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RESEARCH ARTICLE

Heat Unit Establishment as Harvest Criteria on "Mas Kirana" Banana at Various Times of Anthesis

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Abstract

The method for determining the appropriate time to harvest banana could affect the shelf life and quality of banana fruits during storage. The objectives of this study were to establish the heat unit as harvesting criteria of "Mas Kirana" banana and to evaluate how heat unit affects fruit shelf life and postharvest maturity characteristics. The research was conducted at PTPN VIII Parakansalak Plantation, Sukabumi, West Java, Indonesia, in November 2017 to February 2018. Laboratory analysis was conducted in Postharvest Laboratory, Department of Agronomy and Horticulture IPB in February to April 2018. The experiment was organized in a completely randomized design with a single factor of eight different flower tagging times after anthesis. Each treatment was replicated five times totaling 40 experimental units. The results showed that the different times of anthesis did not affect fruit size, weight per hand, number of fruits per hand and weight per fruit. Different time of anthesis did not affect respiration rate, fruit shelf life, physical and chemical quality. The minimum heat unit of 650ºC degree days can be used as harvesting criteria for banana "Mas Kirana". The number day after anthesis was 39 to 43 with fruit shelf life of 12 to 16 days.

Keywords: degree day, maturity, metabolites, respiration, shelf life

Introduction

Banana is the most popular production fruit when compared to other fruits in Indonesia. Domestic production of banana in 2015 was 7,299,265 tons from 88,728 million trees. In 2016, the total production had decreased into 6,982,041 tons from 81,307 million trees. The banana export volume had also decreased from 22,308 tons in 2015 to 19,024 tons in 2016 (Kementan, 2016). One of the problems in banana production is in the postharvest handling which can directly impact the banana quality. As a climacteric fruit, banana should be harvested at the right time during its physiological mature period. Prior to the physiologically mature stage, the banana would be of low quality, and likewise when harvested too late. Therefore, it is important to develop a standard method to determine the proper time and criteria for banana harvesting.

The proper time of fruit harvesting would impact the fruit nutritional quality, especially fruits for fresh consumption. One of the banana cultivars that consumed as fresh fruit is "Mas Kirana". Description of "Mas Kirana" cultivar according to the Indonesian Ministry of Agriculture/Kepmentan No. 516/Kpts/SR.120/12/2005, the fruit is 9:55 ± 3:09 cm in length, 3:06 ± 1.74 cm in diameter, 71.36 ± 8.44 g in weight per finger, 21% of sugar content, 0.063% of acid and 3.905 mg/100 gof vitamin C. The shelf life of banana cultivars at room temperature varies from five to six days (Kementan, 2005). "Mas Kirana" banana contains secondary metabolites from the class of phytosterols, terpenes, fatty acids, aldehydes and phenolic. The dominant compound found in "Mas Kirana" bananas is a group of phytosterols in the form of sterol lipids. Phytosterols are natural cholesterol that has functions in the formation of muscle mass. Vitamin E is commonly found in vegetable and fruits, including banana, and a source of the antioxidants (Cao et al., 1996).

There have been limited information available about the levels of fruit maturity and how it impacts the shelf life and post-harvest quality of banana fruits. According to Hailu et al. (2013) determination of maturity level of a banana can vary based on the age of fruit from anthesis until harvest, the size of fruits and fruit peel color. Most farmers used the fruit age method

or the number of days after anthesis (DAA) method to determine the level of banana fruit ripeness. This method can lead to variability in fruit quality because of the differences in the level of physiological maturity of banana. Other environmental conditions that affect the level of maturity and quality of bananas at harvest are the light intensity during the fruit set.

Heat unit accumulations are the method that can be performed to determine the ripeness of bananas by taking into account the difference in temperature and light intensity between growing locations and seasons. The fundamental principle of this method is the calculation of the actual average temperature obtained by considering the base temperature crop until the plant reaches the optimum maturity for harvesting (Mc Master and Wilhelm, 1997). Every fruit and vegetables requires a certain amount of heat units every day to promote growth and development, and every one of them is different, including different cultivars of the same crop. Previous research by Widodo et al. (2016) showed the best harvesting time for “Mas Kirana” banana to provide the longest shelf life of nine days can be reached in 40 to 50 day after anthesis (DAA) with 576.5 to 725.5°C degree days of heat unit. Other studies suggested that the harvesting of “Mas Kirana” bananas at 625-700°C degree day may be able to extend the shelf life of fruit from 8.5 to 9.9 days (Prasetyo, 2017).

