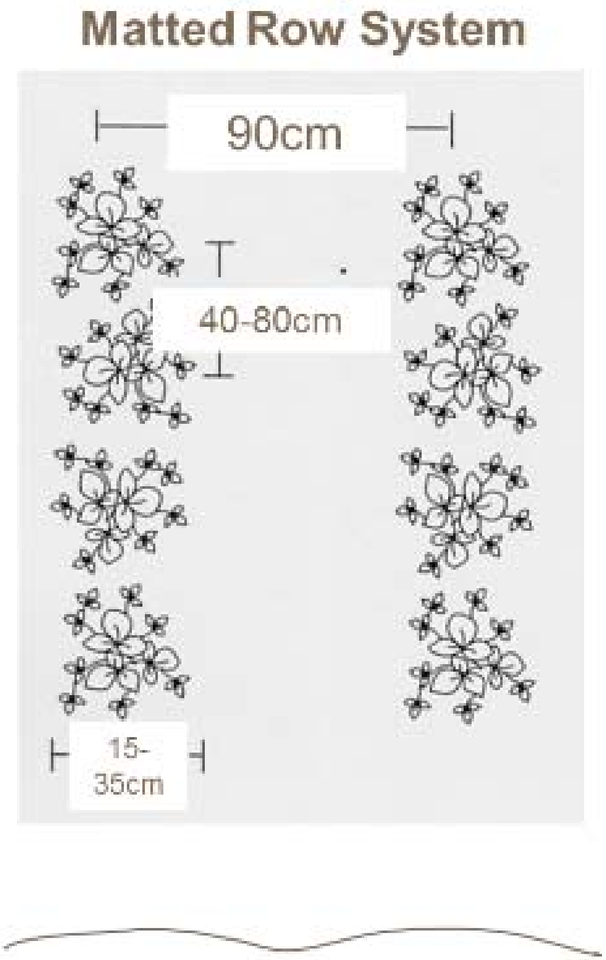
Most strawberry nurseries are located in areas with very specific characteristics. These facilities require large flat surfaces, whose soils are deep, very sandy and well drained, with a pH between 6 and 7, and with a good water supply. Nurseries must be established in isolated areas, away from fruit production, in order to promote sanitary conditions. Altitude and latitude of the nursery should also be taken into account, as these elements determine the time when the plant's floral differentiation and physiological maturity occur.

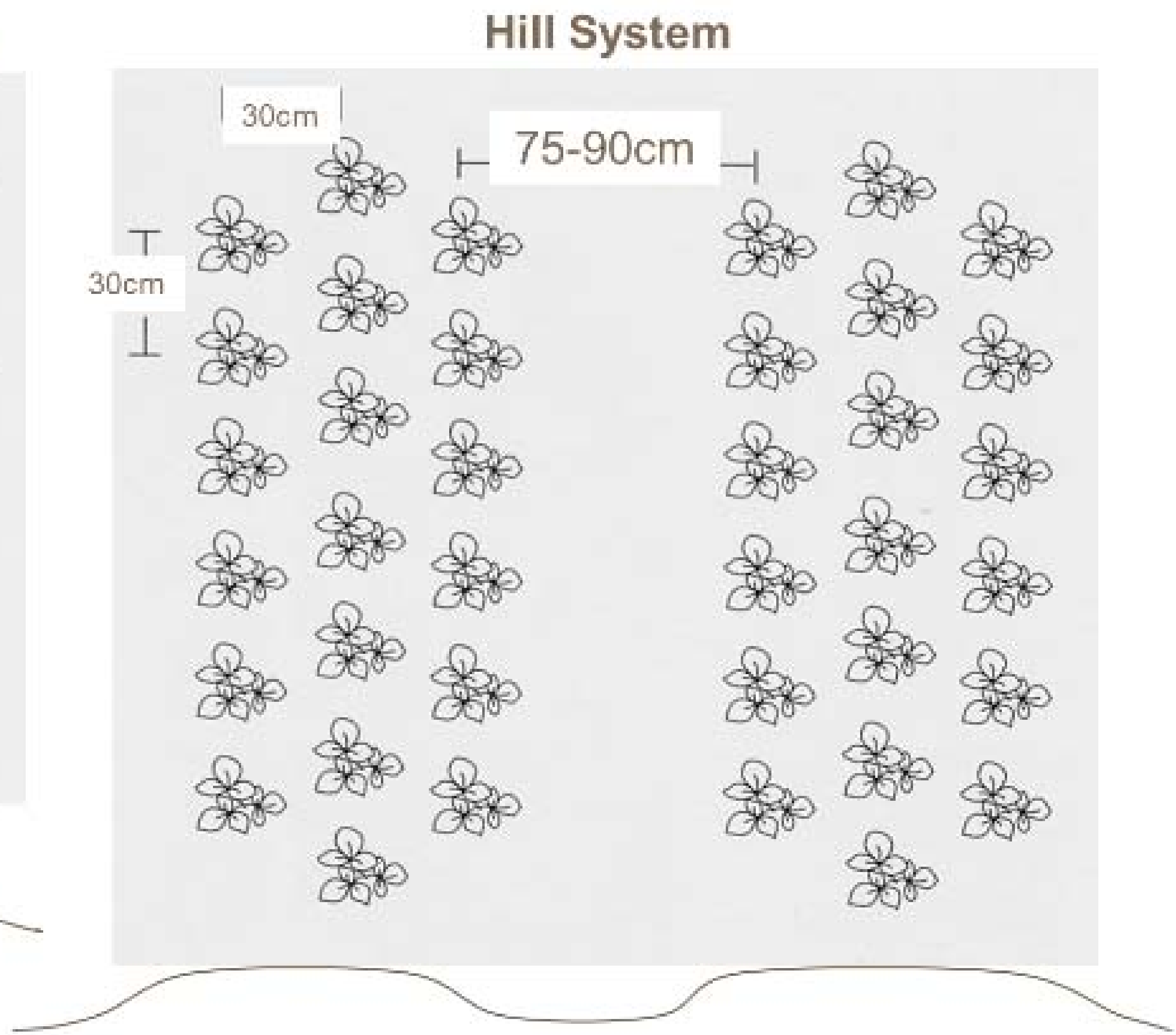
The production of runners is favoured in areas whose geographical location – north or south – ensures an adequate photoperiod and temperatures between 25 and 30°C in summer. Autumn temperatures should decrease quickly, so that plants receive an accumulation of chilling hours (below 7°C), which in some cases is achieved in high-altitude areas (over 1000 m above sea level) or in more extreme latitudes. In Europe, nurseries are mainly located in Spain (provinces of Avila, Segovia and Valladolid), northern Italy (Veneto and Emilia-Romagna regions) and France (Aquitaine and Midi Pyrenées). Countries such as Poland and Romania have also developed an interesting nursery industry.

