Do strawberry plants need larger canopies, more flowers, or higher rates of photosynthesis for higher yields?

Christopher Menzel, Principal Horticulturist, Department of Agriculture and Fisheries

- Productivity in strawberry depends on the production of new leaves, crowns and flowers
- Research to determine if cultivars with open canopies have higher yields than those with dense canopies would be helpful
- The structure of the canopy may become more important in the future
- This is because higher temperatures under global warming will promote the leaves at the expense of the flowers and fruit

Introduction

Productivity in strawberry is dependent on the production of new crowns, leaves and inflorescences, with fruit growth dependent on photosynthesis occurring in the leaves. A review of several reports showed that the relationship between yield, growth and photosynthesis is not always clear. Cultivars achieve high yields in different ways, depending on the population, growing system and environment. The relationship between yield and plant architecture is an important consideration when developing new cultivars. Research to determine if cultivars with open canopies have higher yields than those with dense canopies would be helpful. The structure of the canopy may become more important in the future. This is because higher temperatures under global warming will promote the leaves at the expense of the flowers and fruit.

The yields of new cultivars peaked in the 1970s and 1980s in many locations around the globe. This was possibly because of the focus of breeding on fruit quality and other plant traits. There has also been a loss of genetic diversity across commercial breeding populations. This article explores the impact of breeding on the productivity of strawberry. Specifically, it assessed whether cultivars need larger canopies, more flowers, or higher rates of photosynthesis to achieve higher yields. Higher temperatures under global warming are likely to change many aspects of strawberry physiology, including higher rates of photosynthesis, more leaves and fewer flowers and fruit.

Impact of breeding on plant architecture and yield

There are a few studies that have examined whether the increases in productivity in strawberry have been associated with changes in photosynthesis or the architecture of the plants.

Harbut (2009) reported on the productivity of 20 cultivars released in north-eastern United States from 1891 to 2003. Productivity was variable with no trend with the year of release for yield. The number of flowers per plant halved over the period. Total plant dry weight increased over time, primarily due to an increase in crown dry weight and less importantly root dry weight. Leaf area ratio (LAR) decreased over time, while photosynthesis was stable. Leaf area ratio is the amount of leaf area per unit of plant dry weight. Low LARs reflect open canopies and high light levels at the base of plants. It is difficult to separate the factors affecting productivity in this study. Higher yields in the 1980s reflect larger plants with open canopies, whereas more recent cultivars have insufficient flowers for high yields.

Shaw and Larson (2008) indicated that the mean (± SE or standard error) yields of cultivars released in California from 1993 to 2004 were three times (1429 ± 61 g per plant) those released from 1945 to 1966 (595 ± 42 g per plant). The newer cultivars had larger canopies than the old cultivars.

Chiomento et al. (2021) examined the productivity of nine cultivars released from the University of California from 1992 to 2013. Mean yield was 356 ± 24 g per plant and ranged from 218 to 453 g per plant. There was no relationship between yield and the year that the cultivar was released.

Flanagan et al. (2020) collected data on growth and yield for 12 cultivars released from 1984 to 2017 from California, Florida and Maryland. Mean canopy diameter was 21.0 ± 0.4 cm and ranged from 17.2 to 22.7 cm. Mean marketable yield was 347 ± 27 g per plant and ranged from 215 to 529 g per plant. There were no relationships between canopy diameter or yield, and the year that the cultivar was released.

Scott et al. (2021) investigated the performance of ten cultivars in Texas that were released from 1992 to 2014. Data were collected on yield and plant vigour (1= poor vigour and 4 = excellent vigour). Mean yield was 342 ± 22 g per plant and ranged from 222 to 431 g per plant. Mean plant vigour was 2.9 ± 0.2 and ranged from 1.7 to 4.0. There was no relationship between yield or plant vigour, and the year that the cultivar was released. Later cultivars had similar yields as the early cultivars, although Texas accounts for less than 1% of total strawberry production in the United States.

Plant breeding has increased the productivity of strawberry over the last 100 years. Higher yields have been associated with increases in the size of the plants. Information is now required to determine whether there have been changes in architecture and the distribution of light within the canopy.

Relationship between yield and photosynthesis

Healthy strawberry leaves absorb about 90% of the incoming radiation. Some of the incoming energy is lost in heating the plant and some is reflected into the atmosphere. Overall, about 75% of energy is used for cooling and not used in photosynthesis.

Hancock et al. (1989) studied the relationship between yield and photosynthesis in seven cultivars in Maryland in the United States. There was no relationship between yield and mean photosynthesis over the season. In contrast, there was a moderate relationship between yield and the stability of photosynthesis. Photosynthesis was more stable in high-yielding cultivars than in low-yielding cultivars over a range of favourable and unfavourable conditions for carbon assimilation.

Strik and Proctor (1988) examined the performance of several cultivars in North America over two seasons. Photosynthesis was higher during periods of strong shoot or fruit growth. Yield and photosynthesis varied across the cultivars, however, there was no relationship between the two measures of productivity.

