RELATION BETWEEN EARLY FRUIT DROP AND EMBRYO DEVELOPMENT IN APPLE

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Summary

It was possible to identify potential drop fruit by the reduced rate of fruit enlargement which was found between 6 and 10 days before abscission. Early drop of fruit was enhanced by heating at night and the abscised fruits are about 10 to 20 mm in diameter. During the spherical embryo stage, the embryo abortion in potential drop fruit was first observed at the middle and late stages of fruit drop process, and consequently, it did not seem to be the cause of fruit drop. Fruit drop at this stage appeared to be related to endosperm abortion or some other unidentified factors. However, at the trans-shaped embryo stage, the embryo development in potential drop fruit stopped at the early stage of the fruit drop process. Therefore, the embryo abortion at this time seemed to be a possible cause of fruit drop. Moreover, the embryo abortion at the trans-shaped embryo stage was suggested to be caused by a disturbance in endosperm.

Introduction

In the apple, the early drop of fruit has a close relation with seed abortion, but the mechanism of this phenomenon has remained obscure. Understanding of this mechanism will be usefull for June drop control and developing chemical thinning.

MOSTAFAWI[5] observed that the embryo of June drop fruit was retarded in development in comparison with that of persisting fruit of the same age and stated that embryo abortion was associated with June drop. WEINBAUM and SIMONS[8] did not support the concept of embryo abortion as a causal mechanism in natural fruit abscission during the post-bloom period because they found no apparent reduction in the integrity or relative abundance of organelles associated with the embryo of fruit in which fruit drop had been

initiated.

We reported previously that fruit enlargement and early drop of fruit were enhanced by heat treatment at night[7], and that the former had a close relationship to the development of endosperm and nucellus.

In the present study, an attempt was made to study the relation between early drop of fruit and embryo development.

Materials and Methods

Nine-year-old 'McIntosh' apple trees, after flowers were artificially pollinated with 'Summer Red', were covered with plastic film and heated with a kersen heater in order to increase early drop of fruit. The temperature was held at 25°C from 5 : 30 P.M. to 6 : 30 A.M. for 30 days from the 10th day after full bloom. The temperature in the day time was allowed to follow the natural course, since during daylight hours the upper cover was opend. Two hundred central fruits were labelled and measured for their equatorial diameters at the same place with a slide caliper every other day during the heating period. The lateral fruits were allowed to follow their natural course of development.

Seeds were collected from the persistent and potential drop fruit 18 to 30 days after full bloom. They were fixed in formalin-acetic-alcohol, embedded in paraffin and sectioned in 15 μm. These sections were stained with Mayer's acid-haemaraun, mounted to be used for a histological study of embryo development.

Results

Identification of Fruit Drop Potential by the Rate of Fruit Enlargement

The early drop of fruit was enhanced by heating at night. The total percentage of furit drop in treatment was 94%, while that in the control was 54% (Fig. 1). Fig. 2 shows the relation between fruit drop and fruit diameter in heating treatment at night. Two peaks were recognized at about 6 mm and 15 mm in diameter. These peaks were also observed in the control. It seemed that the peak at about 6 mm was caused by unfertilization, not heating, as the fruit diameter was 8.2 mm at the start of heating. The early drop of fruit by heating was seen in fruit of 10 to 20 mm in diameter.

Fig. 3 shows a pattern of enlargement of persistent fruit and fruit abscission of potential drop fruit. The rate of the enlargement of persistent

fruit was about 2.2 mm in diameter every 2 days, while that of potential drop fruit was less than 1.0 mm. All fruits in which the rate of enlargement had reduced abscised from the cluster. Therefore, the identification as potential drop fruit could be made from measuring the rate of fruit enlargement measured every two days 6 to 10 days before abscission. And that occured prior to fruit or peduncle yellowing using as a standard rule of thumb of identification of fruit drop.