In North America, the main area for nursery production is northern California, south-east of Oregon and North Carolina in the USA and Ontario in Canada. In South America, Chile and Argentina produce strawberry plants to meet their own demand and to supply countries such as Mexico, Brazil, Peru, Bolivia and Colombia, among others.

It should be noted that the strawberry plant production process requires laboratory technologies such as *in vitro* culture, techniques of sanitation and detection of viral diseases, and prolonged periods of cold storage, among others, which imply specialization and a high technological level. For this reason, in order to obtain plants of adequate genetic and phytosanitary quality, the plant production process should be performed in specialized nurseries, following a methodology that has been proven and

Planting Systems





The hill or plasticulture system uses the crowns to produce fruit with any runners removed to encourage the plant to focus on production.

Open Field Production Systems

	Hill	Matted Row
Winter temperatures	Mild	Cold
Planting dates	Summer or winter	Spring
Bed height	Raised	Flat
Mulch	Clear or black plastic	Straw
Irrigation	Trickle	Overhead
Production seasons	1–2	3–5
Cultivars	Everbearing	June bearing


Plastic covered hills ready for planting


Matted rows are planted at a lower density

Matted row system of planting

- 2 feet between plants
- 3-4 feet between rows
- Watch runner placement
- Flower bud removal the 1st year for June bearing and first 60-80 days for ever-bearers

Plant in spring March-April-May

Planting depth - crown at soil level

Remove flowers during planting year

Removing the runners to maintain rows and decrease disease problems

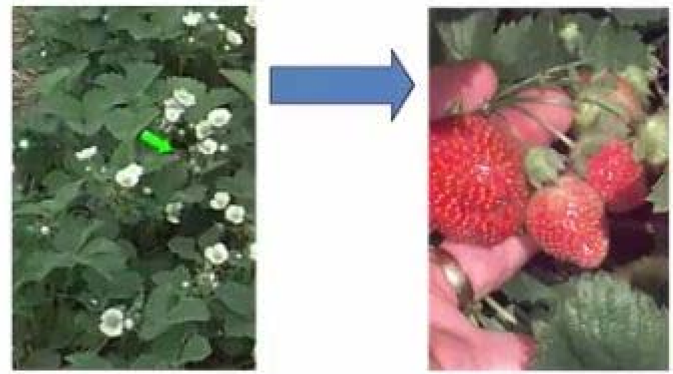
Getting strawberries ready for winter with mulch

Mulching strawberries

- Spread clean straw in late November or December
- 3 nights in the low 20's
- 4-6 inches deep -300 to 400 small straw bales per acre
- Rake into row when growth begins in spring
- Put back on for early frost protection-hard to do on a larger scale

Frost protection

30 days from bloom to harvest



Frost protection

- Watch for frost warnings whenever flowers are present
- The real need for irrigation
- Keep an eye on the Dew Point each night
- What do frosted flowers look like – black flower centers two days after a frost

Floating row covers

-earlier fruit harvest

-also an alternative to mulch

Renovating strawberries after harvest

1st - Mow off leaves

2nd - Narrow rows to 8-10 inches

3rd - Fertilize

First, the farmer makes soil mounds.

The mounds are called beds.

Some farmers use a machine to do this.

The machine is called a bedformer.

Next, the beds are covered with plastic.

The farmer makes holes in the plastic and plants the strawberry

The plastic keeps the strawberries warm and helps them grow.

The production system basically consists of the following four stages.

9.2.1. Nuclear stock

9.2.2. Propagation stock I

9.2.3. Propagation stock II

9.2.4. Commercial nursery

Fig. 9.1. Mother plants (a) and propagation stock I (b, c) in a greenhouse with double doors, a footbath and insect mesh.

9.3. Plant Types and Cycles

The advances in increasingly specialized cultivation techniques, together with the expansion of production areas to more extreme climate zones, have forced nurseries to produce different types of specific plants adapted to modern cultivation requirements. Plant types provided by the nurseries through various propagation techniques are the starting point for a wide range of producing cycles aiming towards expansion of the fruiting season and cultivation in different areas. In fact, the cultivation technique of strawberry has undergone a constant evolution over the last 20 years. The most traditional plant cycle is the annual crop cycle with a single fruiting season in the spring (using June-bearing, short-day varieties) following the summer planting. In many areas, other innovative growing techniques have been introduced and the harvest of strawberries now covers the whole year.

