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Effects of Submerged Condition, Temperature, and Ripening Stages on Viviparous Germination of Rice

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Viviparous germination causes yield loss and quality deterioration of rice. This study was conducted to investigate varietal differences of the viviparous germination with different days after heading (DAH) and different temperatures. In the laboratory examination, the averaged germination rate of all varieties at 45DAH and at 25DAH was 79.9%, and 27.5% under the incubation at the temperature of 30°C/20°C (day/night) for 12 days. Andabyeo, Da- sanbyeo, and Nonganbyeo showed the lowest viviparous germination rates among the tested varieties. The shoot length of the viviparous germination measured 12 days after incubation at 30/20°C ranged from 21 to 53 mm, indicating significant deterioration of rice quality. In the field test, the averaged viviparous germination rates of rice varieties at 25, 35, 45DAH with the underwater conditions for 4 days were 2.2, 6.2 and 9.2%, respectively, while their rates at 12 day after underwater conditions increased to 17.6, 44.2 and 43.8%, respectively. A variety that showed the highest viviparous germination rate at 25 and 35 and 45DAH was Heukjinjubyeo. When standing rice panicles without lodging were examined after consecutive raining for 7 days Juanbyeo showed the highest viviparous germination (45.5%), followed by Odaebyeo (16.0%), Jinbubyeo (14.5 %), Bongkwangbyeo (14.2%) and Obongbyeo (12.6%). The viviparous germination of rice was greatly affected by variety, days after heading and temperature settings. Bongkwangbyeo, Juanbyeo, Dongjinbyeo, Hwasunchalbyeo, Naepoongbyeo and Heukjinjubyeo were classified as the most susceptible varieties to the viviparous germination in the field conditions.

Keywords : viviparous germination, rice

Occurrence of viviparous germination would cause not only the deterioration of rice quality but also the loss of yield. Owing to the geographical position of the Korean peninsular, we have often experienced the lodging and the flooding damages in many of the paddy fields with the typhoon, which has come to the Korean peninsular on September every year. Since the typhoon used to comes either the middle or after ripening periods of rice, the viviparous germination of rice has inevitably been induced in many paddy fields. It has been known that the most important varietal traits related to the viviparous germination are dormancy and germiability under low temperature (Rho, 1990). In addition, the viviparous germination of rice could be influenced by various cultural factors, including the weather conditions. Cho *et al.* (1988) reported that rice plants transplanted on May 25 had higher viviparous germination rates than those transplanted on June 5. Sa *et al.* (1988) found that early maturing japonica type showed higher rate of viviparous germination compared to the late maturing type.

Higher viviparous germination rates of rice have been shown from 20 days after the heading stage(Hong *et al.*, 1980; Suh and Kim, 1994) and the viviparous germination rate was positively correlated with the amount of sucrose content in brown rice (Kim, 1995). Imperfect kernels increased as the rate and length of the viviparous germination increased, resulting in greater yield decrease of hulled rice rather than that of unhulled rice (Oh, *et al.*, 1987).

Varietal differences in viviparous germination were obser-ved with an artificial raining treatment by Hong *et al.* (1998). Average viviparous germination rates of 45 rice varieties were about 15 and 24% after 8 and 12 days of the artificial raining treatment, respectively. However, it was only about 2% under natural conditions, indicating that very lower viviparous germination was happened at standing rice panicles without lodging or submergence through continuous raining. Furthermore, we should know that the consecutive raining which could be enough to induce viviparous germination has come in the Korean peninsular every year.

The objectives of this study were to investigate the viviparous germination rates of different rice cultivars and to examine their rates with different days after heading and different temperature settings in both the laboratory and the paddy field.

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MATERIALS AND METHODS

The field experiment was conducted at the paddy field of Kyonggido Agricultural Research and Extension Services. Twenty-eight rice varieties recommended in Kyonggi region were used in this experiment. When they were 35-day-old seedlings, they were transplanted with the planting density of 30 × 14 cm on 25 May, 1999. Fertilizers of N, P, and K were applied with 110-45-57 kg/ha, respectively. The plots were arranged with the randomized complete block design with 3 replications. Each plot size was 9.4 m^2.

