

Optimal Harvest Time of Various Apple Cultivars Grown in Northern Mississippi

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Abstract

This study was conducted to determine the optimal harvest date (OHD) of eight apple (*Malus × domestica* Borkh.) cultivars grown in the unique climate of Northern Mississippi. Fruit were collected randomly from the interior and exterior quadrants of the tree at weekly intervals beginning 30 days after full bloom (DAFB). Maturity indices used to determine OHD were fruit firmness, fresh fruit weight, soluble solids content (SSC), and juice pH. Fruit maturity indices of 'Earligold', 'Jonagold', 'Improved Golden', 'Scarlet Gala', 'Jonafree', 'Macspur', 'Royal Gala', and 'Williams Pride' were monitored weekly. The OHD was defined as the number of days after full bloom where SSC and fresh fruit weight were at or near maximum. The OHD for 'Williams Pride' and 'Earligold' was determined to be 93 DAFB and these cultivars were identified as early cultivars. 'Scarlet Gala', 'Royal Gala' and 'Jonafree' were considered medium harvest date cultivars with OHD of 102, 105 and 108 DAFB, respectively. The OHD for 'Jonagold' and 'Improved Golden', and 'Macspur' was 128 DAFB and these cultivars were identified as late harvest cultivars. For all cultivars, the time lapsed from full bloom to maturity was at least seven days less than in other parts of the U.S. Early monitoring of apple maturity and a combination of maturity indices is recommended to determine maturity for fresh fruit consumption in Mississippi.

Apples (*Malus × domestica* Borkh.), like most fruits, go through three developmental stages: maturation, ripening, and senescence (25). At the beginning of the ripening stage, apples exhibit a dramatic peak in respiration called the climacteric. Usually, optimal harvest time is just before the climacteric (14). However, the climacteric stage is difficult to measure. Thus, different maturity indices have been used to monitor fruit development so that appropriate harvest dates for a given fruit can be determined (17).

The final use of apples will determine the maturity at which apples should be harvested. If harvested for the fresh fruit market, the apples may be allowed to ripen almost entirely on the tree. Ripe apples will twist easily from a branch and change of color will be apparent (21). Fruit to be stored should be picked earlier (7). Harvesting at the proper stage of fruit maturity has a great influence on the quality of stored fruit. Apples picked at the optimum maturity stage are suitable for long storage

because these fruit combine high storage potential and retention of quality (19). Apple fruit vary in quality, storage potential, and shelf life due to factors such as tree age, fruit load, position in the tree, and physiological characteristics of the cultivar (4). Due to cultivar differences, each cultivar must be evaluated to determine optimal harvest date (2).

Fruit maturity is determined by means of several physical and/or chemical characteristics, such as firmness, color, starch content, soluble solids, and ethylene production (16). In certain regions like the coastal fruit growing area of Girona, Spain, standard practices for estimating optimum harvest date of apples are based on soluble solids and flesh firmness which are dependent on growing conditions. Thus, there is a need for establishing harvest date criteria to avoid picking immature fruit and to ensure quality at harvest and after storage (8). Immature fruit are more subject to shriveling and mechanical damage, and are of inferior flavor quality when ripe. Override

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fruit are likely to become soft and mealy with insipid flavor soon after harvest. Fruit picked too early or too late in their season are more susceptible to postharvest physiological disorders such as water core, internal breakdown and soft scald than fruit picked at the proper maturity (9).

The apple growing season in Northern Mississippi is characterized by numerous cloudy, long, hot days, high precipitation and high relative humidity (24). Full bloom date for apple occurs in March, with harvest occurring as early as late July, depending on cultivar and year (13). In Washington, apple harvest begins in mid-August and generally ends in early November (23). Due to the unique climate in Mississippi and its effect on apple fruit maturity, growers have difficulty deciding when to harvest.