There are two traditional types of strawberry plants: 'fresh' and 'frigo' (cold stored). There also exist six other plant types (Table 9.1) that are capable of being adapted to more specialized cultivation systems, such as programmed cultivation, protected cultivation and off-soil cultivation.

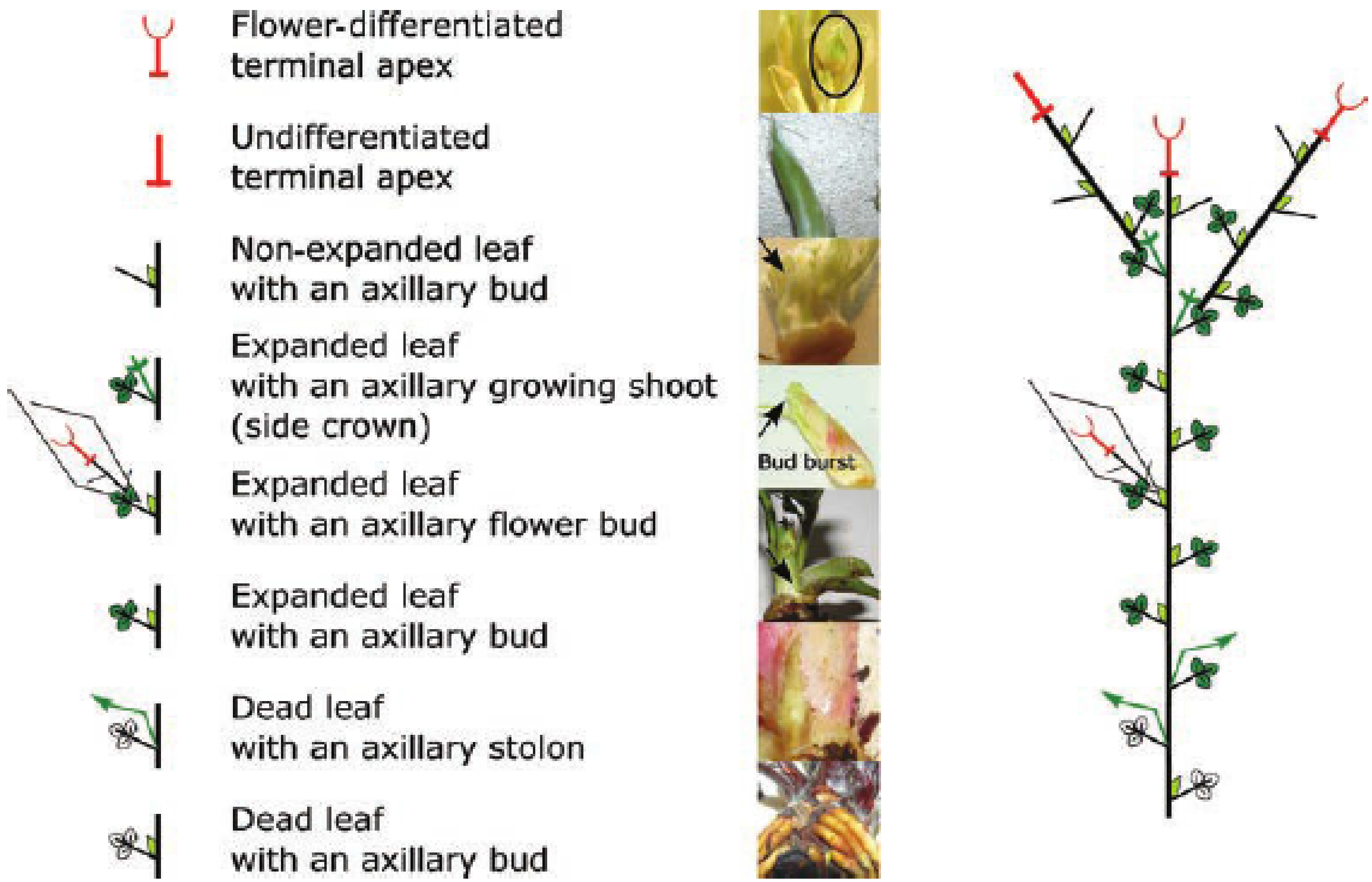


Fig. 7.2. Schematic representation of strawberry plant architecture using conventional symbols. Left: conventional symbols with their definition, illustrated in the photos; right: example of a schematic representation of a single plant.

