

Fruit Setting Behaviour of Passion Fruit

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ABSTRACT

Passion fruit has great prospective to fascinate fruit consumer for its taste and delicious fruit juice and improvement of the economic condition of the fruit grower in the developing countries. The self-incompatibility in the passion fruits is an imperative reason to be considered regarding fruit production. Pollination is an essential for self-sterile crops as passion fruit (*Passiflora edulis* Sims.). The experiment was conducted in the field and laboratories of the Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur, Bangladesh to investigate the fruit setting behavior of passion fruits at during five flashes. We estimated to study fruit setting behavior of passion fruit at different flashes and determine effective pollination method and suitable flashes among five flashes. Result revealed that percent of fruit set of passion fruit was recorded highest; Seeds per plant were recorded highest in third flash when flowers were pollinated by hand compared with self-, and natural pollinations. Length-breadth ratios of fruits in third flashes were recorded higher when pollinates by hand. Individual fruit weight was also recorded higher at third flash. Plants required minimum days from flower anthesis to full maturity during third flash. On the other hand, fruit growth behavior of hand pollinated flowers was recorded higher during third flash of passion fruit. Results indicated that all studied characteristics of fruit and seed of passion fruit of third flash performed best.

Keywords: Passion Fruit; Fruit Setting; Flash; Pollination

1. Introduction

The passion fruit belongs to family passionflowers is an allogamous species [1]. In *Passiflora* genus contain more than 450 species but 12 species are cultivated. Only one species is *Passiflora edulis* Sims that grown as perennial, possess large flowers, and are cross-pollinated and vastly commercialized fruits [2]. It largely distributed around the tropics and warm humid subtropics [3-5]. It is an agronomically important delicious fruits [6] and cultivated for its ornamental, medicinal and nutritive characteristics [7]. Purple and yellow passion fruits are commonly cultivated in northern region of India [8].

Passion fruit has hermaphrodite, solitary flowers, located in the leaf axils. There are usually five stamens and ovary is borne over the androgynophore. There are three styles united at base, and at the top of style there are three bifurcated stigmas [9]. Passion fruits are protan-

drous as anther dehiscence before stigma becomes receptive and stigma remains receptive from time of flower opening to closing. Rhythmic movement of the style of passion flower has been shown self-incompatibility because of the style is in upright position and it starts curving in due course of time. Due to its floral morphology yellow passion fruit is an allogamous plant and self-incompatibility of sporophytic type [10] and cultivated for its edible fruits [11]. Self-incompatibility is an important factor for passion fruit production [12].

Pollination is important for fruit production on passion vines and extent of fruit set is dependent on effective pollination. Many yellow passion fruits do not set fruit unless their flowers are dusted with pollen from a different vine that is genetically compatible. Hand pollination is the easiest way to ensure fruit production. Hand pollination increases fruit yield in passion fruit. Artificial pollination is necessary in passion fruit because of its floral morphology where the anthers placed below the stigma.

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Anther of passion fruit is versatile in nature and turns upside down at the time of anthesis. Pollen grains are large, highly sticky and self-incompatible. The self-incompatibility in the passion fruits is an important factor to be considered regarding fruit production and studies on the heredity [10,12].

The flowers of passion fruit are large, attractive, colorful and fragrant. The flowers produce a plenty of pollen and nectar that facilitate insect pollination. The principal insects visiting passion flower include *Apis mellifera* (honey bee) and *Xylocopa vanpuncta* (carpenter bees). Carpenter bee is most effective pollinator as it has large body and its body brushes along the anther and stigma while collecting nectar. On the other hand honey bees are not effective pollinator because of their foraging habit [13]. Though the passion flowers are hermaphrodite, they are self-sterile and self-incompatible which lead to poor fruit set [10]. The anther at the top of filament is versatile in nature. The anther just at the time anthesis turns upset down. The pollens of passion flower are very sticky in nature which may be another cause of poor fruit set naturally. Wind is ineffective for pollination because of heaviness and stickiness of the pollen though flowers have fertile pollen.

The passion flower usually opens around mid-day that is generally the warmest time of day, until the end of the afternoon. During this period pollinators collect nectar, transfer pollen from one flower to another. The effective pollination occurs in the period after the style curves completely [14].