This study aims to establish the heat unit as harvesting criteria of “Mas Kirana” banana and how it corresponds with fruit shelf life and the postharvest maturity characteristics of the banana fruits harvested at different times after anthesis.

Materials and Methods

Experimental Site

The experiment was conducted at Parakansalak Plantation, PT. Perkebunan Nusantara VIII Sukabumi, West Java, Indonesia (106.706497; -6.795830) in November 2017 until February 2018. The location is located 450 to 810 meters above sea level. The shelf life and post-harvest fruit maturity characteristic analysis was conducted in February until April 2018 at Postharvest Laboratory, Department of Agronomy and Horticulture, Faculty of Agriculture, Bogor Agricultural University.

Flower Tagging and Fruit Sampling

Flower tagging was conducted on healthy plants when at least one floret has reached anthesis or fully opened from week 1 to 8 eight after anthesis. A minimum of five banana trees were tagged every week.

Banana fruit samples for quality evaluation were collected from the second and the third bunch of bananas as described in Rahayu et al. (2014). Fruits were washed and dipped in a solution of sodium hypochlorite 10% for about 30 seconds to prevent fungus infestation, then rinsed with water and air dried. The fruits were placed in the corrugated fiberboard box with a maximum capacity of 12 kg at room temperature (25-30°C; RH 70-80%) during transportation to the laboratory.

Heat Unit and Light Intensity

Maximum and minimum temperature and light intensity were recorded daily to get the degree days (ºC day) starting the first week of anthesis until banana fruits were ready to harvest using a minimum-maximum thermometer and thermometer data logger Elitech RC-4 and RC-5. The temperature data was recorded every 30 minutes. Light intensity was measured every day using lux meter data logger (TL-600). Light intensity data were averaged taken at 09:00, 12:00 and 15:00 pm every day to capture the averagelight intensity. All equipment waskept in a meteorological box and fixed at 1.5 m above the ground.

The formula used to calculate heat units based on Umber et al. (2011) is described below:

$$HU = \sum \left(\frac{T\,max + T\,min}{2} \right) - b$$

Notes:
HU = Heat units (°C day)
T max = Daily maximum temperature (°C)
b = Base temperature (10°C)
T min = Daily minimum temperature (°C)

Scoring

Scoring was conducted on the number of fruits per hand, weight perhand and weight per finger. Grading in “Mas Kirana” banana was based on weight of each hand based on the grading criteria of PTPN VIII (2014) i.e. SS (0.5 to 0.65 kg), S (0.65 to 0.8 kg), M (0.8 to 1.0 kg), L (1.0 to1.2 kg), LL (1.2 to 1.4 kg) and XL (>1.4 kg). Scoring on the physical quality of fruit including the weight loss, the peel and flesh fruit softness, the respiration rate of fruit, the shelf life of fruit, the fruit edible portion, and fruit chemical quality including as total soluble solids (TSS), titratable acid (TA) and vitamin C. Respiration rate was measured based on CO_2 production every day with cosmotector

(Cosmos Cosmotector XP-316A Gas Detector). The shelf life, physical quality and chemical quality of the fruits were scored when the fruits reached scale six of the peel color scale (Figure 1). The degree of yellowness of fruit peel referred to Widodo et al. (2016) (Figure 1). Peel and flesh softness of the fruit was measured with a penetrometer (Stanhope-seta). TSS was measured using a hand refractometer (Atago Hand-held Refractometer N-1 brix 0.32%); whereas TAT and the content of vitamin C were measured by titration method by AOAC (1995).

