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Short communication

Yield estimation in papaya

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ABSTRACT

Fruit yield is an important parameter recorded in many experiments on papaya (*Carica papaya* L.). Yield measurement is a time consuming procedure of weighing individually the harvested fruits throughout the harvesting season. Therefore, present experiment was conducted on twelve uniformly fruited plants of a near-homozygous dioecious papaya line, Pune Selection-3. Actual yield was recorded by individually weighing all the harvested fruits after colour break. At the same time, estimated yield of each plant was calculated by multiplying number of fruits with average fruit weight of the plant which was estimated by nine different methods comprising selecting varying numbers of fruits from different positions (bottom, middle and top) on the fruiting column. The method where average fruit weight was calculated by selecting one/ two/ three fruits each from bottom and top ends, and midpoint of the fruiting column provided the best yield estimate with 9.0/ 8.5/ 7.6% deviation, respectively from the actual yield. The study recommends estimation of fruit yield by calculating average fruit weight by selecting one fruit each from bottom and top ends, and midpoint of the fruiting column and then multiplying it with total number of fruits.

Keywords: Papaya, yield estimation, fruiting pattern, fruit weight, dioecious.

Measurement of papaya (*Carica papaya* L.) fruit yield is the most important parameter required in many experiments. It requires harvesting and weighing of all fruits individually during the entire harvesting period running into months. At present, per plant fruit yield is calculated by summing up weights of all fruits of a plant (de Almeida *et al*., 1; Goenaga *et al*., 4). To obtain yield per unit area, the average yield per plant is multiplied by total number of productive plants in the area. Recording yield by following this method is a cumbersome and time consuming. Therefore, some researchers are reporting estimated yield rather than actual yield. In the absence of any standard method, researchers apply various methods for yield estimation. In hermaphrodite plants where fruit size is uniform, Fitch *et al*. (2) estimated cumulative yields of one week and multiplied it by four to get a monthly estimate and then by 12 for an estimated annual yield. However, yield reported by this method was less than the actual yields because commercial growers harvest their fields four or more times each month. Fitch's method can be applied only when fruit size is less variable and fruit harvest is uniformly distributed throughout the harvesting season which is very difficult to ensure in dioecious varieties. In dioecious plants, fruit yield estimates were obtained by counting number of fruits per plant and multiplying it with the mean weight of fruits on each plant (Vazquez-Hernandez *et al*., 7). While total number of fruits can be counted accurately, estimating average weight of fruit is difficult as the fruit size varies considerably depending on its position on fruiting column (Fig. 1). Sampling of fruits for calculating average fruit weight is a critical step for accuracy of estimated yield. A minor mistake in calculating average fruit weight may result into great error. Hence, there is a need for a standard method for estimating yield in papaya. Although, Wilson (8) published detailed report of papaya production forecast on macro level, we have not come across with any report on standard method for estimating fruit yield. Therefore, the present study was undertaken to standardize the method for estimating fruit yield in dioecious papaya plants. This procedure will save time and manpower required for recording fruit yield. In addition to meeting this prime objective, the data also gave information about fruiting behavior of papaya. The results of this study can be useful for papaya cultivators to estimate fruit yield of their plantations for effective marketing.

The experiment was conducted at Research Farm of ICAR-IARI, Regional Station, Pune (18° 31' N, 73° 51' E), India, during 2012-13 on twelve uniformly fruited plants of a nearly-homozygous dioecious papaya line, Pune Selection-3, with full fruiting column. Pune Selection-3 has been identified as papaya ringspot virus tolerant line with good yield of marketable quality fruits under severe disease pressure (Prakash and Singh, 5). All fruits on the fruiting column of each plant were numbered. If

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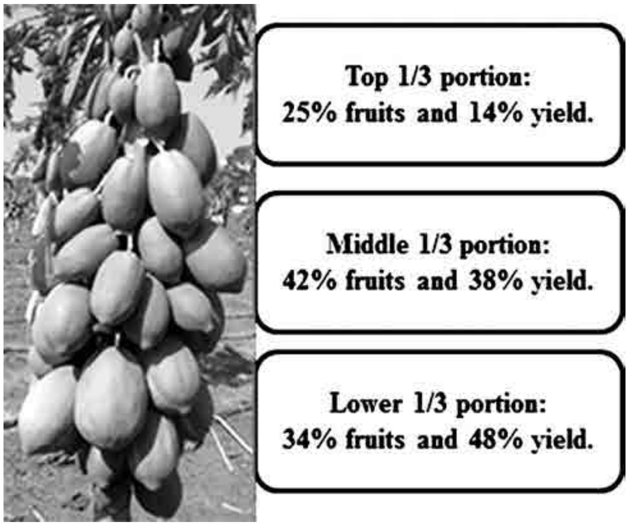

Fig. 1. A typical distribution of fruits on the fruiting column (95 cm).

there were more than one fruit on one axil, each fruit was counted separately. All fruits were harvested after colour break and weighed individually. Actual yield (sum of weights of all fruits) and number of fruits for every plant were recorded, and average fruit weight was calculated. Fruit yield estimates were calculated by obtaining average fruit weight in various treatments and multiplying it by total number of fruits on the plants. Average fruit weight was calculated by selecting 2 (M1), 4 (M2) and 6 (M3) fruits from midpoint; 1 (TB1), 2(TB2), and 3 (TB3) fruits each from top and bottom ends and 1 (TMB1), 2 (TM82), and 3 (TMB3) fruits each from bottom, top and midpoint of the fruiting column. Each plant was considered as one replication. Estimated yield for all nine combinations was calculated for each plant by multiplying total number of fruits by average fruit weights obtained from each treatment. Deviation of estimated yield from the actual yield was expressed as percentage of actual yield for each treatment. These values were subjected to Arc sine transformation before statistical analysis using randomized block design. The treatment where estimated yield was closest to the actual yield was recommended for sampling fruits for the purpose.