Traditionally, Mississippi growers have relied on surface color and days after full bloom to determine when to harvest. Color development is reduced due to cloudy days, and firmness is lost rapidly due to high day and night temperatures. The days from full bloom to harvest that are currently used were established by the leading commercial apple states (Washington, New York, and Michigan) which are characterized by a cooler growing season and low relative humidity. The use of these indices in Mississippi results in harvest of overripe fruit. Commercial apple production in Mississippi is primarily for the fresh fruit market and not for long term storage. Therefore, there is a need for establishing apple harvest date criteria for fresh fruit for immediate consumption. The objective of this study was to identify the optimal harvest date (OHD) for fresh fruit consumption of various apple cultivars grown in northern Mississippi.

Materials and Methods

This study was conducted at the Pontotoc Ridge-Flatwoods Research and Extension Center (38° 08' N, 89° 00' W), Mississippi State University, located seven miles south of Pontotoc, MS. The average annual maximum temperature of this area is 30° C (86°F) and

minimum is -1° C (30° F), with annual rainfall of 81.28 cm (32 inches). The total dormancy period is approximately 1100 hours per year. Soil at the station is classified as Alfisol, Ultisol, Unceptisol, and Entisol orders with deep red color, high in silt to silt loam. The soil pH was 5.6.

The apple trees used in this experiment were planted in 1993 and spaced 2.4 m in rows and 3.6 m between rows. Trees were pruned to a modified central leader system. In May 1998 and 1999, a 5-20-20 fertilizer was applied at a rate of 450 g per tree, and ammonium nitrate (34-0-0) at a rate of 230 g per tree. No irrigation was applied. Weeds were controlled in rows by application of glyphosate herbicide in a 1 m strip, and a mowed common bermudagrass (*Cynodon dactylon* L.) strip was maintained between rows. Insects and diseases were controlled through a spray program recommended for commercial apples in the Southeast (22).

'Earligold'/EMLA7, 'Jonagold'/EMLA111, 'Improved Golden'/EMLA7, 'Scarlet Gala'/EMLA7, 'Jonafree'/Mark, 'Macspur'/M7A, 'Royal Gala'/MM111, and 'Williams Pride'/M7A cultivar/rootstock combinations, replicated 3 times (single tree replications), were evaluated in 1998 and 1999. Five fruit per tree were collected randomly at weekly intervals starting 30 days after full bloom (DAFB). Fruit were collected from the interior and exterior quadrants of the trees. Maturity indices in a sample of 5 fruit per combination per replication were determined. Fruit fresh weight was recorded using a Mettler PC 8000 scale using samples from each replication at each sampling time. Three apple fruit from each replication were homogenized in a Mullinex juice extractor (Fisher Scientific, Spring Field, NJ) and filtered through 3 layers of cheese cloth. Juice samples were used for measurement of soluble solids and pH. Soluble solids content (SSC) of the juice was measured with a Bausch and Lomb Abbe 3L refractometer. Juice pH was determined using an Accumet pH meter 925 (Fisher Scientific, Pittsburgh, Penn.).

Based on these maturity indices the OHD was determined for each cultivar. OHD was

defined as the number of days after full bloom where SSC and fresh fruit weight were at or near maximum. The rationale for the definition of OHD was that at maximum SSC, apples would be more acceptable to the consumer based on flavor, and that at maximum fruit weight, the producer would maximize the marketable yield. Harvest date criteria were based on apples being harvested for the fresh fruit market and not for long term storage. Flesh firmness of the fruit without skin, was measured in Newtons (N) using a penetrometer (Instron Universal Machine, Model 1011 (Canton, Mass.)); a sample (single fruit) was placed on a flat steel washer in the center of the load cell and the flesh punctured with a 12 mm diameter cylindrical probe at a crosshead, chart speed of 50 mm/min and a load range of 20 N which was programmed in the measuring system.

All statistical analyses of variance were made using a completely randomized design with repeated measures. Data were analyzed using PROC GLM (SAS Statistical Software, SAS Institute, Cary, N.C.). Treatment means were separated by Duncan's Multiple Range test at the 5% significance level.

