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FRUIT SET SUCCESS OF STARFRUIT BY USING DIALLEL CROSSES

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Abstract: Starfruit is an important minor fruit crops of most tropical countries especially in South East Asia including Malaysia. Even though starfruit was given less priority in national agriculture policy but they are contributing to significant income as export commodities. Export markets consumed starfruit at the unripe and green stage as a garnish. Whereas at this stage fruit taste is quite astringent and fruit colour is not attractive. Today concumers preferred better eaten starfruit at optimum maturity stage once the fruit turn yellow. Breeding programme was initiated to improve the eating quality of starfruit for fresh export and local demand purposes. It was carried out at MARDI Kluang, Johor since January 2015 till October 2016. Diallel crosses designed and used to produce new hybrids with improved quality. Due to the self-incompatibility character of starfruit, two different accessions with different type of flower style (pin and thrum) required for successful pollination and fruit set. Crossing activity involved seven parents between pin flower accessions (BM89, BM99 and BM101) and thrum flower accessions (B10, B17, BM96 and BM91). This activity was conducted around 8.30-10.30 a.m where is the optimum hour of anther dehiscence and flower anthesis. Results showed that all series crosses produce 10-32% of fruit set for about two weeks after pollination but only 5% of successful fruitlet to harverst at maturity stage. In order to obtain high percentage of fruit set and good fruit quality, starfruit blossoms must be abundantly pollinated with pollen.

Keywords: starfruit, self-incompatibility, diallel crosses, fruit set, F_1 seed

INTRODUCTION

Carambola fruit known as starfruit (*Averrhoa carambola* L.) is an Asian original fruit that is usually consumed freshly as table fruit or used in salads, drinks, and as a garnish (Galan-Sauco 1993; Teixeira et al. 2007). The fruit are star-shaped in cross section with five prominent longitudinal ribs. It is in the family Oxalidaceae because of containing oxalic acid. Starfruit has attained a commercial status in Malaysia and still contributing as one of export commodities although it was given less priority. In Malaysia, two clones have been selected because of their performance and have become most popular with the growers (Abd Rahman & Mohamad, 2003). B10 and B17 were planted commercially by growers which B10 mostly for export market whilst B17 for domestic market (Abd Rahman & Ahmad Hafiz, 2013). The Malaysian starfruit is known to be the best quality and enjoys a niche market in Europe, Hong Kong and Singapore. The fruit is a very good source of natural antioxidants (Sanjib et al. 2013). Mostly the mature ripe fruits are eaten fresh. The ripe fruit has excellent sugar-acid blend which gives a characteristic taste. The consumer initially judges quality by the appearance of the fruit at the point-of-sale and then by the taste of the fruit (Abd Rahman et al. 2006). Consumer preference is for sweeter fruit, more intense flavour and firmer fruit before consumption (Kader, 2002). The challenge in fruit breeding is to produce an attractive fruit with a desirable taste that will survive the process of reaching the consumer. Starfruit is regarded as non-seasonal fruit crop and flowering in Malaysia are continued almost throughout the year. Three main flushes can be observed in February-March, Jun-July and October-November in panicle type of inflorescence which borne in clusters mostly in axils of leaves on young branches. Starfruit is the plants that produced lot of flowers in one inflorescence but at the end will produce one or two fruits per inflorescence. This is due to its self incompatibility and low fruit setting character (Abd Rahman & Ahmad Hafiz, 2009). The starfruit flower has usually five stamens, partially united at the base and a five-lobed compound pistil. The style which supports the stigmas is in two forms, short (thrum flower type) and long (pin flower type). The flowers are heterostylous that means the varieties have styles of different lengths. This mentions the problems of pollination and fruit set in starfruit. Pollination studies in Florida (Watson et al. 1988) indicate that short-style clones are generally self-incompatible and require pollination from long-style clones. Long-style type is self-fertile and generally acts as pollinizer clone. Pollinizer clones used as a source of compatible pollens for cross pollination. In Malaysia, the breeding programme for starfruit was initiated in MARDI to improve the eating quality of starfruit for fresh market consumption (Abd Rahman, 2012). However, one of the problems in starfruit hybridization is the high of flower and fruit drop during fruit development that can reach more than 80% of total flower formation. Although fruit set was high, premature fruitlet drop was also excessive mostly after a month pollination. Consequently, less than 20% of the inflorescence retains and becomes fruit (Samson 1992; Galan-Sauco 1993). Retention or abscission of flower and fruit are influenced by combination of endogenous as well as environmental factors (Bekti Kurniawati, 2009). Plant hormones such as auxin, gibberellin and ethylene are among the endogenous factors controlling abscission organ, including flowers, and fruits (Srivastava 2002; Taiz & Zeiger 2002). Due to the incompatability character of starfruit and its implication on fruit set, fruit development and fruit retention, this study was done to understand the compatibility character in every selected parental clones. Thus the ability of combining clones through some crosses series was determined. Important information was to identify the percentage of fruit set and fruit harvested under starfruit hybridization. Another objective of the study was to improve yield and eating quality of starfruit under conventional breeding programme. This research was aimed to yield hybrid seeds and produce more F_1 seedlings of starfruit for the wider genetic poll.