Fruit setting behavior is an important criterion for plant breeder in the process of development of a variety. The development of variety has been associated with yield and fruit quality [15]. The agro-ecological conditions mainly of hill tract regions of Bangladesh are amiable for passion fruit cultivations [16]. Passion fruit in Bangladesh is grown popularly in home gardens for its lucrative color of flower and flavor and tasty yellow juice. Though the fruit setting behavior of passion fruit has been studied in details in other countries, very little work has been done in Bangladesh [16,17]. Due to above mentioned natural constraints pollination and fruit set of passion fruit is hampered. Considering the above facts the present study was undertaken to find out suitable pollination method for successful fruit setting.

2. Materials and Methods

The study was conducted at the experimental farm of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, situated at 24.09° North latitude and 90.26° East longitudes with an elevation of 8.4 meter from the sea level. The climate of experimental site is subtropical characterized by heavy rainfall during April

to September and scanty during the rest of the year. Annual rainfall is favorable for passion fruit growing. The soil of the experimental field is clay loam in texture and acidic in nature with pH of around 5.8. The yellow passion fruit (*Passiflora edulis* Sims.) was used for the present experiment. Vine cuttings of two years old plant earlier collected from Bangladesh Agricultural Research Institute were used for the this study. Passion fruit were planted in trellised in rows 4.5 m apart and spaced 4.5 m apart within rows. The experimental plot was well-drained high land and where pit were prepared on the raised beds. Recommended fertilizers were applied in the pits (50 × 50 × 50 cm³) 10 days before transplanting of cuttings. Flowers were pollinated by hand compared with self-, and natural pollinations.

Natural pollination: For natural pollination 100 well developed flower buds were tagged for each flash from healthy plants. At 15th day after tagging, fruits were counted. Natural pollination is usually caused by wind, water and insects.

Self-pollination: For self-pollination another 100 well developed flower buds were tagged and bagged from each flash on previous day of blooming from healthy plants. After 5 days the tags were removed. At 15th day after tagging, fruits were counted.

Hand Pollination: For hand pollination another 100 well developed flower buds were tagged from each flash on previous day of blooming from healthy plants. On next day the tagged well bloomed flowers were pollinated by hand. At 15th day after hand pollination fruits were counted.

Data on the Fruit weight, Fruit length, Fruit breadth, Fruit and seed setting and Number of seeds per fruits were recorded.

Fruit and seed setting after open-, self-, and hand pollination: Flowers tagged for natural, self- and hand pollination were done at different times of the day. Twenty flowers of each type were considered for each treatment. The flowers were bagged 24 hrs before anthesis and they were rebagged for another 5 days after pollination. Open pollinated flowers were only tagged. Fruit set was observed by counting the fruits harvested at maturity.

Number of seeds per fruits: To observe the seed setting ability of both types 40 - 45 days old fruits were harvested and numbers of seeds per fruit were counted. Total numbers of seeds per fruit were recorded.

The collected data were analyzed statistically using MSTAT-C computer package (Michigan State University, East Lansing, MI, USA) following the methods of Gomez and Gomez (1984) [18]. The analysis of variance procedure (ANOVA), differences among treatment means were determined using the Least Significant Difference (LSD) at 5% level of significance.

3. Results

3.1. Fruit Set

Fruit set using three pollination methods at different flashes of passion fruit was described here.

3.1.1. Self-Pollination

Fruit set percent at different flashes using self-pollination ranged from 1.71% to 4.51% (**Table 1**). Plants produced maximum (4.51%) fruit during third flash using self-pollination. Before and after third flash using self-pollination, fruit set percent was noticed to be declined gradually. Plants produced significantly higher fruits during third flash compared with other flashes using self-pollination. No significant change of fruit set was observed between third and fifth flashes using self-pollination.

3.1.2. Natural Pollination

At different flashes imposing natural pollination fruit set percent of passion fruit varied from 12.60 to 25.67. As self-pollination plants produced maximum fruit (25.67%) during third flash imposing natural pollination (**Table 1**). Fruit set percent during third flash was recorded highest (25.67) compared with other flashes by natural pollination. Higher rate of fruit set of passion fruit was recorded in all flashes during natural pollination compared with self-pollination.

3.1.3. Hand Pollination

Among the studied methods, hand pollination showed to set highest percent of fruit at all flashes. Imposing hand pollination fruit set percent ranged from 31.61% to 46.71% (**Table 1**). Among the three pollination methods, hand pollination was noticed to be best in respect of fruit set. As other two methods (self-pollination and natural pollination), hand pollination produced maximum fruit during third flash. Among the three pollination methods and five flashes, plant produced highest fruit imposing hand-pollination during third flash. Among the flashes, flowers pollinated by hand produced maximum fruits during third flash followed by fourth, second, fifth and first flashes.