Results and Discussion

The OHD for each cultivar was determined in 1998 and 1999. Due to similarity of results

(ANOVA showed no statistical difference between years) only 1999 results are presented. Cultivars were split into sets based on their maturity (early, mid or late season harvest). Figure 1 shows the maturity changes in SSC, juice pH, fresh fruit weight, and fruit firmness with time of 'Earligold' and 'William's Pride'. At optimal harvest, fruit firmness was 84.8 N, and 68.5 N respectively. Based on our definition, the OHD for fresh fruit consumption of 'Earligold' and 'William's Pride' was 93 DAFB (Table 1 and Figure 1). These cultivars were considered early harvest cultivars.

Maturity changes in SSC, juice pH, fresh fruit weight, and firmness for 'Jonafree', 'Royal Gala', and 'Scarlet Gala' are shown in Figure 2. An increase in fresh fruit weight, SSC, and juice pH occurred until a maximum, followed by a final maturation period where little or no significant change occurred. Fruit firmness at OHD for 'Jonafree', 'Royal Gala', and 'Scarlet Gala' was 156 N, 133.5 N, and 151.2 N, respectively (Table 2). Based on these results, OHD for 'Jonafree', 'Royal Gala', and 'Scarlet Gala' was 108, 105, and 102 days after full bloom (DAFB), respectively (Table 1). These cultivars were considered mid-season harvest cultivars for fresh consumption.

Maturity changes in SSC, juice pH, fresh fruit weight, and firmness of 'Improved Golden', 'Macspur' and 'Jonagold' are pre-

Table 1. Optimal harvest date for fresh market use for eight apple cultivars in Mississippi, based on physiological changes in soluble solids content (SSC), pH and flesh firmness.

Cultivar	Optimal harvest		SSC (%)		Juice pH		Firmness (N)	
	DAFB ¹	Harvest	1998	1999	1998	1999	1998	1999
Earligold	93	Early	13.0 e ²	12.8 c	3.5 b	3.6 cd	68.5 d	84.8 d
William's Pride	93	Early	13.5 bc	13.9 ab	3.9 a	3.8 a	81.6 d	68.5 d
Scarlet Gala	102	Medium	13.7 a	13.9 ab	3.9 a	3.7 bc	156.0 a	151.2 ab
Jonafree	108	Medium	13.6 ab	14.4 a	3.3 d	3.4 e	113.7 c	156.0 a
Royal Gala	105	Medium	13.5 b	13.9 ab	3.9 a	3.8 a	132.9 d	133.5 bc
Jonagold	128	Late	13.5 bc	13.9 ab	3.5 b	3.6 d	151.2 ab	113.7 c
Improved Golden	128	Late	13.5 bc	14.1 a	3.6 b	3.7 c	133.5 bc	145.5 b
Macspur	128	Late	13.4 cd	13.4 b	3.4 c	3.4 ef	137.4 ab	134.3 bc

² Means within columns followed by the same letter do not differ (Duncan's multiple range test, P = 0.05)

