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AN INVESTIGATION INTO THE RELATIONSHIP BETWEEN MATURITY AND SHELF LIFE OF PLANTAIN GROWN IN THE SOUTHEAST OF DOMINICA

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ABSTRACT

Ship ripening is a recurrent problem for plantain exported to England, from Dominica. In this study, bunches were harvested at different ages, ranging from 6½ to 13½ weeks after shooting. The maturity grade of each hand was scored visually (from thin to ¾ full). The caliper grade of the central finger in each hand was also recorded. Fruit were stored at 10°C, for 10 days, followed by storage at 21°C. All fruit were inspected every other day, for signs of ripening. Hands that were proximal on the bunch (first hand to set) demonstrated a significantly shorter shelf life than hands from the middle or distal end of the bunch. There was an increase in shelf life for a decrease in the age at which bunches were harvested ($P < 0.001$). This relationship was also found to be linear ($P < 0.001$). Shelf life decreased linearly, as caliper grade and maturity score increased ($P < 0.001$). The r values were highest for the bunch age/shelf life relationship (0.8311 for bunch age, compared to 0.64944 for caliper grade and 0.6575 for maturity grade), indicating that this was the most reliable indicator of shelf life. These results indicate that farmers should harvest bunches at 10 weeks (predicted shelf life 26 days, with a 95 % confidence interval of 6.3 days) after shooting, when shipping plantain to the U.K. by sea.

INTRODUCTION

Plantain has been identified as a priority crop in the diversification efforts of the Windward islands, particularly in Dominica. Plantains are grown in a wide variety of farming systems but generally production is small scale, with most farmers growing plantains on plots of 0.5 acres or less. Plantains are often intercropped with crops such as dasheen and pumpkin.

Most farmers in Dominica grow a type of plantain known as the French or Apem plantain. Its cooking and eating qualities are generally favored by East Caribbean people, both regionally and extra regionally. A number of different varieties of plantain are grown in Dominica but the most common is the "ordinary."

Traditionally, exports of plantains out of Dominica have been to other islands in the Caribbean. However, over recent years volumes shipped extra regionally, in particular to England, have increased, to approximately 220 tons per annum.

Apem plantains that are shipped extra regionally must arrive green if they are to fetch their optimum selling price. This is because many consumers consume them green, by boiling. It also allows retailers to stock the plantain over a much longer period of time before deterioration. Accounts of sales received in 1993 have shown that the average selling price of a carton of green plantain is approximately three times that of ripe plantain.

The plantain, being a climacteric fruit, continues its ripening processes when it has been harvested. At present, all plantain exported by Dominica to the U.K. are sea freighted. They are held in lockers or containers, which are refrigerated to 13°C. The journey from Roseau port to the U.K. market takes, on average, 13 days. Despite the refrigerated conditions, a significant proportion of plantains reach the market ripe. At present an average 16% of plantains exported from Dominica, to the U.K. arrive ripe. This represents a $US 570 loss in revenue for the exporter, for an "average" sized consignment (5.2 tons).

The problem of premature ripening has been confounded by a lack of understanding of the factors that affect the shelf life of the plantain. Results of research conducted on the economically dominant banana crop have often been transferred to the plantain. However, as the work of Karikari et al.(1979) showed, the physiology of their ripening processes differ greatly. This indicates a need for specific research into factors that influence the storage life of the plantain.

At present plantains bound for the extra regional market are harvested early in the morning, the day before shipment. All fruit are field packed into cartons, to improve quality. Farmers harvest fruit at the Light ¾ stage of maturity. This is assessed subjectively by the presence of ridges running lengthwise along the fingers.

In the Windward Islands, a caliper is an important tool in determining the harvest maturity of bananas. If fingers are too fat they are rejected as over grade fruit. Conversely, if they are too thin they are rejected as under grade fruit.

Various researchers (e.g. Montaya et al., 1984) have found a direct relationship between the age of a bunch of bananas and its shelf life. Work of this kind has led to the adoption, in Latin America, of a system of harvesting by bunch age. This involves tagging a bunch of bananas at fruit set and harvesting it after a fixed period of time. A similar system of tagging, in conjunction with a caliper system, has recently been introduced to the Windward Islands (WINBAN, 1993).

From the results of research carried out in Honduras, Medlicott (1992) concluded that fruit age also controls the length of green life of Horse plantains. However, it was also observed that ripening rates of fruit harvested at the same age, but at different times of year, were different. Caliper grade was found to be a less reliable indicator of shelf life, though was strongly correlated to bunch age. It was recommended that, in commercial operations, a combination of both systems be used. That is, fruit should be harvested after a set period of time (9 10 weeks) but, if their caliper grade exceeds 27, they should not be shipped by sea.