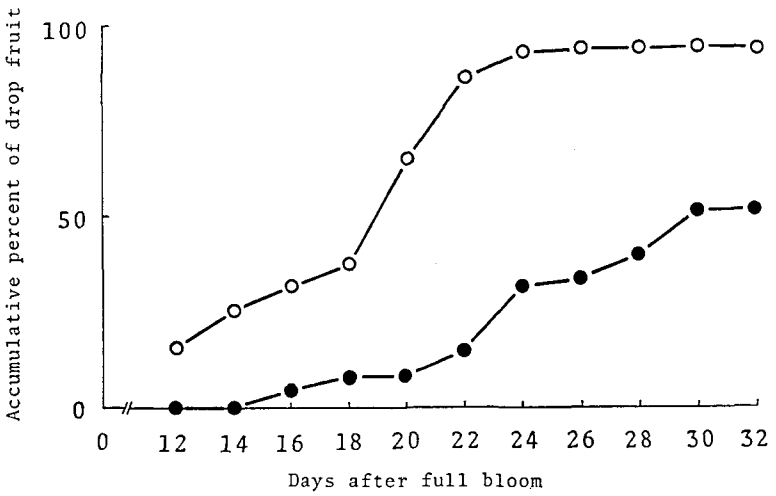

Fig. 1. Effect of heating at night on fruit drop.
○ : heated at night. ● : control.

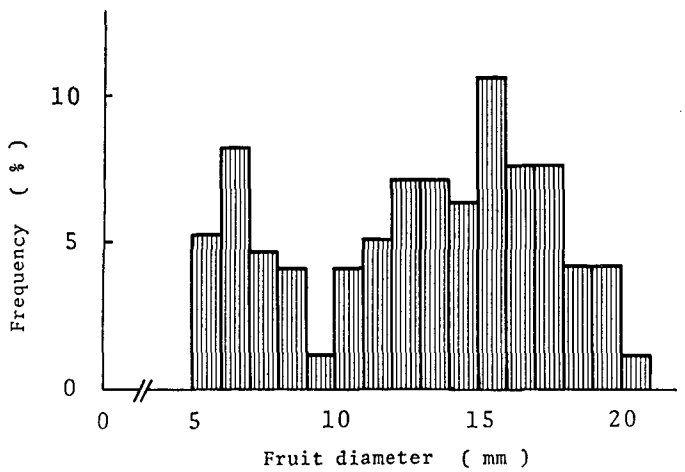

Fig. 2. Relation between fruit diameter and fruit drop in heating treatment at night.

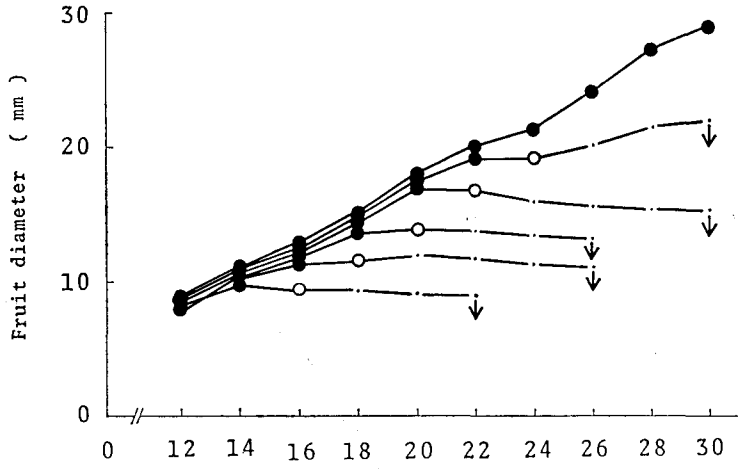

Fig. 3. Pattern of persistent fruit enlargement and fruit abscission of potential drop fruit.
● : persistent fruit ○ : potential drop fruit
↓ : fruit abscission