¹ DAFB: days after full bloom

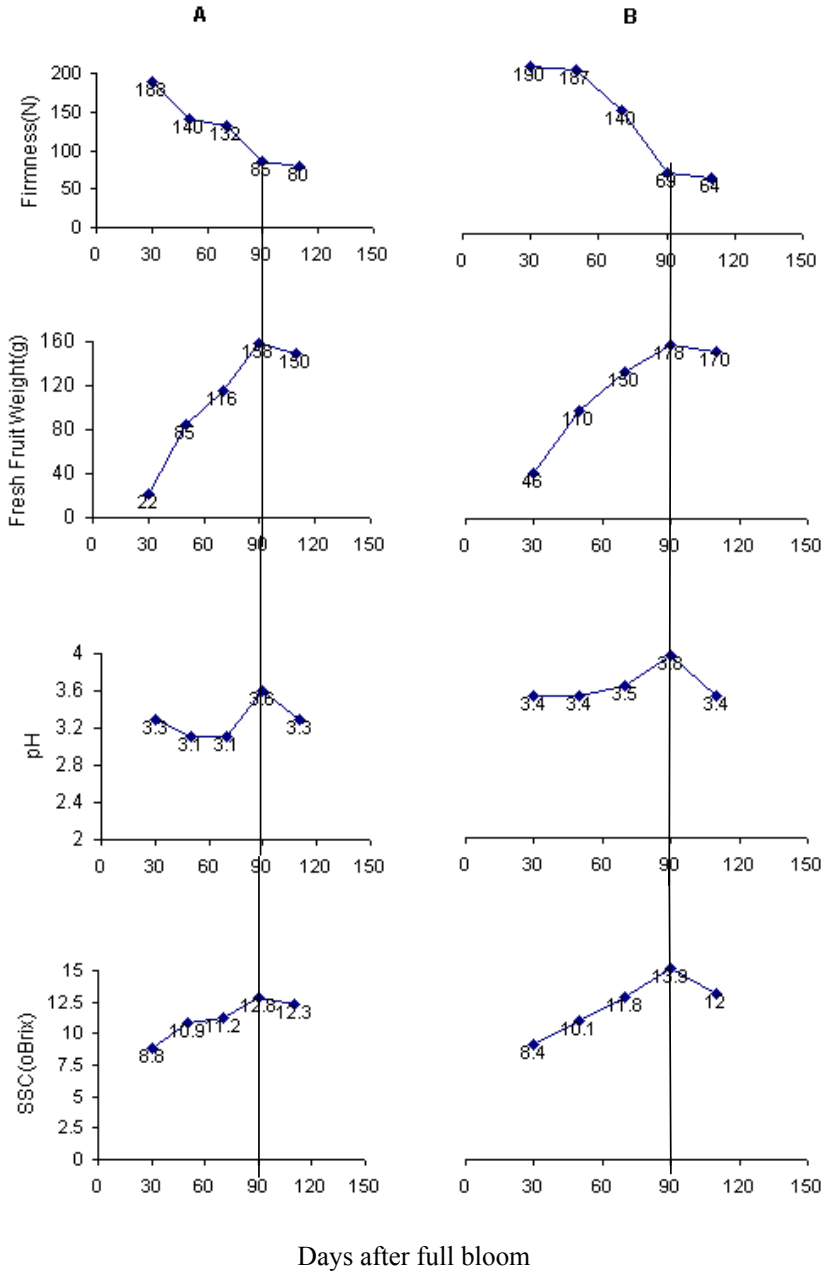


Figure 1. Maturity changes of A) 'Earligold' and B) 'William's Pride' apple. The optimal harvest time was based on firmness (N), fresh fruit weight (g), pH, and soluble solids content (SSC). Vertical lines represent optimal harvest date when fresh weight and soluble solids content were at or near maximum.