Karikari et al.(1979) also observed that an increase in bunch age led to a decline in the pre climacteric period (PCP) of Apem plantain.

Medlicott (1992) also demonstrated that the ripening rate of hands of plantain, positioned basally on the bunch (that is, the first hands to be set on the bunch), was significantly faster than that of apical hands. Similarly, Karikari et al.(1979) found that the PCP of hands of Apem plantain, harvested from the same bunch, decreased, proceeding towards the basal end of the bunch.

From field observations made in Dominica, it is claimed that for the ordinary variety ripening processes occur evenly, whilst for the larger bunched centlivre variety ripening proceeds unevenly along the bunch (Stephenson, 1986).

MATERIALS AND METHODS

No plot large enough to supply all the plantains for this trial was available. Plantains were obtained from seven plots in the Delices area.

Each plot was visited weekly, for eight successive weeks, from August 19 until October 7, 1993. On every plot, bunches that had just set the last hand were tagged and dated (approximately 1 week after shooting). Two plots (A and B) were larger and afforded more bunches at the correct stage of development for tagging. The remaining plots were smaller and generally provided only a single bunch for tagging each week. Eight bunches, in total, were tagged each week. On November 22, 1993, all 64 bunches were harvested. This provided bunches of 6½ through to 13 ½ weeks in age (eight ages in all).

As the bunch was dehanded each hand was laid out to drain in the order in which it had arisen on the bunch. Every hand was labelled with: the name of the farmer; its age (from 6½ to 13½ weeks); the bunch on which it had occurred and the position in which it had arisen on the bunch (for example, whether it was the first hand to set or the last).

The fruit were packed into cartons without clustering. The cartons were transported to the Produce Chemist's Laboratory, in the Botanical Gardens, on the day of harvest. In the laboratory the diameter

of the central finger of each hand (on the outer whorl of fingers) was measured, to the nearest tenth of a millimeter. This measurement was taken at the central portion of each finger.

The maturity of each hand was also recorded, using the subjective assessments commonly used in the field. Maturity was scored as follows: 1='Thin'; 2='Light'; 3='Light ¾; 4= '¾; 5='Full ¾.

The plantains were packed, completely at random, into cartons. No refrigerated container was available for storage at this time. The cartons were stored in a cool room, for 10 days, in an attempt to simulate shipping conditions. It was unfortunate that the temperature regulation of this room was not constant and a regime of 11°C (+2°C) prevailed during this period.

After 10 days in cool storage, the fruit were removed to the laboratory, where they were stored in an air conditioned room for the remainder of the trial. A temperature of 21°C (+1°C) prevailed.

All fruit were inspected, every two days, for signs of ripening. Since many fruit were very pale at harvest, a characteristic of many fruit harvested in this locality, it was difficult to make the distinction between fruit that were naturally pale and fruit that were beginning to ripen. Thus, shelf life was recorded as days to complete yellowing of at least one finger in the hand, since yellowing cannot be confused with inherent paleness.

Once at least one finger in the hand had completely ripened, the hand was removed from the carton.

RESULTS AND DISCUSSION

Farmer

Table 1 shows the mean shelf life of bunches harvested at different ages from the different plots.Insufficient replication was carried out to enable a full statistical comparison of shelf life between all plots, except between plots A and B. This analysis showed that there was no statistically significant difference in shelf life, between fruit of the same age, for these two farmers ($P > 0.05$).

By observation, the shelf life of fruit submitted by other farmers was generally similar to that of farmers A and B. Larger differences that may be observed are not consistent over the weeks and so no conclusion can be drawn from them. The data from the different plots has been combined in the remaining analyses.

Hand position

A statistical comparison of shelf life, between hands that had arisen from different positions on the bunch, was carried out. The shelf life of hands that were basal on the bunch, at the centre of the bunch and were the last on the bunch were compared (Table 2). For bunches that held an even number of hands, the mean shelf life between the two middle hands was calculated and used in the analysis.

This was conducted as a two way analysis of variance, with bunch age as the other variable factor.

The analysis showed that hand position had a significant effect on the shelf life of the fruit ($P < 0.01$). A statistical comparison of hand position means demonstrated that basal hands (the first hands to set) showed a significantly shorter shelf life than the middle hands ($P < 0.05$) and last hands ($P < 0.01$) in the bunch. The differences in mean shelf life between the middle hand and the last hand were not significant ($P > 0.05$).