3.2. Seeds Per Fruit

Effect of the pollination methods on seeds per fruit at different flashes was presented in **Table 2**.

3.2.1. Self-Pollination

Seeds per fruit in multiple seeded fruits depend upon number of pollens availability on the stigma of flower. Seeds per fruit of self-pollinated flower of passion fruit at different flashes were recorded variable. Seeds per fruit at different flashes ranged from 3.59 to 10.51 (**Table 2**). Seeds per fruit were recorded maximum (10.51) at third flashes followed by fourth, second, fifth and first flashes. From the finding it was

noticed that imposing self-pollination early and late flowers produced minimum seeds per fruit.

3.2.2. Natural Pollination

From the findings it was observed that seeds per fruit imposing natural pollination at different flashes were recorded higher than that of self-pollination (**Table 2**). As self-pollination seeds per fruit in open pollinated flower at third flash were recorded maximum (16.51 seeds/fruit). The trend of seeds per fruit in open pollinated flowers at different flashes was noticed more or less as self-pollinated flowers. Seeds per fruit were recorded minimum (8.56) at fifth flash compared with self-pollination.

3.2.3. Hand Pollination

Among the three pollination methods, hand pollination produced maximum seeds per plant at all flashes (**Table 2**). It was recorded that among the three pollination methods and five flashes plant produced maximum seeds per fruit imposing hand-pollination at third flashes. Stigma of passion flower received maximum number of pollen which is the cause of maximum seeds per fruit. On the other hand, hot-humid weather was noticed favorable for better growth and development of passion fruit which prevailed during third flash. On the contrary average seeds per fruit imposing hand pollination were recorded maximum (**Figure 1**).

3.3. Fruit Weight

Effect of pollination methods on individual fruit weight (g) of passion fruit at different flashes at maturity on fresh weight basis was reported in **Table 3**.

3.3.1. Self-Pollination

Individual fruit weight of passion fruit at different flashes at maturity using self-pollination was noticed variable (**Table 3**). Individual fruit weight at different flashes ranged from 25.28 to 35.81 g. Individual fruit weight was noticed maximum at third flash compared with other flashes. At first and fifth flashes individual fruit weight was recorded minimum as compared with other flashes imposing self-pollination.

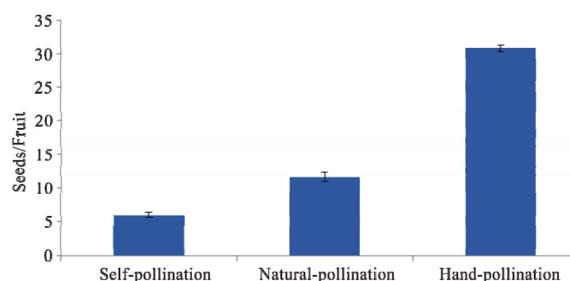


Figure 1. Effect of pollination methods on seeds per fruit (mean value).

Table 1. Effect of pollination methods on fruit sets of passion fruit at different flashes (%).

Flashes	Self-pollination	Natural-pollination	Hand-pollination	Mean
First	1.71d	15.50 c	31.61d	16.27
Second	2.16c	20.45b	35.45c	19.35
Third	4.51a	25.67a	46.71a	25.63
Fourth	3.67b	15.18c	40.12b	19.66
Fifth	1.90d	12.60d	32.15d	15.55
Mean	2.79	17.88	37.21	19.29

Mean followed by same letter in the column are statistically similar

Table 2. Effect of pollination methods on seeds per fruit of passion fruit at different flashes (seeds/fruit).

Flashes	Self-pollination	Natural-pollination	Hand-pollination	Mean
First	3.59 ± 0.76	10.18 ± 0.55	30.64 ± 0.47	14.80 ± 59
Second	5.84 ± 0.52	12.25 ± 0.63	30.90 ± 0.66	16.33 ± 0.60
Third	10.51 ± 0.67	16.51 ± 0.64	35.18 ± 0.52	20.73 ± 0.61
Fourth	6.38 ± 0.67	10.91 ± 0.76	31.65 ± 0.75	16.31 ± 0.73
Fifth	4.12 ± 0.66	8.56 ± 0.46	25.68 ± 0.66	12.79 ± 0.59
Mean	6.09 ± 0.66	11.68 ± 0.61	30.81 ± 0.63	16.19 ± 0.63

Table 3. Effect of pollination methods on individual fruit weight of passion fruit at different flashes at maturity on fresh weight basis (grams).