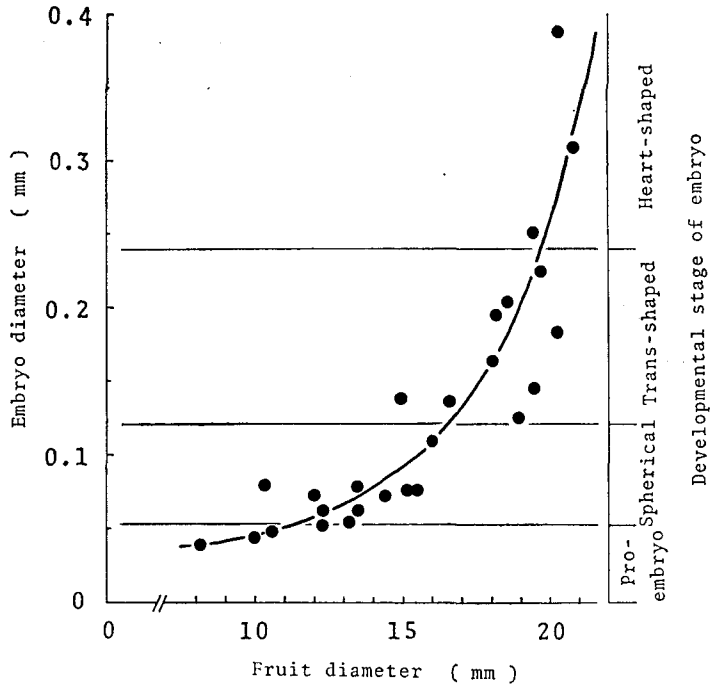

Fig. 4. Relation between fruit diameter and the embryo development in persistent fruit.

Fruit Drop and Embryo Development

Fig. 4 shows the relation between fruit diameter and the development of embryo in persistent fruit. Since the early fruit of drop was within a range of 10 to 20 mm in diameter, their embryos were at spherical or trans-shaped stage. The following regression equation for persistent fruit was set up based on the relation between fruit and embryo diameter.

$$y_1 = 0.02 \times 1.3^{(x_1 - 10.7)} + 0.028 \qquad \text{(a)}$$

y_1: embryo diameter of persistent fruit
x_1: fruit diameter of persistent fruit

Embryo diameters of potential drop and persistent fruits 2 days before sampling were obtained by solving equation (a) by substituting the value of fruit diameters 2 days before sampling for x_1. The embryo development of persistent and potential drop fruits for 2 days before sampling is shown in Fig. 5. The ratio of increase in embryo diameter of persistent fruit was about 1.5 at almost all stages of embryo development. That of potential drop fruit was also about 1.5 under 16 mm in fruit diameter (spherical embryo). There was no significant difference between the embryo development of potential drop fruit and that of persistent fruit. However, at the

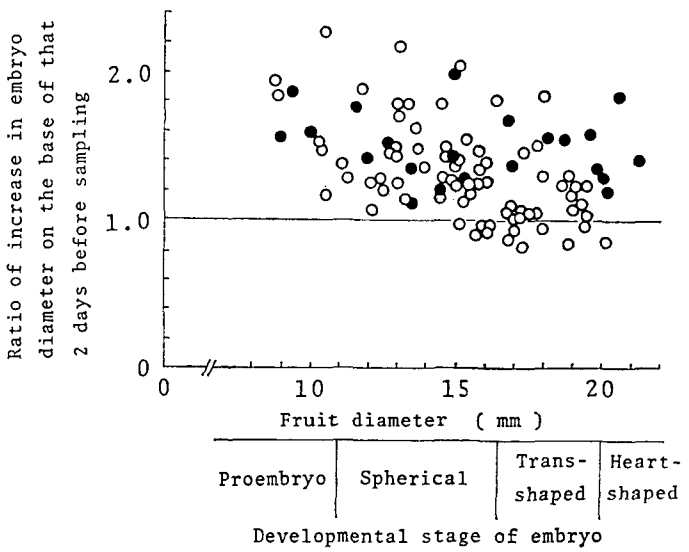

Fig. 5. Embryo development in persistent fruit and potential drop fruit.
● : persistent fruit ○ : potential drop fruit

stage of 16 mm or more in fruit diameter (trans-shaped embryo), the ratio was about 1.0 in potential drop fruit and this indicated that the embryo development has stopped.