METHODS

This research was conducted at MARDI Kluang, Johor from January 2015 till October 2016. Seven accessions or clones that show potential yield and fruit quality were selected as parent. The mating design was a seven-parent diallel using B10, B17, BM91 and BM99 (thrum flower type) in one group, and BM89, BM99 and BM101 (pin flower type) in another group of different style length. Those plants that already flowered were used in the hybridization programme. A diallel crosses were used to get F_1 seeds by using hand pollination technique. Starfruit flowers were emasculated and other nearby flower discarded to prevent pollen contamination before selected pollen transfer. The pollen used was collected from flower of the different clones. Then, assisted pollination was done by putting the pollen into the stigmatic surface of female flower by using forceps, bagged with muslin paper and labeled. Fruit setting was recorded after two weeks. Percentage of fruit set for each series of crosses was calculated as;

$$\text{Fruit set (\%)} = \frac{\text{Total number of fruit set}}{\text{Total number of crossing}} \times 100$$

A month after pollination where is 5cm length of premature fruitlets (rice grain size) were observed and total number of retention fruits till harvesting stage were recorded for determination of harvested fruit percentage. F_1 seeds produced in this study will be germinated and planted for further evaluation i.e. percentage of seed germination and survival rate of F_1 seeglings. Total number of germinated seeds was calculated and determined its percentage by divided with all produced seeds from a series of crosses and multiply with 100. Same as the mentioned calculation, the survival rate of seedlings after three months germination for every cross combination was determined by comparison of survived seedlings with germinated seeds and multiplies with 100. Statistical analysis of variance and Duncan Multiple Range Test was performed according to SAS programmed.

RESULTS AND DISCUSSION

Analysis of variance showed that the eleven crosses were significantly different diferent (p <0.05) for four parameters studied in crossing activity of starfruit (Table 1). This indicates that all crosses series were significantly different diferent from each other terms of percentage of fruit set, harvested fruit, germinated seed and survival rate of seedling. Mean, standard deviation, coefficent of variation (CV) and range of all parameters for eleven crosses are also shown in Table 1. Coefficient of variation (CV) analysis showed that fruit development and seed performance had low variability, with CV values ranging from 9.5 - 14.2% for all combination of selected parental clones. The mean of fruit set percentage was 17.2% and the range of fruit set percentage for each crosses series was 9.5 - 31.7%.

All eleven crosses were significantly different (p <0.05) each other and their percentage of fruit set were quite low between 9.5 - 31.7% (Table 2).The highest fruit set percentage was achieved for crosses BM96 x BM89 (31.7%) while the lowest fruit set was produced by crosses BM96 x BM101 (9.5%). The mean percentage of harvested fruit was 4.9% with the range of 2.3 - 9.9%. The average of mature fruit was four times less than fruit set rate. The lowest percentage of harvested fruit was recorded for BM91 x BM99 crosses (2.3%) while the highest was produced by BM96 x BM89 (9.9%). It was not significantly different between BM96 x BM101 and BM96 x BM99 (3.2%) in term of percentage of harvested fruit. For seed germination, the mean percentage was 56.5% with the range of 59.3 - 66.7%. The maximum percentage of germination seed among the eleven crosses was showed by BM96 x BM99 (66.7%) while the minimum was recorded by BM91 x BM99 (40.0%). The mean of survival rate of seedlings from the period of germinated seed was70.5% and the range of percentage of survived seedling for individual crosses was 50.0 - 87.5%. The eleven crosses were significantly different from each other except for B10 x BM89 was not significantly different from BM96 x BM99 with percentage value of 62.5%. Crosses BM96 x BM101 was produced more seedlings with survival rate of 87.5% compare other crosses. While crosses BM91 x BM99 was showed the lowest value of survived seedlings with percentage of 50.0%. However, there is no significantly different between B10 x BM89 and BM96 x BM99 with the value of 62.5%.