Flashes	Self-pollination	Natural-pollination	Hand-pollination	Mean
First	26.42 ± 0.57	34.18 ± 0.62	30.41 ± 0.65	30.34
Second	32.91 ± 0.51	36.76 ± 0.49	33.56 ± 0.62	34.41
Third	35.81 ± 0.54	42.67 ± 0.53	39.40 ± 0.66	39.29
Fourth	33.95 ± 0.56	40.01 ± 0.60	35.63 ± 0.40	36.53
Fifth	25.28 ± 0.44	34.91 ± 0.53	31.18 ± 0.62	30.46
Mean	30.87	37.71	34.04	34.21

3.3.2. Natural Pollination

Imposing natural pollination individual fruit weight of passion fruit at different flashes varied from 34.18 to 42.67 grams at maturity (**Table 3**). Results revealed that plant produced largest fruit (42.67 grams) using natural pollination followed by fourth, second, fifth and first flashes. As self-pollination, plant produced largest fruit during third flash imposing natural pollination. Comparing with self-pollination, individual fruit weight at different flashes imposing natural pollination was recorded higher. Individual fruit weight is associated with the number of seeds per fruit. Fruit set of passion fruit was mainly caused by *Apis mellifera* (data not shown).

3.3.3. Hand Pollination

Individual fruit weight imposing hand pollination at different flashes ranged from 30.41 to 39.40 grams (**Table 3**). As self and natural pollinations, individual fruit weight at third flash was also recorded higher. Individual fruit weight of passion fruit at all flashes was noticed comparatively lower than natural pollination. Individual fruit weight depends upon number of fruits per plant. As fruit set it was higher imposing hand pollination. So the individual fruit weight was recorded comparatively lower than natural pollination.

Among the pollination methods at different flashes plant produced biggest fruit (42.67 g/fruit) during third flash pollinated with natural pollination. During third

flash, plant showed vigorous growth which may be the cause of formation of longer fruit during third flash.

3.4. Days Required from Anthesis to Maturity

Fruit maturity of a crop is influenced by genetic make-up, physiological condition of the specific crop as well as environmental factors such as rainfall, humidity, temperature, day length etc. Fruit maturity of passion fruit at different flashes was noticed variable (**Figure 2**). Results revealed that plants required minimum days (42 days) from flower anthesis to full maturity during third flash. Days to maturity from anthesis was observed to be enhanced. On the other hand maturity of fruit was noticed to be delayed during first and fifth flashes of passion fruit. During third flash hot and humid weather as well as longest day-length prevailed that might be the cause of enhancement of fruit maturity.

3.5. Fruit Length and Diameter

Effect of pollination methods on fruit length and diameter of passion fruit at different flashes was presented in **Table 4**.

3.5.1. Self-Pollination on Fruit Length

Fruit length of passion fruit imposing self-pollination at different flashes was recorded not uniform (**Table 4**). Fruit length at different flashes ranged from 3.19 to 4.16 cm. Fruit length was recorded maximum (4.16 cm) at third flash followed by fourth, second, fifth and first flashes. No significant change of fruit length between third and fourth flashes imposes self-pollination.

3.5.2. Natural Pollination on Fruit Length

Similar trend of fruit length at different flashes imposing natural pollination was noticed. But fruit length at all flashes was recorded little bigger than that of self-pollinated fruits. As self-pollination, plant produced longest fruits (5.91 cm) imposing natural pollination at third flash. Among the flashes, plant produced smallest fruit (3.36 cm) at first flash. Fruit length of passion fruit between third and fourth flashes did not show any significant change.

cant change.

3.5.3. Hand Pollination on Fruit Length

Plants produced longest fruit at all flashes imposing hand-pollination compared with self-and open pollinations. Plant produced longest fruit imposing hand pollination as self and open pollination at third flash (**Table 4**). Among these methods of pollination at different flashes plant showed longest fruit imposing hand pollination at third flash. Fruit length of multiple seeded fruit depends upon number seeds set in the fruit.

3.6. Fruit Diameter

Fruit diameter of passion fruit imposing self-, natural and hand pollinations at different flashes was mentioned in **Table 4**. No noticeable change of fruit diameter of passion fruit was observed imposing the above mentioned pollination methods during five flashes. Fruit diameter was affected by pollination methods and flashes.

3.7. Length-Breadth Ratio

Length-breadth ratio of passion fruit imposing different methods of pollination at different flashes was shown in **Figure 3**. It was noticed that length-breadth ratios of fruits of all flashes were recorded higher when passion flowers were pollinated by hand pollination followed by natural and self-pollinations.