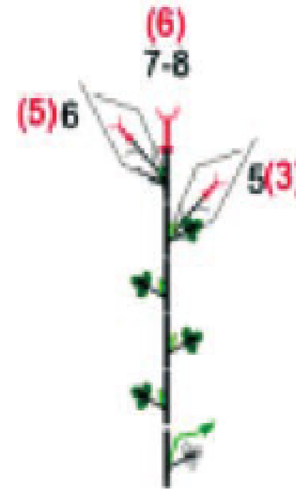
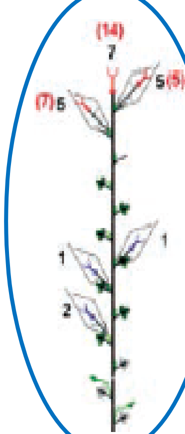
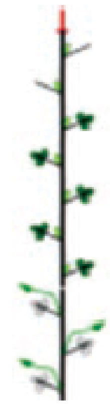
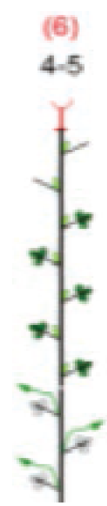
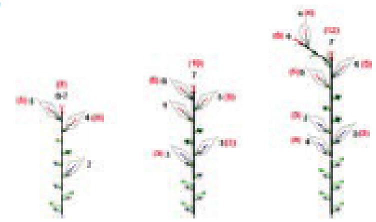
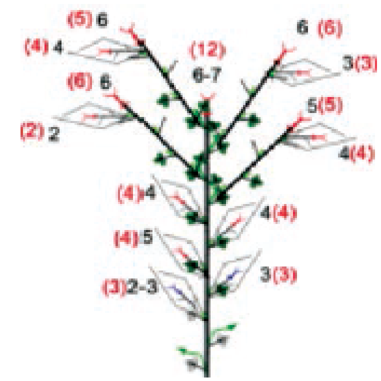
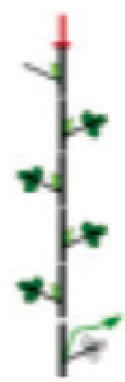
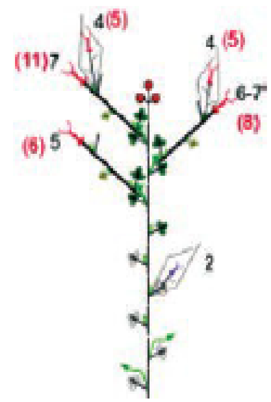
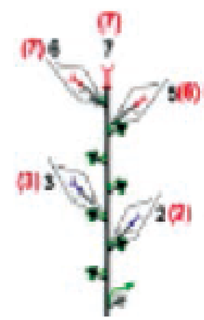
Commercial name	Physiological status	Starting material	Root free of substrate (bare roots)	Pots	Cold storage	No. of crowns and inflorescences (architectural model) at transplanting	Season and duration of production	Crown diameter (mm)	Nodes on the crown (*n*)	Side flower buds (*n*)	Flowers per plant (*n*)	Plant architecture
Rooted runner (misted tip)	Fresh plant in pot; flower differentiated	Runner	No	Yes	No	1 crown, 1 inf.	Winter–spring/ 3 months	8–10	5–8	0–3	15–20	
Tray plant	Pot plant; cold stored; flower differentiated	Runner	No	Yes	Yes, 3–9 months	1 crown, 2–3 inf.	Out-of-season, spring–autumn /1–2 months	12–15	10–16	4–5	20–40	

Fig. 7.3. Example of a schematic representation of the architecture of a tray-plant of a non-remontant cultivar. The crop potential of this plant derives mainly from three well-differentiated inflorescences. The terminal one is at an advanced stage of development and is able to develop early after planting. It is composed of many flowers (21), suggesting that the late growth in the nursery took place in mild/warm temperatures. The other two inflorescences in the uppermost positions of the crown are on the top of extension crowns and are able to develop with a little delay and fewer flowers. The lower differentiated buds show very early stages of development and have little chances of developing and growing out, because they can remain dormant or even die, mainly after cold storage. Black numbers, flowering stage; red numbers, number of flowers.

Commercial name	Physio-logical status	Starting mate-rial	Root free of sub-strate (bare roots)	Pots	Cold storage	No. of crowns and inflores-cences (architect-ural model) at transp-lanting	Season and duration of produ-ction	Crown diameter (mm)	Nodes on the crown (*n*)	Side flower buds (*n*)	Flowers per plant (*n*)	Plant architecture
Freshly dug plant: fresh plant = without leaves; green plant = with leaves	Freshly dug plant; not flower differe-ntiated	Runner	Yes	No	No	1 crown, 0 inf.	Traditio-nal crop, spring–summer/ 1 month	9–13	9–14	0	0	
Freshly dug plant high altitude (two categories as above)	Freshly dug plant; flower differe-ntiated	Runner	Yes	No	No	1 crown, 1 inf.	Winter–spring/2–3 months	9–13	9–14	0	5–10	

Commercial name	Physio-logical status	Starting mate-rial	Root free of sub-strate (bare roots)	Pots	Cold storage	No. of crowns and inflores-cences (architect-ural model) at transp-lanting	Season and duration of produ-ction	Crown diameter (mm)	Nodes on the crown (*n*)	Side flower buds (*n*)	Flowers per plant (*n*)	Plant architecture
Frigo plant (A, A+, AA+ plant size)	Dug plant; cold stored; differe-ntiated	Runner	Yes	No	Yes, 7 months	1–2 crowns, 3–4 inf.	Spring–sum-mer/1 month	A–, 6–8; A, 8–12; A+, 12–15; AA+, 15–18	A, 7–11; A+, 9–13; AA+,12–17	A, 3–5; A+, 4–6; AA+, 6–8	A, 15–25; A+, 25–35; AA+, 35–45	
Waiting-bed plant	Large dug plant; cold stored; flower differe-ntiated	Freshly dug plant; frigo plant; rooted runner	Yes	No	Yes, 3–9 months	3–4 crowns, 4–6 inf.	Out-of-season, spring–autumn/1 month	13–19	8–17	6–10	40–70	
Rooted runner (misted tip or plug plants)	Fresh plant in pot; not flower differ-entiat-ed	Runner	No	Yes	No	1 crown, 0 inf.	Spring/1 month	8–10	5–8	0	0	