Table 1: Mean squares, mean, standard deviation, coefficent of variation (CV) and range of fruit set, harversted fruit, germinated seed and survived seedling for eleven crosses.

Percentage (%)	Mean squares	Mean	Standard deviation	Coefficient of variation	Range
Fruit set	119.4*	17.2	1.8	14.2	9.5 - 31.7
Harvested fruit	15.7*	4.9	1.2	11.8	2.3 - 9.9
Germinated seed	148.1*	56.5	0.9	9.5	40.0 - 66.7
Survived seedling	393.9*	70.5	1.5	12.1	50.0 - 87.5

* Significantly different at $p < 0.05$

Table 2: Mean of percentage of fruit set, harversted fruit, germinated seed and survival rate of seedling for eleven crosses.

Crosses	Number of crossing	Fruit set (%)	Harvested fruit (%)	Number of seed	Germinated seed (%)	Survived seedling (%)
B10 x BM89	85	17.6d	3.5g	27	59.3d	62.5h
BM96 x BM89	100	31.7a	9.9a	50	64.0b	78.1d
BM91 x BM89	91	27.5b	8.8b	40	62.5c	64.0g
B10 x BM101	73	13.9g	3.8f	18	50.0i	55.6i
B17 x BM101	70	13.8h	5.7d	25	52.0h	84.6b
BM96 x BM101	63	9.5k	3.2h	14	57.1e	87.5a
BM91 x BM101	61	11.5j	4.9e	16	62.5c	70.0f
B10 x BM99	82	14.6f	6.1c	22	54.5f	83.3c
BM96 x BM99	95	21.1c	3.2h	12	66.7a	62.5h
BM91 x BM89	110	15.5e	2.7i	17	52.9g	77.8e
BM91 x BM99	88	12.5i	2.3j	10	40.0j	50.0j

Mean value with the same letter are not significantly different at $p < 0.05$

Total number of 918 crossing has been made and successful set 168 fruits. From that amount only 47 ripe mature fruits remain at harvesting time for F_1 seed collection purposes. A total of 251 hybrid seeds were collected and germinated and only half of them (146 seeds) were showed successful rate of germination and. Finally, there was only produced 105 good performance of seedlings survived after 3 months transferring to the polybag in the nursery. The results of the present study revealed that the initial fruit set of starfruit was very low (17.2%) and this finding was supported by Nand (1970), Pramanik (1972) and Srivastava (2005). Initial fruit set defined as the number of fruitlets retained on the branches 2 weeks after pollination is relatively quite high compared to the fruit retention after a month of pollination till harvesting stage. In general, the conversion percentage of rainy season flowers into fruit was low which may be attributed to loss of viable pollens due to heavy rain as well as poor pollination (Sanjib et al. 2013). Failure of pollination and deficiency in embryo fertilization are two important factors limiting fruit set of starfruit. Xenia is the direct effects of the pollen on the embryonic or endosperm tissue within the seed. In starfruit, incompatibility is a physiological mechanism that prevents self-fertilization. Assisted pollination in starfruit breeding will increase the percentage of fruit set although it was not much than open pollination method.

CONCLUSIONS

From the findings of the present study it can be inferred that starfruit tree in this assisted pollination produced low fruit set and decreased development of premature fruitlets that affected production of F_1 hybrid i.e. germination of F_1 seed and survival rate of F_1 seedling. The low intensity of fruit set due to various reasons was discussed in the present finding. Types of flower morphology and biology played a significant role in regulation of fruit set, fruit drop, growth and development throughout the synchronization and coordination of breeding system even including the good vector activities and selected parent as pollinizer clone. The important findings on fruit set success of starfruit by using dialled crosses therefore suggest the breeding programme for improved starfruit varieties through controlled pollination would be practical. It would not be necessary to rely mainly on chance pollinations.

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