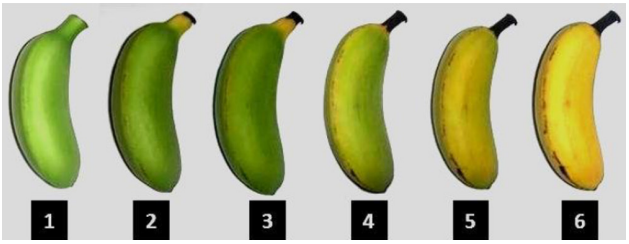

Figure 1. Color scale index number for “Mas Kirana” banana ripening: 1) green, 2) light green, 3) yellowish, 4) greenish, 5) yellow with green tips, and 6) yellow (Widodo et al., 2016)

Experimental Design

The experiments were performed in a completely randomized design (CRD) with single factor, i.e. heat unit (°C degree day) at week 1 to 8 after anthesis. Each treatment consisted of five replications so there were 40 experimental units in total. Each plant represented a single experimental unit.

Results and Discussion

Harvest Criteria

“Mas Kirana” banana on week 1 tagging with 655 °C days heat unit accumulation had the most extended number of days after anthesis (DAA) of 43. The number of days after anthesis related to the low average light intensity on the study area since tagging until harvest, i.e. about 79,043 lux (Table 1). That condition is related to weather conditions during week 1 where rain occurred for several days and was accompanied by strong winds due to the Cempaka storm that affected several areas in Indonesia including Parakansalak plantation, Sukabumi. The shortest number of days after anthesis was obtained at week 2 and week 3, which was 39 DAA (Table 1) . Previous study by Prasetyo (2017) reported that “Mas Kirana” bananas harvested using heat unit accumulation at 650 °C degree days has a lifespan of 43 DAA.

The highest average light intensity of 85,452 lux occurred at week 8 with heat unit accumulation of 656°C degree days and number of days after anthesis of 40. Weather condition at week 8 tends to be warm, likely associated with the end of the rainy season at the end of February each year. The tagging at week 4 to 7 shows the same number of days after anthesis of 41. However, the amount of accumulated heat units and the average light intensity is different at each time of anthesis. Conditions mentioned above shows that the different anthesis times can lead to the difference in heat unit accumulation, number of days after anthesis, and the average light intensity. Light can be a major limiting factor to growth even though water and nutrients were in an optimum condition (Israeli et al., 1995). Low light intensity reduced banana “Grand Nain” weight per bunch, per hand and per finger (Israeli et al., 1995). According to Khaerunnisa (2017) differences in altitude, temperature, and general geographical location might lead to differences in the number of days after anthesis. “Raja Bulu” Banana grown at an altitude of 10 m above sea level (Kendal, Central Java) has a life span to harvest 16 to 20 days

Table 1. Summary of heat units, average light intensity, number of days after anthesis, number of fruit per hand, hand weight and weight per finger of “Mas Kirana” banana at various times of anthesis

Anthesis (Date)	Heat unit (°C degree day)	Light intensity (lux)	Day after anthesis (DAA)	Total fruit per hand	Hand weight (kg)	Weight per finger (g)
Week 1 (28/11/2017)	655	79,043	43	22	1.32	60.63
Week 2 (03/12/2017)	653	83,297	39	19	0.99	51.47
Week 3 (09/12/2017)	660	82,077	39	18	0.86	46.01
Week 4 (17/12/2017)	663	82,773	41	20	1.01	51.02
Week 5 (26/12/2017)	667	82,452	41	20	1.00	50.61
Week 6 (02/01/2018)	660	81,997	41	19	0.99	50.30
Week 7 (08/01/2018)	656	82,849	41	21	1.09	52.99
Week 8 (16/01/2018)	656	85,451	40	20	1.01	49.63

shorter than those at an altitude of 900 m above sea level in Sumedang, West Java (Khaerunnisa, 2017).

Fruit size at harvest is one of the general criteria that can be used to determine the time of harvest. Fruit size also determines whether or not the fruits are marketable. The main criteria in the grading of "Mas Kirana" banana are the fruit weight per hand. The results showed that different anthesis times using the accumulated heat units of minimum 650°C degree days did not significantly affect hand weight, number of fruits per hand, and weight per finger at harvest. Different time after anthesis did not affect fruit size at harvest.