To induce viviparous germination, six panicles of each variety from different hills were placed into the irrigated water by gently bending stem toward ground and kept their panicles under water for 12 days by tieing them to a wooden stake. These treatments were started at 25, 35, and 45 days after heading (DAH) based on heading date of each rice varieties. Field plots were irrigated as needed to keep the panicles wet throughout the experiment. A daily field water temperature was recorded and shown in Fig. 1.

For the examination of viviparous germination conducted with different temperatures in the laboratory, fifteens panicles from each experimental unit were harvested at three different heading date of 25, 35, and 45DAH based on each heading date of rice cultivars. Harvested panicles were laid on a presoaked cotton sheet put into the plastic box of 24W × 15.5L × 7.5H cm, covered with a cotton sheet, and incubated for 12 days with the 12/12h photo period of day/night at the temperature of 20/10°C, 25/15°C, and 30/20°C. Germinated seeds were counted every other day for 12 days both in the field and in the laboratory test. The length of germinated shoots was measured. Since there was consecutive rain for 7 days, which resulted in precipitation of 429 mm from Sept. 18 to Sept. 24, the viviparous germination occurred at the standing rice panicles without lodging or submergence. After the raining, panicles were randomly sampled from each variety and the viviparous germination by the natural raining was evaluated.

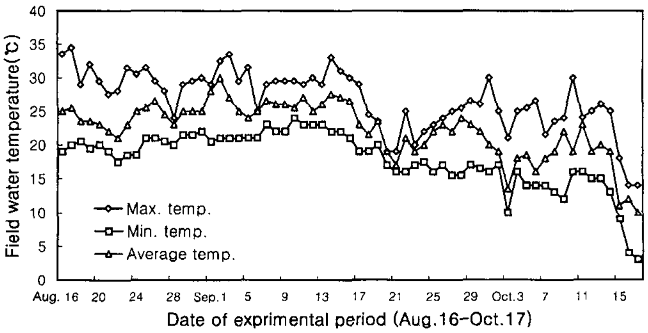

Fig. 1. Average, minimum, and maximum temperature of daily field water during the experimental period.

RESULTS AND DISCUSSION

In the laboratory test, the viviparous germination of each rice variety according to their own heading dates was increased with passing the days after heading from 25 to 45DAH (Table 1). The averaged germination rate of all varieties at 45DAH was 79.9% compared with 27.5% at 25DAH under the incubation with the temperature of 30/20°C, day and night. Although most of varieties showed low viviparous germination rate at 25DAH, some of varieties such as Hwasunchalbyeo, Shinsunchalbyeo, Seoanbyeo, Obongbyeo, and Heukjinjubyeo were germinated more than 50% at 30/20°C. It was appeared that the incubation temperature greatly affected the viviparous germination rate; the viviparous germination rate was about 28.7% at the incubation temperature of 20/10°C at 45 DAH, but it was 79.9% at 30/20°C.

There were significant varietal differences in the viviparous germination throughout the investigating period. Andabyeo, Dasanbyeo, and Nonganbyeo, which were developed by crossing between indica and japonica type, showed the lowest viviparous germination rate regardless with the incubation temperature and the days after heading, while other varieties showed different responses depending upon days after heading. This result was similar to the reports by Tang and Chiang (1955) and Thompson and Grime (1983) that the japonica type had shorter dormancy period than that of the indica type. The shoot length of the viviparous germination measured 12 days after incubation at 30/20°C was ranged from 21 to 53 mm, indicating the significant deterioration of rice quality at favorable environmental conditions for the viviparous germination. Oh et al. (1987) noted that perfect kernel rate was reduced to below 20% with the shoot length of viviparous germination ranging 1.6~2.0 mm.

In the field conditions, the viviparous germination rate was generally lower compared to that of the laboratory test examined at 25/15°C and 30/20°C. Average viviparous germination rates at 4 days after underwater treatment at 25, 35, and 45DAH were 2.2, 6.2 and 9.2%, respectively, while their germination rates at 12 days after underwater treatment were increased to 17.6, 44.2 and 43.8%, respectively (Table 2). There were significant varietal differences with both different days after heading and different temperature as shown in the laboratory test. Heukjinjubyeo which had the earliest heading date among tested varieties showed the highest viviparous germination rate at 25 and 35 and 45DAH. Since Heukjinjubyeo has been considered to be susceptible to lodging according to previous reports (Han *et al.*, 1999), its yield loss and rice quality deterioration would be greater due

Table 1. The viviparous germination of rice and the shoot length affected by different days after heading and diurnal temperatures in the laboratory test.

