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COMMENTARY

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Restricting growth for improved fresh produce scheduling: A role for stomatal blockers?

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INTRODUCTION

Scheduling the supply of fresh produce to meet consumer demand is difficult, and much waste can result if the production of crops exceeds demand and there is no market for the surplus produce.[1] Growers can reduce this problem by using a range of cultivars maturing at different times and by planting on different dates to spread out the maturity of the produce and readiness for harvest. However, these methods do not help if demand changes over a short period, for example, due to changes in weather altering consumer preferences. One approach to reduce this problem is to use different methods, either pre- or post-harvest, to preserve the mature produce by slowing down deterioration. This may not help with reducing oversupply, however, if the crop is still continuing to grow fast and more produce is maturing at the same rate. Another approach could be to restrict the growth of immature produce so that there is temporarily less produce maturing and becoming ready to harvest. This may be possible by using hormone inhibitors as growth retardants applied to the crop before the produce is mature. This paper, however, proposes a new approach for retarding fresh produce growth using polymers to block stomata and reduce photosynthesis. Strawberries are used as an example of a fresh produce crop grown in many countries where it would be financially beneficial to growers to have the ability to slow the production of mature fruit, delay the need to harvest and reduce supply onto the market in response to short-term reductions in demand.

GROWTH RETARDANTS

There are many circumstances in crop production when growth needs to be manipulated in different ways and to do this plant growth regulators are applied to many crops, including fresh produce.[2] In some situations, a reduction in growth is desirable and plant growth regulators, which retard growth by inhibiting hormone biosynthesis or action, are an important type of plant growth regulator. There are several growth retardants approved for use on fresh produce, examples include paclobutrazol for reducing vegetative growth of avocado trees and thereby improving fruit set[3] and uniconazole for restricting the growth of young tomato plants before transplanting.[4] The review by Rademacher gives a comprehensive list of plant growth regulators, including retardants, and their uses.[2] Some retardants, such as paclobutrazol, are persistent in the soil and may leave residues in food leading to possible consumer health concerns.[5] There is therefore a need for consumer-friendly retardants for fresh produce, which have short-term effects and leave little or no residue.

STOMATAL BLOCKERS

Here, we propose that polymers sprayed on leaves to physically block stomatal pores and restrict water loss may also have the potential to fill this need for short-term retardants with little or no residue, and we refer to these materials as stomatal blockers. The blockage of the pores is illustrated in scanning electron micrographs of leaves treated with these polymers.[6,7] Stomatal blockers are used commercially to reduce water loss from plants, in this context being referred to as film antitranspirants.[8] They have been mainly used on ornamentals, but there is now good evidence that, if they are applied at the most drought-sensitive stage of development, they can benefit food crops such as wheat[9,10] and rapeseed.[11,12] There may be a new direction for research on these polymers as growth retardants because it has been reliably established in a large number of studies and in many species that stomatal blockers reduce photosynthesis in addition to transpiration.[6] The reduction in photosynthesis from stomatal blockers has been assumed to lead to a reduction in dry matter growth,[13] but published data demonstrating reduced growth is sparse. However, the potential of stomatal blockers as growth retardants has been shown in grape vines by reduced pruning weight from pre-flowering application to limit photosynthesis.[14]

Stomatal blockers should be simple for most fresh produce growers to apply to their crops because most growers will have a sprayer for applying herbicides, insecticides and fungicides. Furthermore, stomatal blockers may be well-suited to short-term retardation of fresh produce because these materials usually reduce photosynthesis for less than 4 weeks,[6] although the reduction may last much longer in some circumstances.[14] The persistence of the reduction in photosynthesis from a common commercial type of blocker, terpenes, appears to vary according to the extent of polymerisation and may be as short as 16 days.[15] Some of the polymers used as stomatal blockers may be more acceptable to consumers than synthetic growth retardants because they are derived from natural products. For example, one of the common commercial products, di-1-*p*-menthene, is derived from pine resin.[8] Other polymers which can act as stomatal blockers and are possibly even more-acceptable to consumers are natural products derived from plant extracts without chemical modification and may include extracted leaf wax,[16] and vegetable oil.[17] An additional advantage of vegetable oils is their much lower cost, and as a consequence they may be more likely to be adopted by smallholder farmers in low-income countries.

However, it is possible that stomatal blockers may have some unwanted effects because it has been found that when applied to grape vines pre-flowering, there is a reduction in berry size[14] and when applied during berry ripening, berry size and sugar concentration are lower.[18] In other fruit crops, these effects could lead to reductions in quality since there is often a minimum berry size and minimum sugar concentration in the retailers' quality specification to growers.[19]

STRAWBERRY EXAMPLE

We use strawberries as an example of a fresh produce crop where the ability to restrict growth and delay harvest would help growers avoid oversupply and better meet short-term changes in demand. Traditional seasonal-flowering strawberry cultivars (often referred to as June bearers) produce flowers and ripe fruit in a period of a few weeks in the northern hemisphere early summer when grown outdoors.[20] The production pattern of June bearers starts with a few berries ready for harvesting in the first week, then the number rapidly increases with a flush of many berries ready for harvesting over 2 or 3 weeks and production declines sharply in the final week of fruiting.[21] Scheduling of strawberry production has been greatly improved by the introduction of ever bearer cultivars which do not have the seasonal flowering characteristics of June bearers and produce fruit over many weeks with a reduced peak in production. Growing strawberries in plastic-covered tunnels has also been a major advance enabling a greater spread of fruit production.[21]

Despite the improvements in scheduling from ever bearer cultivars and growing in tunnels, there are still peaks in production which lead to oversupply reducing prices and creating waste, and the ability to retard berry growth and reduce peaks in production would be advantageous to growers.[19] For one major grower of strawberries in the UK, the economic loss from production exceeding demand is estimated at up to 4% of the total value of production.[19] It is possible that using stomatal blockers to restrict growth could be a new management procedure which would help reduce this loss. We are conducting preliminary research with strawberries to validate our proposal.

CONCLUSIONS

Oversupply is a cause of waste and economic loss in many fresh produce crops[22] and stomatal blockers may have application in reducing economic losses from oversupply throughout the global fruit and vegetable industry. Further research is needed in a range of fresh produce crops, ideally with food-grade natural product stomatal blockers. This research should quantify the reduction in growth and any variation resulting from environmental factors affecting photosynthesis and growth, such as incident solar radiation and accumulated temperature. It will also be important to evaluate possible unwanted effects on produce quality. In addition, there is also a need for research to estimate the possible financial benefit to growers of reduced growth from stomatal blockers, and this will require complex economic modelling in relation to short-term changes in supply, demand and price.

In summary, we believe that the theoretical basis for stomatal blockers to retard fresh produce growth, outlined above with particular reference to the strawberry crop, is sufficiently supported by the literature to justify research on stomatal blockers as crop scheduling aids in the management of commercial fresh produce.

AUTHOR CONTRIBUTIONS

Peter Kettlewell: Conceptualisation (supporting); writing – original draft (lead); writing – review & editing (lead). **Jim Monaghan**: Conceptualisation (lead); writing – review & editing (supporting).

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

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