However, differences in shelf life were not significant between hand positions, for all of the bunch ages. For example, for bunch ages of 13½, 8½, 7½ and 6½ weeks, there were no significant differences in shelf life between hands taken from different positions on the bunch. However, for bunch ages of 12½, 11½, 10½ and 9½ weeks, the last hands in the bunch had significantly longer shelf lives than the basal hands ($P < 0.05$ for weeks 12½, 11½ and 10½; $P < 0.01$ for week 9½). The last hands did not show significantly longer shelf lives than the middle hands ($P > 0.05$), except for a bunch age

of 12½ weeks ($P < 0.05$).

These results largely correspond to those of other investigators. The last hand that is set in a bunch does tend to demonstrate a longer shelf life than hands taken from basal positions on the bunch. The fact that this pattern was not observed for the oldest bunch age could be because all hands on the bunch were near to their natural time of ripening. Essentially they had all reached the stage of initiation of ripening, at the time of harvest.

The pattern of an increase in shelf life for the last hand did not persist for the youngest three bunch ages (8½ to 6½ weeks). This could be expected since, when they were harvested, these fruit were immature and well away from the time for the initiation of natural ripening. Thus, it would follow that their ripening processes would be less synchronized.

Since hand position affected the shelf life of fruit, some way of accounting for, or controlling this variation, was necessary in the remaining analyses.

Bunch age

The results (Table 2) showed a clear trend of an increase in shelf life for a decrease in the age at which bunches were harvested. This trend slowed down for the younger ages, however. This can also probably be explained by the immaturity of these fruit and consequent lack of coordination in their ripening processes. These results were highly significant ($P < 0.001$), indicating that bunch age did affect shelf life.

Linear regression analyses were carried out to explore the relationship between bunch age and shelf life. The analyses were performed separately for the different hand positions (basal; middle and last hand). An additional analysis was carried out on data obtained by combining all three positions, to give a single line.

A highly significant linear relationship was found to exist between bunch age and shelf life ($P < 0.001$), for all three separate hand positions and for the combined data ($P < 0.001$). The three regression lines were statistically compared with this single regression line. This showed that the use of three separate lines gave a significantly better fit ($P < 0.01$). The data support that relationships between bunch age and shelf life are different, for hands taken from different positions on the bunch.

These three regression lines are shown in Figure 1. The r values for basal, middle and last hands were 0.856; 0.9226 and 0.7355 respectively (the r value for the single regression line was 0.8311). This indicates that the prediction of shelf life by bunch age is most accurate for hands taken from the middle of the bunch.

Figure 1 indicates that, in order to obtain plantains with a shelf life of at least 21 days, the crop should be cut at 11½ weeks. The 95% confidence interval (C.I.) for a bunch cut at this age is 21 days +6.4 days, indicating that there is a considerable chance that the bunch would ripen in only 14 days. This wide confidence interval may be indicative of the small scale of this trial.

The 95% C.I. of a crop cut at 10½ weeks is 26 days +6.3 days. Based on the data of this experiment, one could be 95 % certain that a bunch cut at 10 weeks or less would last at least 19 days, which is closer to the shelf life that is required for a typical shipment.

In practice, it is hard to advise farmers to harvest their crop at a single age, since they harvest only once a week. Thus, a time frame of 9 to 11 weeks could be offered (9 weeks implies a shelf life of 30 days and 11 a shelf life of 23 days).

The visual appearance of fruit cut at 9 and 10 weeks was observed to be Light/Light¾ and for those cut at 11 weeks, Light¾.

Caliper Grade

Mean caliper grades for the middle hand in each bunch were calculated. These results were categorized as follows: less than 31 mm; 31 36 mm; above 36 mm.

The mean shelf life of the bunches of each category are shown in Table 3.

The differences in shelf life were highly significant ($P < 0.001$), indicating that caliper grade could act as a useful indicator of maturity. That is, with an increase in caliper grade, there is an apparent decrease in storage life.

Fruit with a caliper grade greater than 36 mm demonstrated a significantly shorter shelf life than those of 36 mm or less ($P < 0.001$). Fruit with a caliper grade of 31 36 mm showed a significantly shorter shelf life than those less than 31 mm ($P < 0.001$).

A regression analysis revealed a highly significant linear relationship between caliper grade and shelf life ($P < 0.001$), for all three hand positions and for all data combined. The use of three separate lines did not, however, give a statistically better fit than a single line, combining all data ($P > 0.05$). That is, the relationships between caliper grade and shelf life are not statistically different between hands arising from different positions on the bunch.

The single regression line is shown in Figure 2 and clearly shows that a linear model should not be fitted for this data. This is supported by the low r value for this relationship, of 0.6494.