Variety	Viviparous germination(%)†									Shoot length (mm)
	25DAH			35DAH			45DAH			
	20/10°C	25/15°C	30/20°C	20/10°C	25/15°C	30/20°C	20/10°C	25/15°C	30/20°C	30/20°C
Andabyeo	0.0	0.0	0.1	0.0	0.1	2.2	0.0	0.5	1.4	3
Dasanbyeo	0.0	0.1	0.5	0.1	0.8	9.4	0.1	2.4	16.8	21
Nonganbyeo	0.0	0.0	0.3	0.0	1.1	3.4	1.1	4.1	36.7	20
Odaebyeo	0.2	0.4	8.1	2.1	14.5	20.3	8.3	30.4	41.8	31
Ansanbyeo	1.4	3.1	15.4	15.3	20.0	27.8	19.2	56.1	65.0	53
Daejinbyeo	3.4	13.8	17.9	20.1	70.8	77.8	14.6	58.8	72.5	46
Ilpoombyeo	0.0	5.7	8.7	0.1	7.1	57.6	0.5	63.5	78.4	26
Obongbyeo	1.1	13.3	54.0	1.9	31.6	53.5	18.7	83.6	82.5	33
Seoanbyeo	9.1	31.0	54.3	0.0	46.8	65.8	17.6	72.3	83.6	30
Soorabyeo	0.1	6.1	8.5	3.5	29.3	50.8	26.8	56.8	83.6	24
Kwanganbyeo	1.7	27.9	35.3	0.6	23.6	29.9	19.6	67.7	87.4	38
Naepoongbyeo	5.4	4.0	27.1	33.3	61.1	70.4	57.4	82.6	87.4	35
Hwamyeongbyeo	0.0	4.0	10.3	20.9	72.3	89.4	54.1	86.9	88.1	26
Hwajinbyeo	1.6	8.3	30.2	25.3	78.1	79.0	22.0	89.1	88.1	32
Daeanbyeo	1.5	5.3	20.2	51.4	74.4	83.1	29.9	92.2	88.5	39
Dongjinbyeo	6.2	8.7	22.6	52.7	75.1	85.0	54.7	86.2	90.4	43
Juanbyeo	8.3	26.0	47.2	48.6	79.1	86.3	69.7	81.2	91.5	45
Seojinbyeo	1.7	7.9	26.9	0.6	68.3	72.3	37.9	94.5	92.7	33
Anjungbyeo	0.0	9.2	15.9	39.5	63.6	75.1	31.5	91.9	92.9	50
Hwasungbyeo	0.0	10.5	25.3	0.4	16.3	28.8	13.7	66.9	93.5	28
Hwajungbyeo	1.6	5.7	27.0	49.2	59.7	87.8	39.3	85.7	94.6	46
Janganbyeo	1.0	7.4	27.0	1.7	46.0	49.2	34.8	73.4	96.0	32
Chuchungbyeo	0.0	1.0	10.0	0.1	19.1	82.0	2.2	55.3	96.2	19
Jinbubyeo	0.1	11.4	48.9	2.2	51.8	65.2	21.2	95.1	96.8	42
Hwasunchalbyeo	10.8	56.6	73.7	34.4	96.8	91.0	67.5	93.0	96.9	32
Heukjinjubyeo	0.0	10.7	53.4	0.2	50.2	74.7	21.7	95.0	97.1	46
Shinsunchalbyeo	17.3	37.4	62.0	24.0	72.0	79.2	79.2	92.2	98.5	31
Bongkwangbyeo	12.6	25.4	38.4	50.7	80.6	90.1	41.0	98.5	99.2	36
Mean	3.0	12.2	27.5	17.1	46.8	60.3	28.7	69.9	79.9	34
LSD(0.05)	6.10	12.33	20.25	15.68	22.08	16.07	11.08	12.70	10.48	9.46

†All data represent viviparous germination rates at 12 days after incubation.

to the viviparous germination if the lodging occurs. There were no clear differences among the maturing types in the field experiment. However, Sa *et al.* (1988) reported that the early maturing varieties had higher viviparous germination rates compared to the late maturing varieties. This discrepancy might be due to the differences in the tested varieties and the differences in environmental conditions during grain filling periods (Park and Park, 1984).