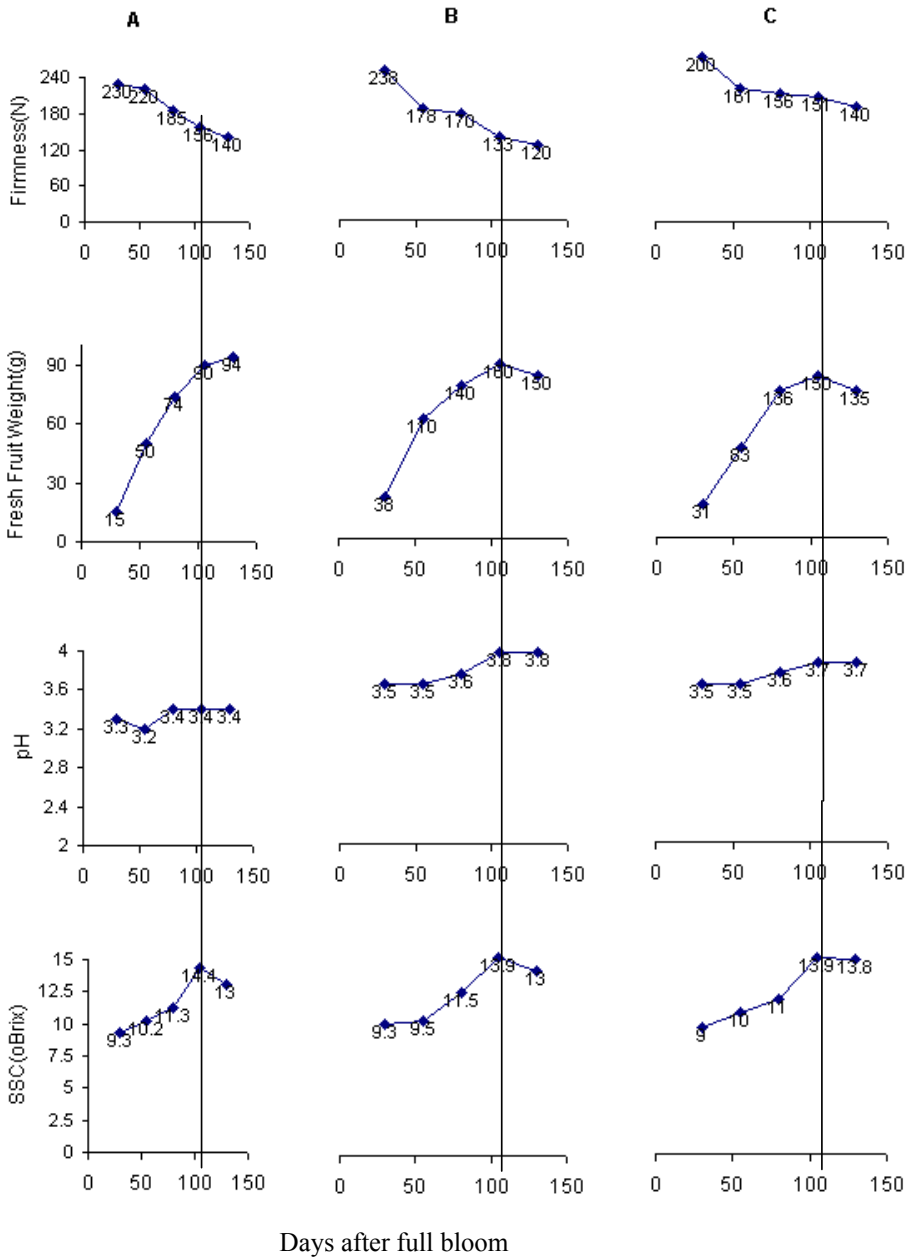


Figure 2. Maturity changes of A) 'Jonafree', B) 'Royal Gala', and C) 'Scarlet Gala' apple. The optimal harvest time was based on firmness (N), fresh fruit weight (g), pH, and soluble solids content (SSC). Vertical lines represent optimal harvest date when fresh weight and soluble solids content were at or near maximum.

sented in Figure 3. Apples from these cultivars required more time to complete their physiological maturity. Thus, it was possible to observe a maximum increase in fresh fruit weight, soluble solids content, and juice pH at harvest with less change in fruit firmness (Figure 3). The OHD for 'Improved Golden', 'Jonagold' and 'Macspur' was 128. (Table 1 and Figure 3). These cultivars were considered late-harvest cultivars.

In 1999, SSC ranged from 12.8% for 'Earligold' to 14.4% for 'Jonafree' with an average of 13.8%. In general, SSC values of 13% or above are recommended for immediate consumer consumption (15). Our results are consistent in that, the SSC will depend on cultivar (7). In addition, SSC readings are within the recommended value for fresh fruit consumption. SSC will be lower in fruit from trees with a heavy crop compared to fruit from trees with a light crop (15). In this study, efforts were made to fruit thin trees to have the same crop load.