Commercial name	Physio-logical status	Starting mate-rial	Root free of sub-strate (bare roots)	Pots	Cold storage	No. of crowns and inflores-cences (architect-ural model) at transp-lanting	Season and duration of produ-ction	Crown diameter (mm)	Nodes on the crown (*n*)	Side flower buds (*n*)	Flowers per plant (*n*)	Plant architecture
Tray plant from frigo plants	Large plant in pot; cold stored; flower differ-entiat-ed	Frigo plant	No	Yes	Yes, 4–9 months	2–3 crowns, 3–6 inf.	Out-of-season, spring–autumn/ 1 month	14–18	8–17	5–10	30–60	
Minitray plant	Plant in pot; cold stored; flower differ-entiat-ed	Runner	No	Yes	Yes	1 crown, 2–3 inf.	Out-of-sea-son, spring–autumn /1–2 months	10–13	8–12	4–5	15–35	

Recent Advances in Strawberry Plug Transplant Technology

Edward F. Durner, E. Barclay Poling, and John L. Maas

Table 1. Definitions of terms specific to the commercial strawberry industry.

Term	Definition
Runner tip	An unrooted plantlet on the tip of a stolon (runner)
Plug plant	
Moduled plant	
Tip-raised potted plant	Small containerized plants produced from runner tips, generally grown for 3–5 weeks in 50-cell plastic trays with cell depths of 5–6 cm (1.9–2.4 inches), average crown diameter 8–11 mm (0.3–0.4 inches).
Tray plants	Containerized plants produced from runner tips, typically grown over a 5-month period (late July–December) in 8-, 12-, or 16-cell plastic trays with individual cell depths of 8–9 cm (3.1–3.2 inches), average crown diameter of 15–18 mm (0.6–0.7 inches).
Waiting-bed plants	Fresh-dug nursery plants with a crown diameter of 17 mm (0.7 inches) or more.
Fresh-dug bare-root plant	A field nursery-grown strawberry plant that is dug and transplanted to the production field within several days.
Frigo plants	Dormant strawberry plants stored for several months at –1.5 °C (29.3 °F).

Figure 1 Strawberry Plug Plant

Producing the runner tips

Site selection and establishment

The first step in producing strawberry plug plants is to produce the runner tips. Runners are produced from mother plants, which can be grown either in a greenhouse or field. Plants can be grown in the soil or in peat-filled grow bags placed on the soil or on benches. Runner production is favored by high temperatures and long days, hence outdoor production would be limited to the summertime. With either system (outdoor or greenhouse) care should be taken to prevent runners from coming in direct contact with soil. In the greenhouse, suspended growing systems (Figures 2 & 3) are used to prevent runners from coming in contact with soil. In the field, a combination of straw mulch between rows and plastic mulch within the row will prevent runner tips from contacting the soil. In the greenhouse, the first runner tips can be expected about 8 to 10 weeks after establishing the mother plant.

Greenhouses provide the ideal setting for runner production. Greenhouses can be managed to provide ideal day time temperatures (above 75°F) and long photoperiods (about 16 hours). With supplemental heat and light, runner production can occur year round.

Figure 2 Suspended growing system

Figure 3 Suspended growing system with hanging runners

Runner tips should be harvested when root initials (little white or brown pegs, Figure 4) are present on the runner tip. Root initials should not be longer than ½ inch. Additionally, at least two trifoliate leaves (first leaves that appear from the runner tip) are needed and should be between 2½ and 4 inches in length (Figure 5). Runner tips where the oldest trifoliate leaf is larger or smaller will have limited success in establishment. Depending on individual needs and desire for uniformity of runner tips, tips are generally harvested every 10 to14 days.

Figure 4 Root Pegs on Strawberry Runner Tips

Figure 5 Properly sized runner tip. Note 2 fully expanded trifoliate leaves as well as extra ½" of runner that is used to anchor the plant (arrow).

- سیستم کشت تجاری توت فرنگی (Annual hill)
- زمان کاشت: اواخر تابستان
- نوع گیاهان: یا گیاهان دختری تازه برداشت شده یا گیاهان dormant سرما دیده (frigo)
- در این زمان معمولا گیاهان fresh dug تا مهر ماه که توسط خزانه دار برداشت میشوند در دسترس نیستند (بسیار دیر برای کاشت).
- گیاهان dormant معمولا در اوخر پاییز از خزانه برداشت میشوند و در انبار سرد نگهداری میشوند تا برای کاشت در بهار استفاده شوند. (انبار طولانی مدت و کاهش زنده مانی در سیستم کشت تجاری)

- گیاهان ریشه لخت سرما دیده ((bare root frigo (cold stored) میتوانند برای کاشت رقم های روز کوتاه در سیستم .mat در بهار در مزرعه استفاده شوند.
- یک فصل برداشت کوتاه در بهار
- تنها یک جوانه گل تمایز یافته در موقعیت انتهایی
- کیفیت کم گل آذین به دلیل آسیب انبار سرد طولانی
- توصیه به حذف گلها و رانرها در سال اول کاشت
- تولید طوقه های جدید از جوانه های جانبی در پایان تابستان
- گل انگیزی و تولید عملکرد مناسب در بهار آینده

- امکان استفاده از این گیاهان (frigo) برای رقم های همیشه بارده در سیستم .mat نیز هست.
- شروع سیکل رشد در اسفند
- حذف گلها در بهار به هدف تقویت رشد
- برداشت از تیر تا مهر

- ولی گیاهان frigo برای کاشت در سیستم annual که زمان کاشت اواخر تابستان است، به دلیل:
- انبار سرد طولانی مدت و کاهش viability
- زمان کم جهت تمایز گلها در مزرعه و تولید زودهنگام

مناسب نیست.