Viviparous germination rates at 35DAH were similar to those at 45DAH (Table 2). However, there were different responses among varieties depending upon days after heading. Some of varieties such as Hwamyeongbyeo, Hwajungbyeo, Hwajinbyeo had lower viviparous germination rates at 45DAH than that at 35DAH. This result could be attributed to weather conditions, especially temperature at the specific time of germination periods. The viviparous germination of rice was greatly dependent on variety, days after heading, and temperatures. Andabyeo, Dasanbyeo and Nonganbyeo showed the lowest germination rate from 0 to 2.6% throughout the experiment, supposedly due to dormancy during the ripening period. According to the research result of Rho (1990), rice varieties developed by crossing of indica/japonica generally exhibited stronger dormancy and poor germination under low temperatures compared to japonica type varieties.

When rice panicles standing upright without lodging were

Table 2. Viviparous germination rate of rice panicles with different days after heading and different treating days of the irrigated water in the field conditions.

Type of maturity	Variety	Heading date	Viviparous germination(%)									By natural rain‡
			25DAH			35DAH			45DAH			
			4†	8	12	4	8	12	4	8	12	Sept. 25
Early maturing	Odaebyeo	7.27	0.3	1.0	2.0	1.3	14.3	24.9	7.2	18.6	32.8	16.0
	Daejinbyeo	8. 3	0.2	5.6	19.9	13.9	30.5	39.5	4.4	24.8	51.0	2.0
	Obongbyeo	7.25	0.0	5.2	9.9	9.3	37.1	57.3	8.8	51.8	70.6	12.6
	Jinbubyeo	7.23	1.3	9.0	16.3	7.5	32.0	47.4	18.2	68.3	84.8	14.5
	Heukjinjubyeo	7.22	26.2	52.5	59.5	6.0	52.3	100.0	7.6	73.5	87.5	0.0
Mid-maturing	Andabyeo	8.13	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Dasanbyeo	8.12	0.0	0.0	0.0	0.2	1.9	2.6	0.1	0.2	0.2	0.0
	Nonganbyeo	8. 8	0.0	0.0	0.5	0.1	0.4	1.0	0.4	1.0	2.4	0.0
	Hwasungbyeo	8.11	0.1	0.3	6.0	0.1	2.4	7.2	2.5	3.8	9.2	2.5
	Kwanganbyeo	8.11	0.3	1.7	14.5	2.0	5.6	15.4	4.6	8.1	17.5	0.4
	Soorabyeo	8.11	0.0	0.3	6.6	0.3	6.7	16.4	6.6	11.8	24.7	3.0
	Janganbyeo	8.11	0.2	3.0	11.9	2.4	15.8	40.9	6.2	12.9	31.4	0.8
	Anjungbyeo	8.12	1.0	10.9	16.8	2.1	16.0	47.8	6.9	20.4	33.1	3.7
	Seoanbyeo	8.13	1.1	11.3	28.3	0.6	15.6	46.2	4.6	12.8	35.6	9.5
	Hwajinbyeo	8.16	2.2	12.0	22.1	7.3	42.6	76.6	1.8	11.4	43.2	1.2
	Ansanbyeo	8. 3	0.4	5.0	18.9	9.2	22.3	29.5	4.0	20.6	45.9	7.4
	Hwajungbyeo	8.15	1.5	7.9	16.8	9.1	36.8	69.0	7.5	19.0	49.8	0.8
	Seojinbyeo	8.13	0.1	4.3	13.3	1.7	23.8	56.1	7.0	22.1	52.0	1.1
	Shinsunchalbyeo	8.11	0.2	9.3	24.5	1.6	24.6	57.4	15.9	29.0	58.3	2.0
	Bongkwangbyeo	8.12	17.6	38.9	45.8	16.4	55.5	80.5	34.6	61.5	74.0	14.2
	Naepoongbyeo	8. 4	0.4	12.7	35.8	16.8	50.3	61.7	9.7	32.3	74.2	3.3
	Juanbyeo	8.14	4.5	27.3	41.4	14.1	46.4	72.0	44.9	58.4	74.8	45.5
	Hwasunchalbyeo	8.10	0.7	13.4	30.8	26.7	61.8	81.4	42.5	71.4	87.1	8.4
Mid-late maturing	Ilpoombyeo	8.20	0.2	4.3	9.2	0.1	0.5	0.8	0.0	0.2	2.8	0.0
	Chuchungbyeo	8.21	0.0	0.0	1.6	0.4	0.9	1.9	0.3	2.6	5.2	0.0
	Hwamyeongbyeo	8.16	0.5	4.4	12.1	5.3	36.7	63.3	1.7	7.5	37.6	0.8
	Daeanbyeo	8.14	0.1	4.1	8.7	6.8	39.2	68.5	5.1	25.6	63.7	0.9
	Dongjinbyeo	8.17	1.6	9.9	19.1	11.5	57.0	72.5	4.7	36.5	77.7	0.0
	Mean	-	2.2	9.1	17.6	6.2	26.0	44.2	9.2	25.2	43.8	5.4
	LSD(0.05)	-	3.16	9.86	13.75	10.19	13.46	13.95	7.67	10.61	14.80	7.17