Observation on fruiting behaviour revealed that the average fruiting column length was 95 cm but only 81 cm (86%) bore marketable fruits (weight > 400 g). Average number of fruits on a plant was 52, out of which 42 (81%) were marketable. Lower one-third portion of the fruiting column bore 34% of total fruits 48% of marketable fruits. Higher contribution of lower portion of fruiting column towards fruit yield was because fruit weight in this region was 142% of the average fruit weight of the plant. Higher average fruit weight in the lower region may be attributed to the fact that these fruits were set earlier and got longer time for development as compared to the fruits in the middle and top portions. Middle one-third portion of the fruiting column bore 42% of fruits in number, which contributed 38% of marketable fruit yield. Average fruit weight in this region was closer to the average fruit weight of the plant. The top one-third portion of the column bore one-fourth of the total fruits, but they contributed only 13% to the total fruit yield. Fruits in the top portion set later, and weigh less because they got less time for development (Table 1, Fig. 1). Values reported for number of fruits per plant and their average weight in this trial were within the range of what was reported by O.E.C.D. (6) for number of fruits (25 to 100) and average fruit weight (350 to 3000 g). Majority of fruit production came from the lower two-third portion of the column. This portion bore 75% of the total fruits in number which contributed 87% to the total fruit yield.

Sampling of fruits from all three positions (top, bottom and middle) of fruiting column provided best representative average fruit weight (8.4% variation from the actual value) which was better than the sampling of fruits from middle portion (14.3% variation), and top and bottom portions (18.4% variation). When fruit samples were taken from all three positions, the variation between the estimated and the actual yields did not vary significantly with the samplesize (1, 2 or

Table 1. Distribution of fruits on a fruiting column.

Length of fruiting column (cm)		No. of fruits		Fruit yield (kg/ plant)	Av. fruit wt. (g)	Bottom 1/3rd portion of fruiting column			Middle 1/3rd portion of fruiting column			Top 1/3rd portion of fruiting column		
Total	Bearing marketable fruits	Total	marketable			Fruit Yield (kg/ plant)	No. of fruits	Av. fruit wt. (g)	Fruit yield (kg/ plant)	No. of fruits	Av. fruit wt. (g)	Fruit yield (kg/ plant)	No. of fruits	Av. fruit wt. (g)
95	81.25 (85.53)*	51.50	41.75 (81.07)	52.465	1280	25.377 (48.37)	14.00 (33.53)	1824 (142.50)	20.011 (38.14)	17.50 (41.92)	1200 (93.75)	7.077 (13.49)	10.25 (24.55)	0695 (54.30)

*Figures in parentheses are per cent of total plant.

3 fruits) from each location. Among other two groups, when fruit sample were taken either from the midpoint, or from top and bottom ends, variation between estimated and actual yields increased significantly with the change in number of fruits sampled. By and large, the variation in estimated yield and actual value decreased with increase in the number of fruit samples. The deviation of the estimated fruit yield from the actual value was minimum (7.58%) in the method where three fruits each were taken from the top and bottom ends, and midpoint. The second best combination (8.50% variation) of the sampling was when two fruits each were taken from the three different locations on the fruiting column (Table 2). Since sampling 3, 2 or 1 fruit from each location provided similar accuracy in yield estimate, sampling of one fruit each may be preferred as it is less cumbersome and cost effective compared to sampling 3 fruits.

Table 2. Variation of actual yield from estimated yield under various combinations.

Treatment combination	*Variation from actual yield (per cent)	Standard error
M1	#16.464[c]	3.37
M2	15.028[c]	2.52
M3	11.931[b]	2.26
TB1	19.735[d]	3.34
TB2	18.220[cd]	2.60
TB3	17.291[c]	2.77
TBM1	8.980[a]	2.52
TBM2	8.501[a]	2.02
TBM3	7.579[a]	1.12

*, value is an average of 12 replications; #, mean values in the second column followed by same superscripted letter indicate non-significant differences among treatments ($p \leq 0.05$).

This method can be utilized for estimating fruit yield of dioecious papaya both for research and commercial purposes. The results are more relevant in subtropical climate where dioecious cultivars are more suitable like northern (sub-tropical) parts of India, Australia and South Africa (Giacometti, 3). Since nature of fruit bearing is different in dioecious and hermaphrodite plants, these results may not be applied to hermaphrodite plants directly. They require separate standardization. The results may be applied by farmers to calculate their yield estimates for effective marketing of their produce.

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