- راه حل:
- استفاده از گیاهانی که تمایزیابی گلها در آنها انجام شده باشد.

این گیاهان:

در خزانه های مناطق مرتفع یا خنک تولید می شوند.

حداقل یک جوانه گل تمایز یافته تولید می کنند

برای مدت طولانی فصل برداشت آنها ادامه دارد.

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استفاده از گیاهان plug یا tray

- با استفاده از گیاهان plug یا tray در سی□تم annualگیاهان قوی در اواخر تاب□تان کشت می شوند.
- قدرت رشد اولیه ب□یار بالایی دارند

- جهت حذف محدودیت دسترسی به آنها: از نوک رانرها (tips) برای تولید آنها استفاده می شود.

7.4. Plant Manipulation in the Nursery

The first opportunity to **manipulate the plant growth and architecture**, and at the same time **plant vigour** and **fruit production**, is control of the growing conditions during plant propagation, obtaining plants with a different number of lateral flower buds and shoots and at a different floral developmental phases.

Knowledge of effective environmental and cultural factors for plant behaviour manipulation is pivotal in applying techniques that allow anticipation or delay of flower induction and to obtain higher or lower numbers of flowers.

In fact, many growing techniques available for nursery plant production, including the **application of controlled stress**, can be effective to manipulate the plant architecture, stimulating flower induction and differentiation, because they can interact with several aspects of plant growth, such as **growth rate**, **shoot-to-root ratio** and **carbon balance**.

The timing of application of a particular technique is crucial in terms of its interaction with the physiological stage of the plant and its organs.

- 7.4.1. Thermophotoperiod

One of the most effective means of manipulating the equilibrium between vegetative growth and reproductive development in strawberry is modification of the **thermophotoperiod**, an environmental factor playing a major role in flower induction.

The light availability duration can be increased using artificial light, to apply long-day conditions to short-day plants and delay flower formation, or decreased by adding a temporary light-proof covering to mimic shortday conditions.

Providing artificial light during the night (night break) under shortday conditions can inhibit flower initiation in non-remontant cultivars or enhance flower production in remontant cultivars.

The natural variation in temperature between day and night is more effective than a constant temperature.

Flower induction can be induced earlier when the oscillation is 26.7/15.6°C day/night compared with a constant 21°C temperature or with warmer temperatures.

Temperatures below 15.6°C are common during summer–autumn in cold areas but are suboptimal for flower differentiation, delaying the formation of flowers.

• 7.4.2. Location

Both **photoperiodic** and **thermal** conditions can be controlled during propagation, by transplanting the plants or moving them to specific locations (changing the altitude and latitude).

The choice of environment for the nursery location and the time of propagation allow control of the vegetative and generative behaviour of the plants, resulting in different numbers of flowers per plant and programming the synchronicity and duration of the cropping.

Flower induction in short-day plants is delayed with increasing latitude, as day length reduces later in the summer.

In Europe, fresh plants can be propagated in environments where the conditions are favourable for floral induction, which takes place earlier at higher altitude in the Alps and in highland nurseries (800–1200 m) or in cold northern areas due to the thermal fluctuations between day and night and to low summer temperatures.

In fact, a mild environment is optimal for a longer and earlier flower differentiation, in order to increase the number of flowers within the inflorescences.

During formation of the primary buds, prolonged favourable conditions in early autumn enhance the formation of flowers within the primary inflorescence, resulting in more flowers (13–14 per inflorescence) in comparison with plants in the south (around 10 per inflorescence).

secondary inflorescences becoming differentiated during the early arrival of the cold temperatures in autumn.

In contrast, if propagation takes place under a long photoperiod and relatively high temperatures, flower induction is reduced and vegetative growth is enhanced, with increasing formation of runners

The cultivation environment also modifies the growth of the plant. For instance, fewer crowns are formed along the principal axis of fresh plants where the winter is warmer.

In tropical climates, temperatures can be very high at low altitude, reducing the vegetative growth of the plants, which develop fewer leaves compared with plants at higher altitudes.

7.4.3. Chilling

Chilling temperatures (between 0 and 7–10°C) are required to overcome dormancy, but they are also effective at increasing vegetative growth and leaf and runner formation; whereas they reduce flower induction and enhance floral differentiation.

In greenhouse cultivation, cold treatments can be applied to prevent a decrease in vegetative vigour, while artificial lighting can compensate for a lack of cold because long days can substitute for chilling.

Cold storage makes the plants available all year round and also provides the required chilling. Nevertheless, sugars and starch content can decrease if the low temperature is maintained for too long (more than 200 days), also reducing the number of emerging inflorescences and flowers, which are inhibited, especially if they are located below the last expanded leaf.

A long duration of cold storage and the consequent low carbohydrate content induce a stress condition that may also result in earlier flowering, although not for all types of plant.

7.4.4. Light quality

Light quality and intensity may be effective in regulating flower initiation, especially in short-day plants.

These features of the light reaching the plants can be modulated in different ways, using covering nets or specific artificial lights.