Average hand weights in this experiment was up to 1.03 kg per hand, or belonging to L class based on "Mas Kirana" bananas category (PTPN VIII 2014). The average number of fruits was 20 fingers per hand with an average finger weight of 51.58 g at harvest. The medium size fruits in this experiment were possibly due to the insufficient fertilization to the crops, as the amount was less than the standard fertilization guideline. Insufficient or imbalanced fertilization might reduce plant growth and inhibit fruit development. Lack of nitrogen can reduce the number of hand, number of fruits per hand and weight per finger of bananas (Gowen, 1995). In addition, calcium deficiency in banana plants will result in thin and weak fruit bunches and the crop to easily lodge. Application of fertilizers to banana is necessary for both vegetative and generative stage (Paul and Duarte, 2011).

Respiration Rate and Fruit Shelf Life

Respiration rate is one of the indicators that can be used to determine the banana shelf life. Table 2 shows that the respiration rate was significantly different in color scale 4. Anthesis at week 7 has the highest respiration rate (615.12 ml CO_2/kg/hr) and the lowest was at week 4 (206.57 ml CO_2/kg/hr). The decrease of respiration rate at week 4 showed that the condition of fruit on those color scale has not entered the climacteric phase, whereas on color scale of 5 the whole fruits had entered the climacteric phase.

Respiration rates that occured on peel and banana flesh indicates the bio activities in banana tissue metabolism. The banana peel and fruit flesh respiration rate was 1308.54 ml CO_2/kg/hr and 664.73 ml CO_2/kg/hr, respectively. Banana peel respiration rate was higher than the respiration rate of banana fruit flesh, as most of the gas exchanges, including CO_2 and O_2, occurred on the fruit peel. Fruit peel color should be used as one of the criteria of banana maturity. The color of the banana peel will change from green to yellow during the ripening process. Bananas can be consumed when the color of the peel has reached the color scale of 5 or 6. Ahmad (2013) states that during the process of maturation in fruits, chlorophyll is broken down enzymatically by chlorophylase to form chlorophyllide. Chlorophyll is also broken down in a non-enzymatic due to changes in acidity (pH) to form pheophytin; both components converted to pheophorbides through the oxidation process so that the color becomes faded and eventually disappears (Ahmad, 2013). Discoloration of the peel fruit can indicate the level of the respiration rate of banana.

"Mas Kirana" banana that harvested at different time of anthesis using the minimum heat unit accumulation 650°C degree days has a shelf life of 12 to 16 days. The shelf life is longer than was reported in another study (Prasetyo, 2017), i.e. a shelf life of 8.9 days in "Mas Kirana" bananas harvested at 650°C degree days. These results also demonstrated that the same cultivar of banana can have a different shelf life. Several factors that can affect the shelf life of banana are number days after anthesis, the

Table 2. Respiration rate of banana with peel color scale of 4 and 5, peel and fruit fleshrespiration and the shelf life of "Mas Kirana" bananas at various times of anthesis

Anthesis	Color scale 4 (ml CO_2/kg/hr)	Color scale 5 (ml CO_2/kg/hr)	Peel respiration (ml CO_2/kg/hr)	Flesh respiration (ml CO_2/kg/hr)	Shelf life (day)
Week 1	562.50a [x]	516.63	1,272.36	697.17	12.20
Week 2	432.32ab	520.53	1,339.32	678.82	12.60
Week 3	420.10ab	526.68	1,199.25	680.03	15.40
Week 4	206.57b	592.42	1,090.97	674.81	16.00
Week 5	404.55ab	519.51	1,162.63	683.35	12.00
Week 6	471.16a	547.94	1,821.30	838.16	12.20
Week 7	615.12a	583.04	1,282.00	532.49	13.60
Week 8	495.65a	495.70	300.471	532.97	12.20

Note: [x]mean separation was conducted with HSD test at 5%.

temperature during storage, the concentration of CO_2 and O_2, ethylene concentration,and tissue damage during harvest and post-harvest. According to Zhou and Paul (2001), similar level of maturity in papaya of different ages can be caused by the different physiological activity due to the air temperature and photosynthates competition between fruits, so fruits of the same genotype may take longer to reach the same maturity stage.