In 1998, juice fruit pH was between 3.3 and 3.9. 'Jonafree' was found at optimum maturity when juice pH reached a maximum of 3.4 while its SSC was 14.1% (Figure 2). In 1999, apple juice pH ranged from 3.4 for 'Macspur' and 'Jonafree' to 3.8 for 'Williams Pride' and 'Royal Gala', and the average pH was 3.4 (Table 1). Acidity change and the absolute pH value depend on a number of factors including climate, exposure to light, and cultivar (11). Therefore, it is inappropriate to set specific pH values for optimum harvest (12). There are no guidelines for maturity based on acidity; however, a drop in acid level is an indicator of advanced maturity.

In reference to firmness, Kadir (10) showed values from 80 N to 130 N for 'Jonathan' apples depending on location. Tu et al. (20) reported firmness of 'Granny Smith' to be 125 N for fresh fruit and declining to approximately 80 N after 51 days of shelf-life. In this study, fruit firmness at harvest ranged from 69 N for 'Williams Pride' to 156 N for 'Jonafree'. High fruit firmness can be explained by the fact that in some cultivars, the rate of change in firmness with ripening was slow and not

great enough to enable differentiation between commercially immature fruit and those at commercial maturity (18). Results in this study are well within those reported in the literature. However, pre-harvest factors, such as cultivar, nutrient management, cultural practices, such as crop load and pruning will influence firmness (3, 4).

In comparing the number of days after full bloom in this study with those established by the leading commercial apple states, it was apparent that the time elapsed from full bloom to picking maturity was at least seven days less in Mississippi. For example, 'Gala', 'Jonagold' and 'Improved Golden' required 115, 140 and 140 DAFB to reach maturity as reported by Childers et al. (2). In this study the number of DAFB required for fruit maturity of 'Gala', 'Jonagold' and 'Improved Golden' were 105, 128, and 128, respectively. Because apple cultivars exhibit significant changes during maturation, one characteristic is often not enough to determine precisely the harvest point. Plestenjak and co-workers (16) measured firmness, starch content, SSC and titratable acidity to determine optimal harvest date of five cultivars. In this study, cultivars were picked at the optimum maturity stage for the fresh fruit market by measuring firmness, juice pH, SSC, and fruit weight.

Conclusion

Results from this study show that maturity indices such as SSC, fresh fruit weight, and pH are related independently of the cultivar. All cultivars showed the same pattern of maturity where SSC, fresh fruit weight, and pH of the fruit increased as the apple matured until an OHD which was cultivar-dependent, as previously reported by Haard and Salunkhe (6). 'Jonafree', 'Scarlet Gala', 'Improved Golden' and 'Macspur' had firmer fruit than the remaining cultivars. 'Williams Pride' and 'Earligold' showed the lowest firmness based on their harvest date. The remaining cultivars, 'Royal Gala', 'Jonagold', and 'Improved Golden', had fruit firmness ranging from 113 to 145 N. Firmer fruit in 'Jonafree' may have resulted because fruit were small. It was re-