†Days after placing panicles into irrigated water.
‡Viviparous germination at standing condition without lodging by continous natural rain for 7 days from Sept. 18 to Sept. 24.

examined after consecutive rain for 7 days (Table 2), Juanbyeo showed the highest viviparous germination (45.5%) followed by Odaebyeo (16.0%), Jinbubyeo (14.5%), Bongkwangbyeo (14.2%) and Obongbyeo (12.6%). Accordingly, these varieties will cause yield loss and rice quality deterioration by continuous raining even without lodging. Surprisingly, no viviparous germination occurred in Heukjinjubyeo, which showed the highest viviparous germination in the laboratory and field examinations. Hong *et al.* (1999) reported that viviparous germination rate of Heukjinjubyeo was 0%, when examined after the artificial raining treatment for 8~19 days.

The cumulative viviparous germination rate averaged with all of rice varieties increased linearly with increasing incubation days in both field and laboratory (Fig. 2). In the laboratory conditions of diurnal temperature setting of day and night, 25/15°C, there were clearly different responses according to days after heading, showing higher germination rates as days after heading increase, but no obvious difference was observed at the field conditions between 35DAH and 45DAH.

Daily viviparous germination gradually increased with increasing days after underwater conditions at the field test compared to that at the controlled laboratory test obviously

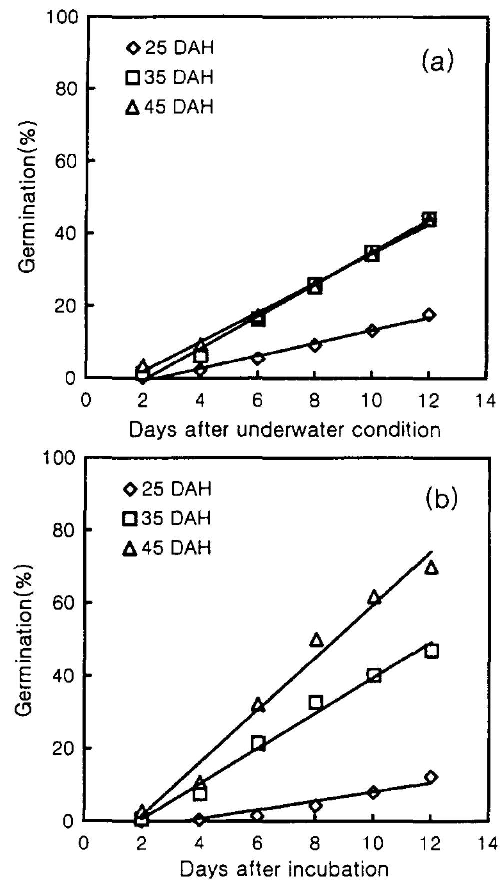

Fig. 2. Cumulative daily-viviparous germination rates with different days after heading in the field test (a) and laboratory incubation at 25/15°C (b).