During a decreasing photoperiod, plant shading reduces light intensity and temperature, promoting flower induction if sunlight is reduced by 75–95%,
but with lower light intensity, crown size and leaf and inflorescence number can decrease,

whereas increasing light intensity can promote flower differentiation

Flower bud initiation is also affected by the spectral composition of the irradiation, which can be selected applying photoselective nets over the plants, with red and blue nets having an inhibitory effect.

Spectral band quality also affects the responsiveness to photoperiod. In fact, light extension to produce long-day conditions delays floral initiation

7.4.5. Nutrient supply

Nutrient supply, in particular the relative ratio between nitrogen and phosphorus, plays a major role in modulating growth and the vegetative equilibrium of the plant and consequently can be a means to modify the whole plant architecture during both propagation in the nursery and further plant growth.

Nitrogen availability and the timing of supply during the growing season affect the formation and growth of new organs and interact with flower initiation, amplifying the effect of inhibitive or stimulating factors.

The nutritional protocol should be managed in different ways. Both stolon and shoot formation can be enhanced by high nitrogen levels, depending on the timing of supply and the plant growth rate.

Therefore, stolon formation is induced and flower induction can be delayed or totally prevented if excess nitrogen is applied before the flower induction period or when there is rapid growth of the apex.

In contrast, a high nutrient supply can increase the induction effect if applied after the beginning of short-day conditions.

It can also stimulate plant vigour after the arrest of apex growth, reactivating axillary latent meristems to form new shoots in the basal part of the crown, increasing the total number of inflorescence sites.

If nitrogen is supplied later on, shoot formation can be stimulated in the upper portion of the plant, increasing the total number of inflorescences and extending the cropping time, because the flowers are less developed compared with the terminal primary inflorescence.

In the nursery, late application of foliar nitrogen during flower differentiation of freshly dug plants can advance flower development and fruiting.

Differing responses are also seen if the supply of nutrients is continuous or temporary; in fact, lateral shoot formation starts from the apical part of the crown and continues downward with continuous fertilization, whereas shoots exclusively involve the apical buds if the fertilization is suspended for 1–2 weeks during the maximum growth period, also advancing flower differentiation.

If the nutritional deficiency persists after flower bud initiation and induction, further development of initiated flowers is prevented, irrespective of the nutrient conditions during the other growth phases, as nitrogen is required for flower differentiation. A reduction in nutrients after mid-October does not affect fruit production.

7.4.6. Growing substrate

- Peat mixes are widely used substrates for soil-less cultivation and for plug plant production in nurseries, but many other growing media have been tested.
- Substrates differ in physical and chemical proprieties involving pH, electrical conductivity, porosity and water-holding capacity, which may affect the water and nutrient availability for the plant and the root activity.
- Consequently, substrates may also modulate the vegetative vigour of the plant and the response to flower induction, with effects on the crop potential.
- These effects can be also detected in the plant architecture, shoot topology and number along the crown.
- The use of an inert substrate without peat (rock wool substrate, sand or perlite), in the absence of nutritional adjustment, reduces the vegetative growth of the plant, decreases leaf number and crown formation, decreases total yield, and advances the production of flowers and the harvest, in comparison with the use of peat.
- The reduction in plant growth on a substrate with low water-holding capacity is detectable, even when some peat is added to the substrate.

7.4.7. Water supply

The water status of the plant influences many physiological processes, interacting with carbon assimilation – with photosynthesis reduced even under mild water stress– nutrient uptake and the growth rate of strawberry plants.

Therefore, an adequate water supply is needed to sustain an acceptable yield, preventing a decrease in mean fruit weight and fruit number.

However, water availability may have different effects on plant development depending on the physiological processes occurring before or during flower induction and differentiation.

Thus, improving the water supply during flower bud initiation and differentiation in autumn may enhance flower formation and fruit production, but abundant irrigation before the onset of inducive conditions may reduce flower production.

Mild water stress may even allow flower induction under unfavourable environmental conditions after the start of flowering.

Water stress affects the growth of the stolons and also the shoots, preventing their development if the water supply is strongly diminished (25% of daily water consumption) and reducing their number under mild water stress, also affecting the ability of the plant to form new inflorescences.

7.4.8. Defoliation

Leaf removal in the nursery affects vegetative growth, altering the shoot-to-root ratio, reducing the assimilating surface and the endogenous nitrogen, and promoting flower differentiation.

Defoliation is also suggested to stimulate compensative growth from lateral shoots and the onset of new inflorescence sites.

7.4.9. Propagation

The use of plug transplants allows earlier plant establishment after transplanting, enhances early growth and determines earlier flowering and fruit yield compared with bare-root transplants, irrespective of tray size and crown
Diameter.

The size of the stolons used for the production of tray plants seems to have no effect on fruit production during cultivation, because one leaf is enough to detect the induction signal. The sequence position and the distance of the daughter plant from the mother plant along the parental stolon affect the
number of leaves.

Pot size determines the volume of substrate available and affects the growth of the root. Small pot volumes increase plant sensitivity to inducing conditions and stimulate early flower induction during plant root system formation.
Root growth can be inhibited once the roots take up the whole substrate volume after too long a growing period in the tray, resulting in stress conditions, leading to a lower flower quality.

Application of gibberellic acid biosynthesis inhibitor reduced early vegetative growth, decreasing the number of stolons

7.4.10. Evaluation of plant quality

Plants are usually graded according to their crown size (diameter) and to the length of the roots.

The weight of the plant, the number of crowns and the length of roots are all parameters positively related to yield potential.