Banana is a climacteric fruit that characterized by an increase in respiration rate during storage. By the time the fruit rate of respiration after harvest is increased due to stress on bananas which separated from the main tree (Figure 2). The graph shows a decrease in respiration rate on color scale of 0 to scale 1 then increased until the climacteric peak in scale 5. Production of CO_2 was high on the first day due to mechanical damage of the fruits; cutting each hand of "Mas Kirana" causes wounding of the plant tissue which then increased the amount of ethylene released and respiration rate (Nurjanah, 2002). Mechanical damage is one of the factors that can speed up the production of CO_2 (Kays, 1991). Climacteric fruit has a pattern of respiration rate which continues to increase during ripening stage (maturation) and decreases in senescence stage (Heydari et al., 2010).

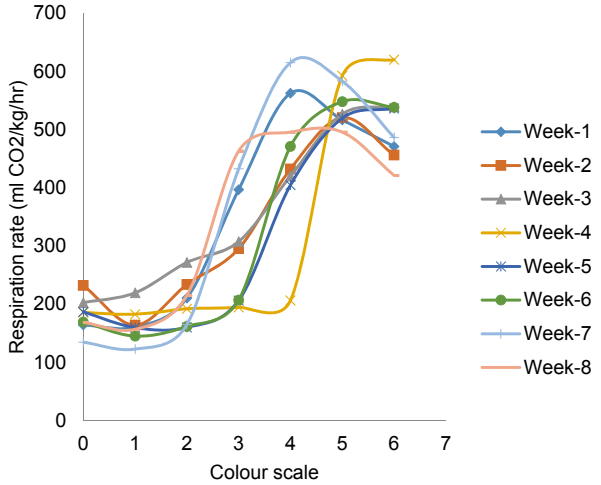

Figure 2. Respiration rate (ml CO2/kg/h) graph of "Mas Kirana" banana at each peel color scale at various times of after anthesis

Fruit Maturity Characteristics

Physical Quality

Physical changes during storage include weight loss, softness of peel and fruit flesh, and edible parts. The physical quality of the fruit is one of fruit criteria to be classified as suitable fruit for consumption. The level of consumer acceptance can be reduced if the physical quality of the fruit is low. Consumers usually prefer bananas that have more edible parts with less-hard fruit flesh softness and bright peel colors. Results showed that different time of anthesis in "Mas Kirana" bananas did not significantly affect the softness of the fruits flesh. Overall weight loss did not differ except in week 3. Weight loss was highest during the 3rd week after anthesis. Peel softness differs only in week 8 (0.14 mm/g/sec). Time of anthesis significantly affected the edible portion. The lowest edible portion was at week 5 (71.87%) and the highest was at week 1 (78.87%; Table 3).

A high weight loss at week 3 was associated with a longer shelf life, which was 15.4 days. Longer shelf life of fruit leads to higher weight loss. Weight loss is also related to the edible parts. Low weight loss causes the edible part to be low. According to Yachuan et al. (2007), weight loss occurs because of the fruit tissue water loss due to transpiration and respiration process during storage. Weight loss also occurs as a result of the use of food reserves in the fruit substrates used as energy reserves (Wills et al.,1989). Purwoko and Suryana (2000) state that wax can be used on the Cavendish bananas peel that could inhibit respiration and transpiration by substituting natural wax lost during harvesting and closes the pores on the peel of banana. Orange fruit peel wrinkle due to weight loss can also be slowed by wax coating and low temperature storage (Susanto et al., 2003).

Peel softness significantly differs between week 4 and week 8. Differences in peel softness in this experiment were not related to the edible part of bananas. Flesh softness has the same quality despite different anthesis time. The softness of fruit according to Soltani et al. (2010) relates to the conversion of starch into sugars that occurs revamp pectin content, transfer of water from the peel to the flesh of the fruit and the increase in the TSS. Sancho et al. (2010) state that there are two main enzymes that act to degrade the cell wall and causes the papaya fruit to become soft during the ripening process of fruit which are polygalacturonase (PG) and pectin methylesterase (PME).