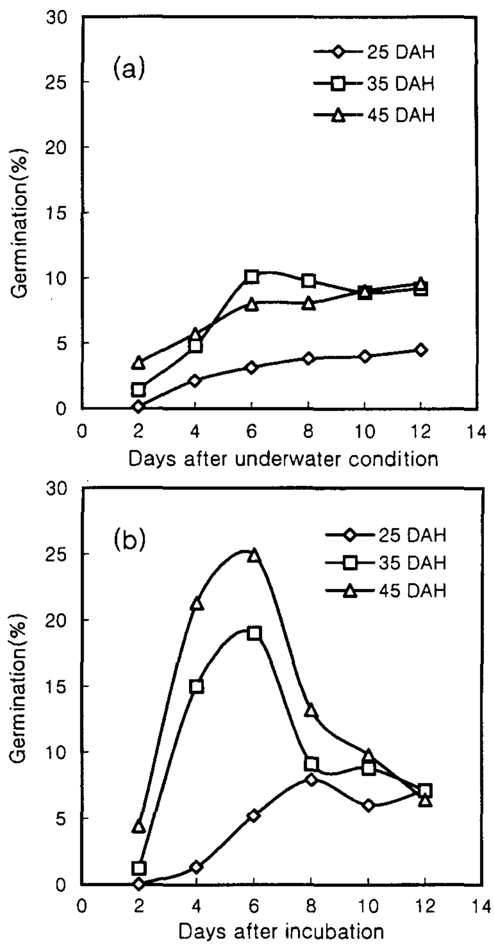

Fig. 3. Daily viviparous germination rate, at different days after heading in the field test (a) and laboratory incubation at 30/20°C (b).

due to the difference of temperature between them (Fig. 3). It reached highest at 6-day incubation under laboratory conditions at 35 and 45DAH. This result was well corresponded with the report by Suh and Kim (1994) who concluded that varietal differences of viviparous germination were observed best 6 days after incubation at the temperature setting of 25/15°C considering field conditions. In this field test, the averaged field water temperature during the experimental period was 22.3°C, the averaged maximum temperature 26.8°C, and the averaged minimum temperature 17.9°C (Fig. 1). Daily germination rates measured 6 and 8 days after underwater conditions were lower at 45DAH than that at 35DAH due to some of late-maturing varieties facing lower tempera-

Table 3. Classification of rice varieties according to the viviparous germination rate in the field conditions by cluster analysis.

Classified groups	No. of varieties	Varieties	Averaged Viviparous germination (%)†
I	6	Bongkwangbyeo, Juanbyeo, Dongjinbyeo, Hwasunchalbyeo, Naepoongbyeo, Heukjinjubyeo	65.3
II	8	Daeanbyeo, Seojinbyeo, Shinsunchalbyeo, Obongbyeo, Jinbubyeo, Hwamyeongbyeo, Hwajungbyeo, Hwajinbyeo,	45.0
III	8	Kwanganbyeo, Daejinbyeo, Soorabyeo, Seoanbyeo, Ansanbyeo, Anjungbyeo, Odaebyeo, Janganbyeo	27.1
IV	6	Dasanbyeo, Nonganbyeo, Andabyeo, Ilpoombyeo, Chuchungbyeo, Hwasungbyeo	2.8

†Data represent the average across germination rates at 25, 35, and 45DAH.

ture at later stage of maturing period. This result means that major factors influencing viviparous germination rate would be temperature and moisture when rice seeds have full germination potential

Tested rice varieties were classified into four groups by cluster analysis based on data from the field examinations at 25, 35, 45DAH (Table 3). The Ward's minimum variance method was applied, and R^2 was 0.86. The averaged viviparous germination rate of the group I was 65.3%. Varieties included in the group I was Bongkwangbyeo, Juanbyeo, Dongjinbyeo, Hwasunchalbyeo, Naepoongbyeo, and Heukjinjubyeo. The averaged viviparous germination rates of group II and III were 45.0 and 27.1%, respectively. The group IV, which included Dasanbyeo, Nonganbyeo, Andabyeo, Ilpoombyeo, Chuchungbyeo and Hwasungbyeo, showed the lowest viviparous germination rates with an average of 2.8% ranging from 0 to 9.2%. Therefore, utilization of these varieties could minimize yield loss and quality deterioration from viviparous germination in the event of flooding during ripening periods.

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