The regression equation (b) for potential drop fruit and (c) for the fruit 2 days after identification as that were set up in the same manner as equation (a).

$$y_2 = 0.02 \times 1.3^{(x_2 - 11.1)} + 0.052 \qquad \text{(b)}$$

$$y_3 = 0.02 \times 1.3^{(x_3 - 12.3)} + 0.048 \qquad \text{(c)}$$

y_2: embryo diameter of potential drop fruit
x_2: fruit diameter of potential drop fruit
y_3: embryo diameter of fruit 2 days after identification as potential drop fruit
x_3: fruit diameter of fruit 2 days after identification as potential drop fruit

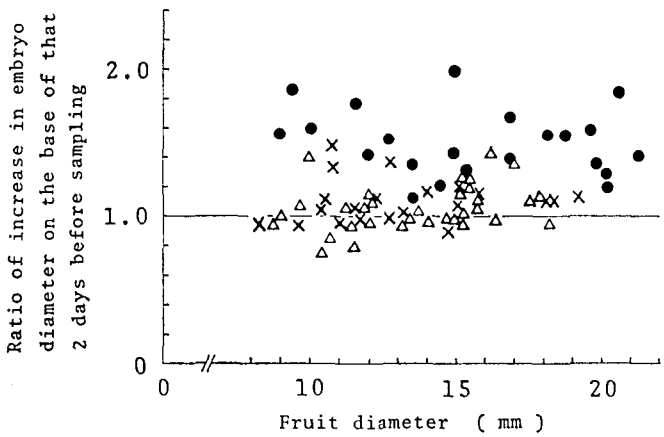

Fig. 6. Embryo development in persistent fruit and fruit 2 or 4 days after identification as potential drop fruit.

●: persistent fruit
△: fruit 2 days after identification as potential drop fruit
×: fruit 4 days after identification as potential drop fruit

Fig. 6 shows the embryo development for 2 days before sampling of fruit 2 or 4 days after identification as potential drop fruit by solving equation (b) or (c). The ratio of both development was about 1.0, while that in persistent fruit was 1.5. This indicated that the embryo had stopped developing.

Discussion

Fruit abscission has been studied for a long time and 3 indices used for identification of potential drop fruit have been reported. These are color change to yellow[1], decline in fruit removal force (FRF)[9] and reduction of the rate of fruit enlargement[8]. The potential drop fruit identified by yellowing or FRF is in a later stage of fruit drop process and these indices are unsuitable for the study of mechanism of fruit drop process. According to WEINBAUM and SIMONS[8], the identification of potential drop fruit is possible on the reduced rate of fruit enlargement 7 to 10 days before abscission or peduncle yellowing. In this experiment as well, potential drop fruit abscised within 6 to 10 days after the identification (Fig. 3).

Early drop of fruit was observed within a range of 10 to 20 mm in diameter and their embryos were at spherical or trans-shaped stage.

The potential drop fruit under 16 mm in diameter (spherical embryo) showed no embryo abortion. However, reduction of the rate of fruit enlargement was observed in this potential drop fruit, and the process of fruit drop

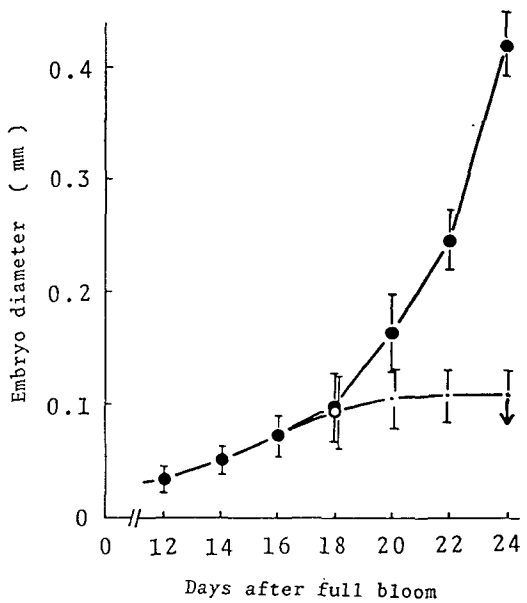

Fig. 7. Pattern of the embryo development in persistent fruit and potential drop fruit.