In many banana farming systems, fruit are harvested by age but a maximum caliper grade in also used to "double check" maturity. It would not be appropriate to allocate a maximum caliper grade for Apem plantain shipped to extra regional markets, until more research is carried out.

Visual Assessment

An analysis of variance was carried out to compare the shelf life of hands taken from the middle of the bunch which had different visual maturity scores (14). The mean shelf lives for hands with each score are shown in Table 4.

The analysis of variance showed that visual maturity scores do significantly correlate with shelf life ($P < 0.001$). That is, there is a trend of a decrease in shelf-life, for an increase in maturity score. From this, it can be concluded that the visual assessments currently used to judge maturity do provide some indication of shelf life.

Regression lines were plotted and were found to be highly significant for separate hand positions and for all data combined ($P < 0.001$). The use of separate lines did not, however, give a statistically better fit than a single line, combining all data ($P > 0.05$). The single regression line is shown in Figure 3 and shows that a linear model should not be fitted for these data. The low r value for this relationship, of 0.6575, also indicates that bunch age acts as a more reliable indicator of shelf life.

Table 5 shows, for the middle hand position, the percentage of hands, with each maturity score (1 4), that lasted at least 21 days (the minimum green life required, when shipping plantains to the U.K.).These results exemplify the problem of ship ripening as it currently exists. That is, plantains which are cut by eye, at the Light¾ stage of maturity, frequently do not have the shelf life required to reach extra regional markets.

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Table 1. Mean shelf life of bunches harvested from different plots, at different ages.

	Mean shelf life (days)							
	Bunch age (weeks)							
PLOT	13½	12½	11½	10½	9½	8½	7½	6½
A	15.8	18.9	21.5	25.4	25.8	31.0	29.5	35.7
B	15.2	16.5	20.4	25.0	27.4	33.5	34.8	37.4
C	-	-	-	29.6	33.0	33.0	-	36.4
D	15.6	16.6	17.8	25.8	29.2	36.0	28.8	34.5
E	15.0	15.0	16.4	31.0	31.3	29.0	30.6	28.1
F	15.0	15.2	23.5	24.2	31.3	31.7	33.0	33.3

* indicates no bunches of this age available

Table 2. Mean shelf life for hands taken from different positions, harvested at different ages.

	Mean shelf life (days)								
	Bunch age in weeks								
Hand position	13½	12½	11½	10½	9½	8½	7½	6½	Mean
Basal	15.0	15.6	17.3	23.8	23.5	31.8	33.0	35.1	**24.4**
Middle	15.0	16.0	20.8	26.0	28.5	34.0	31.5	37.3	**26.1**
Last	16.6	20.4	22.0	28.6	29.5	33.8	30.8	34.3	**27.0**
Mean	**15.5**	**17.3**	**20.0**	**26.1**	**27.2**	**33.2**	**31.8**	**35.5**	

S.E.D. between any two values = 2.169
S.E.D. between two hand position means = 0.767
S.E.D. between two bunch age means = 1.252, with 168 d.f.

Table 3. Mean shelf life of middle hands of different caliper grades.

CALIPER GRADE	MEAN SHELF LIFE
< 31 mm a (13)	34.7
31 36 mm b (32)	28.2
> 36 mm c (19)	16.8

S.E.D for comparison of a and b = 1.626
S.E.D for comparison of b and c = 1.432
S.E.D for comparison of a and c = 1.780, with 61 d.f.
Figures in brackets represent number of bunches

Table 4. Mean shelf life of middle hands harvested at different maturity scores.

Maturity score	Shelf life(days)
1 (9)	35.1
2 (14)	31.9
3 (26)	24.8
4 (15)	17.7

S.E.D. for comparison of 1 and 2 = 2.420
S.E.D for comparison of 1 and 3 = 2.191
S.E.D. for comparison of 1 and 4 = 2.388
S.E.D. for comparison of 2 and 3 = 1.877
S.E.D. for comparison of 2 and 4 = 2.105
S.E.D. for comparison of 3 and 4 = 1.837, with 60 d.f.
Figures in brackets represent number of bunches

Table 5. Percentage of middle hands with actual shelf life of 21 days.