Fruit Chemical Quality

The chemical composition of the fruit determines the level of consumer acceptance associated with flavor and nutrients in the fruits. Chemical characters determine the quality of the fruit be a total soluble solids content (TSS), titratable acid (TA) and vitamin C. The different time of anthesis on "Mas Kirana" bananas showed that the content was not significantly different in regards to TSS except at week 1. The

Table 3. Physical quality “Mas Kirana”bananas at various times of anthesis

Anthesis	Weight loss (%)	Edible part (%)	Peel softness (mm/g/sec)	Flesh softness (mm/g/sec)
Week 1	18.23ab[x]	78.87a	0.12ab	0.44
Week 2	16.22ab	78.56ab	0.09ab	0.40
Week 3	20.14a	76.97abc	0.09ab	0.37
Week 4	19.72ab	73.20bc	0.07b	0.37
Week 5	14.33b	71.87c	0.08b	0.38
Week 6	16.35ab	75.78abc	0.09ab	0.38
Week 7	18.97ab	75.93abc	0.11ab	0.37
Week 8	18.98ab	77.45ab	0.14a	0.38

Note: [x]mean separation was conducted with HSD test at 5%.

content was not significantly different in TA except at week eight (Table 4). Time of anthesis showed significantly different results on the content of vitamin C (Table 4). The content of TSS at week 2 showed the results of 29.10 °Brix and the content of the TA is also significantly higher at 2.86 mg/100 g. The content of vitamin C was significantly different at week 2 (32.80 mg/100 g) and week 4 (22.83 mg/100 g).

The analysis showed that the content of TSS, TA and vitamin C in “Mas Kirana” bananas was not influenced by the different time of anthesis. Lower TSS at week 2 related to the current climatic conditions and fruit set. Light intensity is higher at week 8 that causes the higher photosynthetic result accumulation on the fruit so that the energy reserve in sugar form also becomes higher. Emaga et al. (2007) stated that the sugar is mostly produced in form of sucrose, fructose and glucose.Those are the main constituent component of total soluble solids. According to Lazan *et al.* (1995), the formation process of sugars in papaya fruit involves the process of respiration which degrades starch molecules into smaller molecules such as sugars and organic acids. Increased PG enzyme activity and B-galactocyde during maturation causes the cell wall degradation by hydrolysis of pectin and hemicellulose which increase the levels of TSS in the fruit.

The content of TA in “Mas Kirana” banana is lower on week 8 due to the weather conditions. Acidity of bananas harvested in the early dry season may lower than bananas harvested in rainy season. Etienne et al (2014) states that there are several factors that may affect the acidity of fruit such as water supply, mineral fertilizers and the cultivation environment temperature. The acidity of the fruit is affected by the concentration of organic acids in the fruit flesh which resulted from the accumulation of water and dry weight accumulations. Citric acid and malic acid metabolites are found in many bananas.

The levels of Vitamin C in “Mas Kirana” did not differ significantly between time of anthesis and did not have a regular pattern over time of anthesis. The analysis showed that a low vitamin C at week 4 was associated with a longer shelf life of 16 days. Pantastico (1986) stated that vitamin C followed an irregular pattern during the growth and development of the fruit, whereas Kays (1991) reported that the loss of ascorbic acid increases with increasing temperature and storage time.

Table 4. Chemical quality “Mas Kirana” bananas at various times of anthesis

Anthesis	TSS (^{0}Brix)	TA (mg/100 g)	Vitamin C (mg/100 g)
Week 1	26.10b[x]	2.64ab	31.12ab
Week 2	29.10a	2.86a	32.80a
Week 3	28.80ab	2.80a	28.44ab
Week 4	27.60ab	1.89ab	22.83b
Week 5	27.20ab	2.35ab	24.85ab
Week 6	27.20ab	2.21ab	26.24ab
Week 7	28.30ab	1.78ab	22.93b
Week 8	28.40ab	1.58b	24.32ab

Note: [x]mean separation was conducted with HSD test at 5%.

Determination of harvest time using heat unit accumulation can be used by banana growers to determine harvest time of banana; this method has a more uniform fruits with good size, longer shelf life and satisfactory postharvest characteristics. Further research should be conducted to explore the application of this method for banana grown at different altitudes.

Conclusion

The different anthesis time of "Mas Kirana" banana did not affect the shelf life of fruit, fruit size at harvest (weight per hand, weight per fruit and number of fruits perhand), respiration rate, physical quality (weight loss, the softness of peel and flesh of the fruit) and chemical quality of fruit (TSS, TA and vitamin C). Heat unit of 650°C degree days can be used as harvesting criteria for "Mas Kirana" banana, with the number of days after anthesis and the shelf life being 39 to 43 days and 12 to 16 days, respectively.

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