Vertical bars indicate±SE.

● : persistent fruit ○ : potential drop fruit I ↓: fruit abscission

had already started. Embryo abortion was first observed at 2 to 4 days after identification of potential drop fruit which was in the late stage of the fruit drop process. Therefore, embryo abortion does not seem to be the cause of fruit drop. WEINBAUM and SIMONS[8], in their ultrastructural observation by electron microscope, confirmed that embryo abortion did not act as a causal mechanism in natural fruit abscission during the post bloom period. On the contrary, MOSTAFAWI[5] observed embryo abortion in abscising fruits. As shown in Fig. 7 the discrepancy between them may result from the difference in the stage where abscission occured. In this experiment as well as WEINBAUM and SIMONS, the fruit at the early stage of fruit drop process was used, while the fruit at the late of fruit drop process on the yellowing of peduncle was used by MOSTAFAWI.

The embryo in potential drop fruit of 16 mm or more in diameter (trans-shaped embryo) stopped developing and embryo abortion was observed. The embryo in persistent fruit developed rapidly in this stage (Fig. 5) and it seemed that this developing embryo required much nutrition. Therefore, embryo abortion seemed to be caused by disturbances in and metabolic inefficiency of endosperm nutrition to the embryo as suggested by MURNEEK[6].

LUCKWILL described that an endosperm in the spherical embryo stage changed from the free nuclear to the cellular condition[3] and there was found a close relationship between this endosperm development and fruit abscission[4]. Accordingly, endosperm abortion may be brought about before embryo abortion.

Fruit set and/or abscission have a close relationship to growth regulators which have been produced in the endosperm and embryo[2]. Therefore, endosperm abortion seemed to be a cause of fruit abscission through decreasing the production of growth regulators.

Acknowledgment

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Literature Cited

1. BLANPIED, G. D.: A study of ethylene in apple, red raspberry, and cherry, Plant Physiol., **49**: 627–630. 1972
2. LEOPOLD, A. C.: Physiological Processes involved in abscission, HortScience, **6**: 376–378. 1971
3. LUCKWILL, L. C.: The hormone content of the seed in relation to endosperm

development and fruit drop in the apple, J. Hort. Sci., **24**: 32-44. 1948

4. LUCKWILL, L. C.: Studies of fruit development in relation to plant hormones I. Hormones production by the developing apple seed in relation to fruit drop, J. Hort. Sci., **28**: 14-24. 1953
5. MOSTAFAWI, M., R. STOSSER and G. BUCHLOH: Uber Beziehungen zwischen Embryoentwicklung und Junifall bei Apfelfruchten, Gartenbauwissenschaft, **35**: 175-184. 1970
6. MURNEEK, A. E.: The embryo and endosperm in relation to fruit development, with special reference to the apple, *Malus sylvestris*, Proc. Amer. Soc. Hort. Sci., **64**: 575-582. 1954
7. TAMURA, T., H. FUKUI and S. IMAKAWA: Effect of temperature at early stage of fruit development on the development of fruit and seed in apple, (In Japanese) J. Japan. Soc. Hort. Sci., **50**: 287-296. 1981
8. WEINBAUM, S. A. and R. K. SIMONS: An ultrastructural evaluation of the relationship of embryo/endosperm absorption to apple fruit abscission during the post-bloom period, J. Amer. Soc. Hort. Sci., **99**: 311-314. 1974
9. WITTENBACH, V. A. and M. J. BUKOVAC: A morphological and histochemical study of (2-chloroethyl) phosphonic acid enhanced abscission of sour and sweet cherry fruit, J. Amer. Soc. Hort. Sci., **97**: 628-631. 1972