VISUAL MATURITY SCORE	PERCENTAGE
1	100
2	100
3	69
4	13

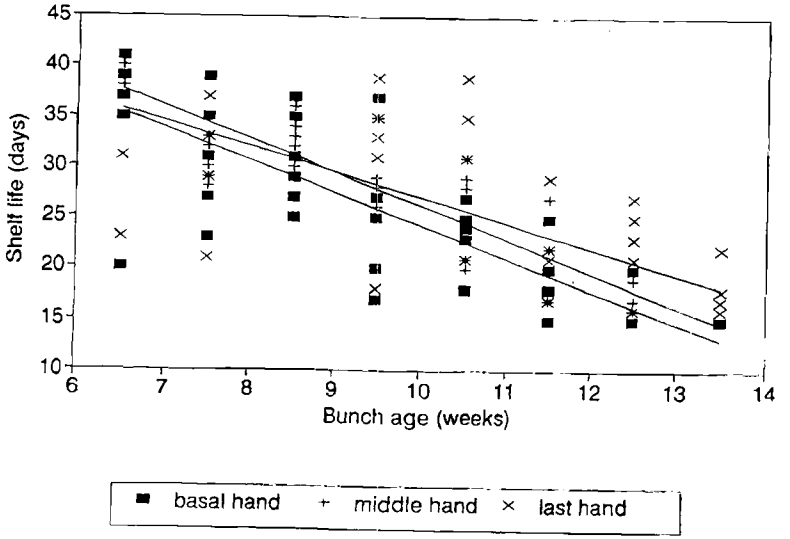

Fig. 1. Bunch age/shelf life relationship

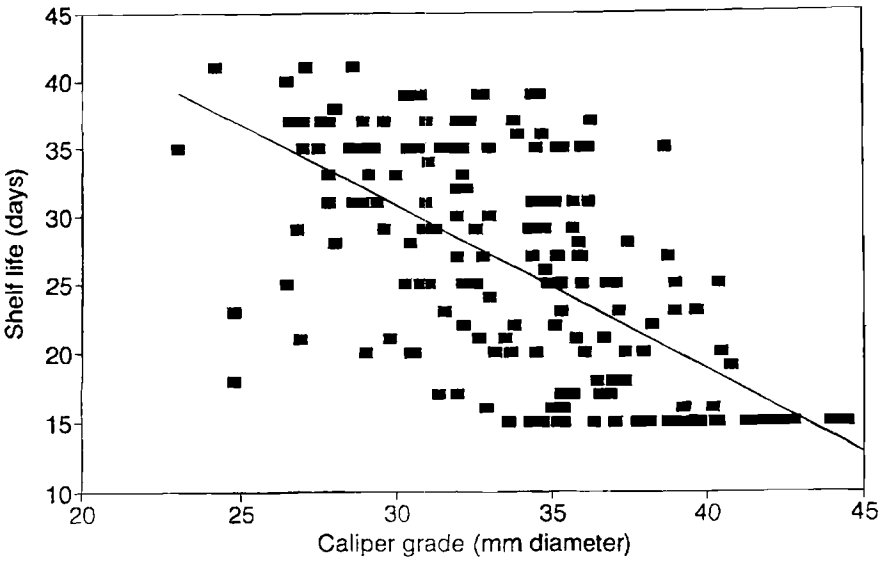

Fig. 2. Caliper grade/shelf life relationship

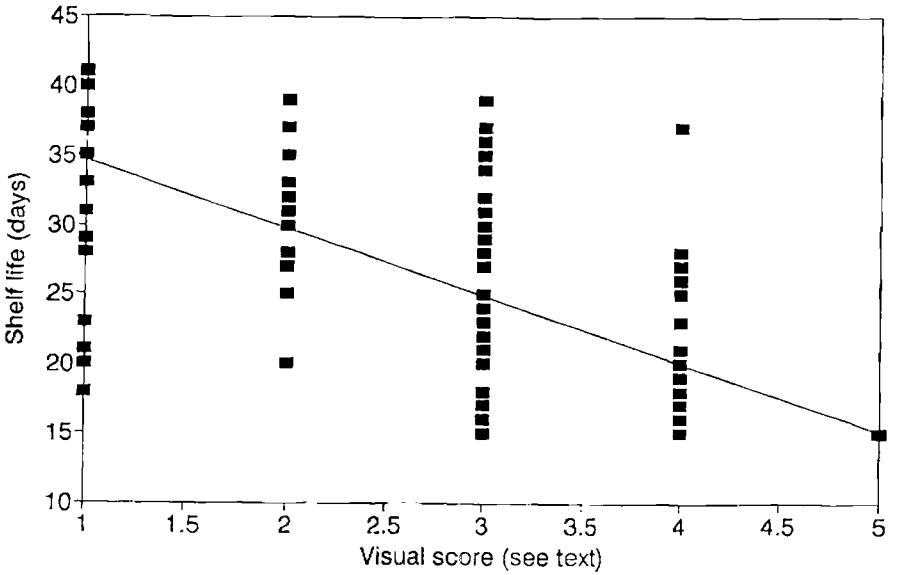

Fig. 3 . Visual score/shelf life relationship