The relationship between yield and photosynthesis in strawberry is unclear. Most of the studies report data on photosynthesis per leaf area over a single day. In many crops, there is usually a better relationship between yield and seasonal photosynthesis by the canopy.

Relationship between yield and plant growth

The correlation between yield and growth can indicate the main traits associated with high yields. The results for strawberry are mixed, with both weak (N = 69 studies) and strong correlations between yield and canopy, leaf, crown or flower production (N = 47 studies). The different responses could be due to variations in productivity, the methods used to assess growth, or the mechanisms associated with high yields in the populations.

Relationship between yield and plant architecture

There is little information on yield and plant architecture in strawberry. In many crops, leaf area index (LAI) is used to estimate the amount of light intercepted by the canopy. Leaf area index is the one-sided area of the photosynthetic tissue or green leaf area per unit ground surface area. In row crops such as strawberry, the surface area is usually taken as the total planted area (ha).

Best yields are often achieved with an LAI of 3 to 4, although some crops such as cotton have the best yields with an LAI of 4 to 6. Leaf area indices greater than 6 or 7 usually reflect excessive leaf growth and shading of the lower canopy. Apple is an exception, with a relatively low optimum LAI of 1.2 to 2.0 in many plantings, while maize is at the opposite end of the spectrum, with an optimum LAI of 6.0 to 9.0.

The arrangement of the leaves within the canopy is just as important as LAI. Leaf area density (LAD) reflects the total area of the leaves per volume of the canopy (m^2 per m^3). Plants with open canopies and low LADs often have higher yields than plants with dense canopies and high LADs. Plants with dense canopies have less light reaching the lower leaves.

Plants with open canopies have higher yields than those with dense canopies. Photo credit: Chris Menzel, DAF

Yield is dependent on new leaves, crowns and flowers. Photo credit: Chris Menzel, DAF

Information on yield and LAI in strawberry is sparse. Mean LAIs ranged from 0.8 to 3.2 and yields ranged from 220 to 1028 g per plant in several studies in Brazil and Turkey. Researchers in Florida suggested that strawberry cultivars with very open canopies (scores below 2.5 in a scale from 1 = very open to 5 = very dense) had lower yields than those with dense canopies.

Conclusions

- The relationship between yield, growth and photosynthesis in strawberry is not clear.
- Cultivars can achieve high yields in different ways, depending on the population, growing system and environment.
- Some cultivars have higher yields because they have larger canopies or more flowers.
- There is insufficient evidence to indicate if other cultivars have higher yields because they have higher rates of photosynthesis.
- The relationship between yield and plant architecture is an important consideration when developing new cultivars.

Research to determine if cultivars with open canopies have higher yields than those with dense canopies would be a good start. The need for more open canopies may become more important in the future. This is because higher temperatures under global warming will promote the leaves at the expense of the flowers and fruit. These efforts will help breeders maximize productivity in different growing areas.

The use of image analyses to characterise the canopy will assist the development of high-yielding cultivars. Genome-wide association (GWA) and genomic prediction (GP) will also accelerate the identification of high-yielding populations and individuals.

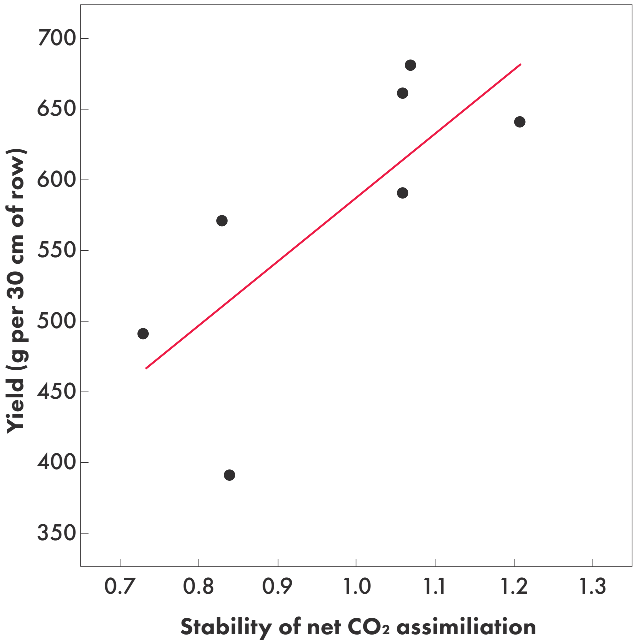

Figure. 1. Relationship between yield and the stability of net CO_2 assimilation (photosynthesis) in strawberry cultivars in Maryland, United States. Photosynthesis was more stable in high-yielding cultivars than in low-yielding cultivars over a range of favourable and unfavourable conditions for carbon assimilation.

Data from Hancock et al. (1989).

Yield = Intercept + 451 × Stability index (P = 0.052, R^2 = 0.48).

Queensland Government

The Queensland Government has funded the research through the Department of Agriculture and Fisheries. Many thanks to the Florida Strawberry Growers' Association (FSGA) for financial support, and Dr Penny Measham (DAF) for reading an earlier version of this article.