When produced under the same growing conditions, larger plug plants (obtained from larger stolons) may produce more flowers than smaller ones

A large plant does not always equate to higher crop, therefore plant size itself is not enough to characterize the crop potential of nursery plants.

7.5. Plant Manipulation in the Field

The response of the plant to environmental signals, such temperature, varies depending on the physiological phase of the different organs and their relative positions.

For instance, axillary meristems at a maximum level of dormancy do not develop secondary shoots after placing the plants in the greenhouse. As the chilling requirement is increasingly satisfied, the axillary meristems initiate new secondary shoots, but if the temperature is too cold, lateral growth can be affected.

- Flower removal may promote the production of leaves and runners in some genotypes.
- In other cultivars, deblossoming treatment increases runner production only in combination with defoliation, or may have no effect on runner formation.
- The removal of runners promotes branch crown development
- Transplant defoliation may affect plant growth, reducing the number of crowns and inflorescences if there is not enough time to restore the leaf surface area.
- Strawberry leaves of different maturity are able to reduce flower bud initiation and under some conditions mature leaves can act as inhibitors compared to immature leaves.

- In remontant cultivars, the number of crowns increases by advancing the planting date and prolonging the growing period, enabling a higher yield if the cultivar is not highly crowned, as the inflorescences derive from the apical meristems of the plant.

- For delayed transplanting in the field, when environmental conditions promoting flower differentiation do not persist, it is necessary to select already differentiated plants from the nursery.

- For a good crop, planting density can be balanced according to the number of inflorescences per plant (flowers m^{-2}) rather than the plant size, as the former is more strongly related to the crop potential.

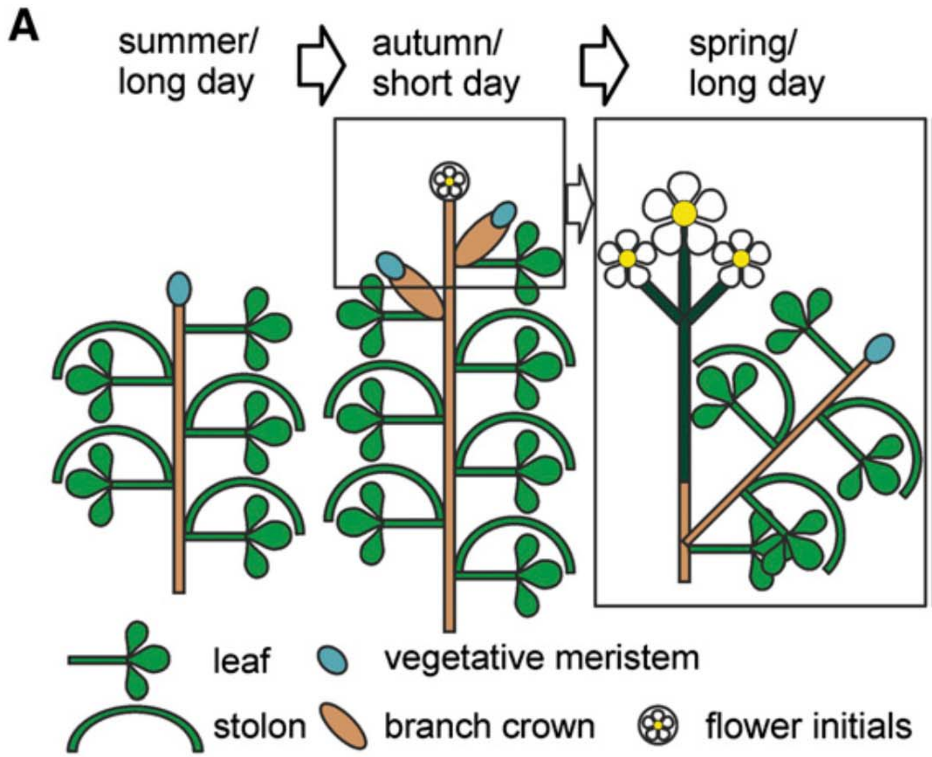
- Increasing plant density (by reducing either row or plant spacing) may reduce the crown diameter and early and total yield, with no effects on the number of leaves.

- At a low planting density, a higher yield is possible.

- Small-sized plants with a few flower buds in addition to the terminal one produce a short harvest. This type of plant is profitable only with high-density planting, mainly in mild climates where the plants can differentiate further flowers on the top of the lateral shoots after the first harvest.

Well-differentiated plants, with the terminal inflorescence at a late developmental stage and with many less-developed lateral shoots and buds, start producing from the terminal inflorescence around 40 days after transplanting and continue producing from the other inflorescences before the end of the first production.

When plants bear vampire buds (flower-differentiated buds at the same stage as the main terminal apex) at the base of the crown, these buds can compete with the terminal inflorescence. It is useful to be aware of their presence in order to plan their removal or to adjust the growing technique, allowing a good harvest. The ability of axillary buds to grow out is related to the degree of apical dominance.



(A) Schematic representation of the shoot structure and development in seasonal flowering strawberry (SD). Under LDs in summer, the plant grows vegetatively and axillary buds typically differentiate into runners. Autumn SDs cause flower initiation in the apical meristem and the development of axillary branch crowns. The terminal inflorescence emerges in the next season, and newly formed axillary branch crowns continue vegetative development. Note that branch crowns formed in the autumn often produce terminal inflorescences in the next spring.

(B) Close-up of a strawberry crown with the main crown in the middle and axillary branch crowns (arrows) in both sides.