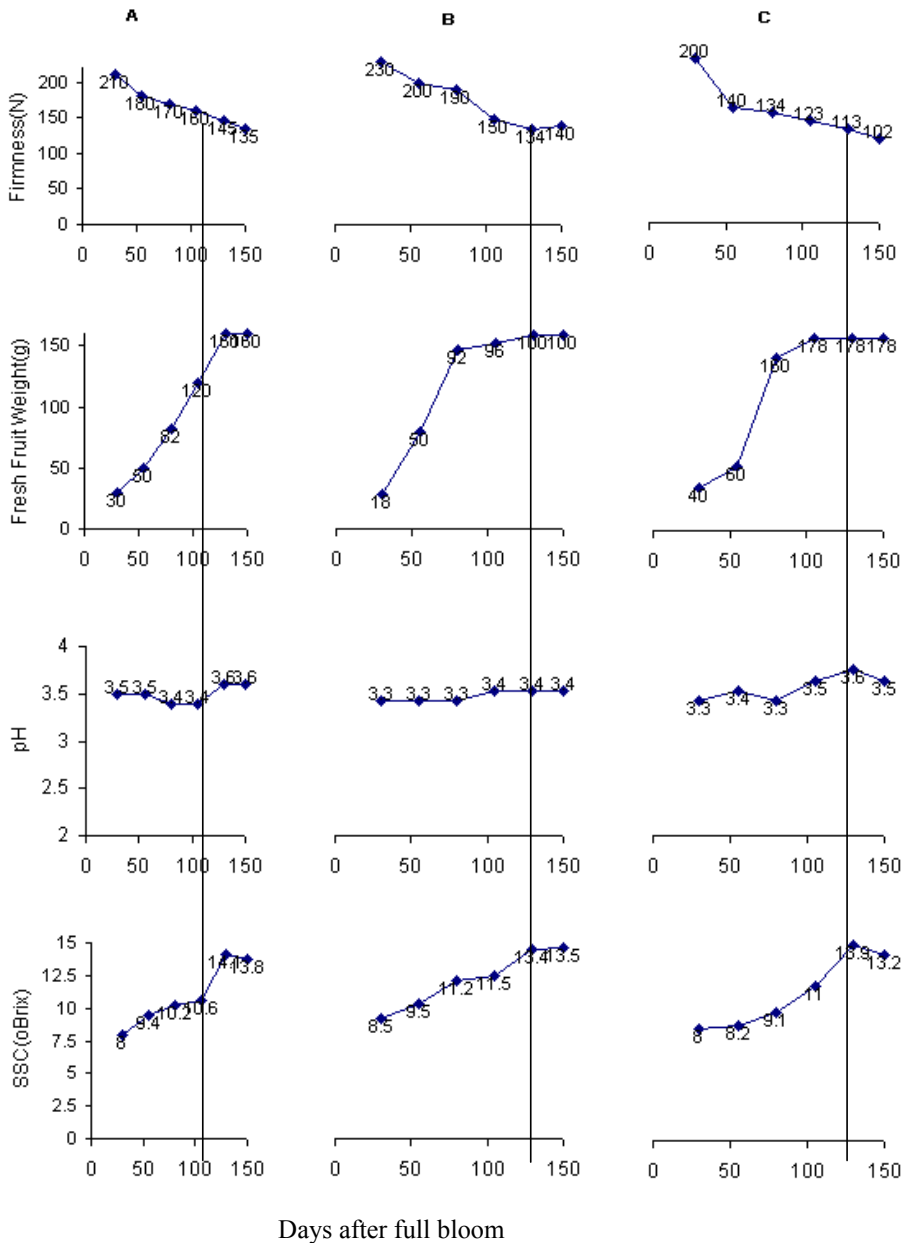


Figure 3. Maturity changes of A) 'Improved Golden', B) 'Macspur', and C) 'Jonagold' apple. The optimal harvest time was based on firmness (N), fresh fruit weight (g), pH, and soluble solids content (SSC). Vertical lines represent optimal harvest date when fresh weight and soluble solids content were at or near maximum.

ported that certain rootstocks tend to promote excessive crop load that reduces fruit size (1). In this experiment, rootstock effects were not studied. However, in previous experiments, rootstock did not strongly affect firmness and SSC of 'Smoothie', but fruit firmness and SSC were affected by year (5). In this study, SSC, juice pH, fruit firmness and fresh fruit weight were used to determine the number of DAFB to reach maturity. For all cultivars, the time lapsed from full bloom to maturity was at least 7 days less than in other parts of the U.S. Therefore, it is recommended that growers in Mississippi start monitoring apple maturity early and that a combination of these and other indices be used to determine maturity for fresh fruit consumption.

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