3.8. Fruit Yield

Fruits per plant ranged from 2 to 28 by natural pollination. Plant produced maximal number of fruit by natural pollination during third flash. Minimal number of fruits per plant was noticed in fifth flash by natural pollination (**Table 5**). Fruit set percent at different flashes varied from 7.41 to 20.00 by natural pollination. As fruits per plant, fruit set percent was recorded highest at third flash. Fresh weight of individual fruit (g) was recorded maximum during third flash though it ranged from 21 to 34 by natural pollination.

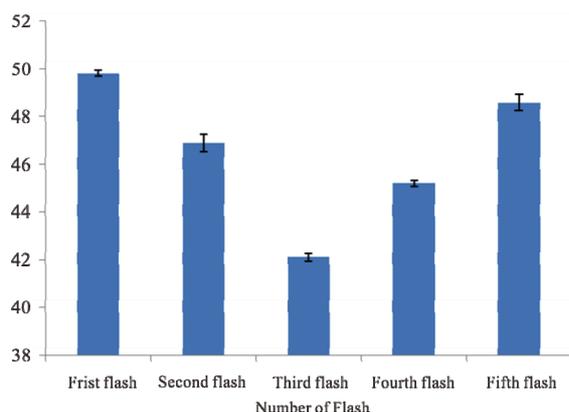
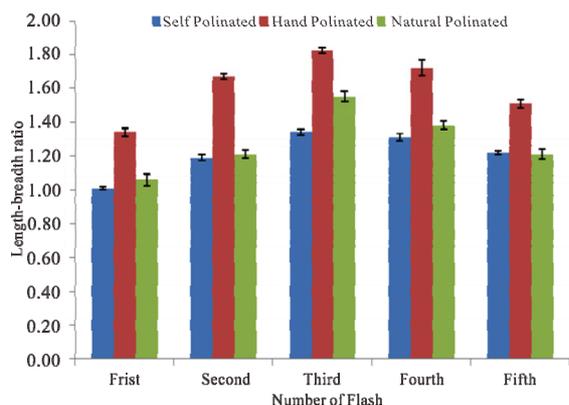
Table 4. Effect of pollination methods on fruits length and diameter of passion fruit at different flashes on maturity (cm).

Flashes	Self-pollination		Open-pollination		Hand-pollination		Mean
	L	B	L	B	L	B	
First	3.19 ± 0.22	3.10 ± 0.29	4.25 ± 0.37	3.20 ± 0.43	3.36 ± 0.27	3.15 ± 0.26	3.60
Second	3.85 ± 0.26	3.12 ± 0.26	5.25 ± 0.34	3.18 ± 0.40	3.95 ± 0.20	3.17 ± 0.21	4.35
Third	4.16 ± 0.26	3.10 ± 0.16	5.91 ± 0.24	3.25 ± 0.46	4.72 ± 0.28	3.16 ± 0.25	4.93
Fourth	4.03 ± 0.35	3.13 ± 0.29	5.37 ± 0.30	3.16 ± 0.35	4.39 ± 0.30	3.20 ± 0.25	4.60
Fifth	3.79 ± 0.33	3.11 ± 0.31	4.76 ± 0.40	3.16 ± .46	3.80 ± 0.30	3.15 ± 0.30	4.12
Mean	3.80	3.11	5.11	3.19	4.04	3.17	4.32

Table 5. Yield of passion fruit per plant by natural pollination.

Flashes	Fruit set %	Fruit per plant	Fresh weight of individual fruit (g)
First flash	15.38 b	8b	21b
Second flash	18.66 ab	25a	31a
Third flash	20.00 a	28a	34a
Fourth flash	17.24 ab	25a	32a
Fifth flash	7.41 c	2c	23b

Mean followed by same letter in the column are statistically similar

**Figure 2. Effect of different flashes on days to fruit maturity from anthesis (days) of passion fruit.****Figure 3. Length-breadth ratios at different flashes by applying different pollination.**

4. Discussion

Pollination is an important criterion for fruit set in passion fruit. Our main aim was to determine the extent to which pollination methods are effective for successful fruit production. Kishore *et al.* (2010) [19] reported that maximum number of bees was observed between 07:00 - 08:00 h in purple and giant passion fruit, but between 13:00 - 14:00 h in yellow passion fruit. In the present study the maximum number of bees was noticed in the field during 13:00 - 14:00 h. For open pollination the most common pollinating bee for purple, giant and yel-

low passion fruit was *A. mellifera*, while *A. cerena* was for *P. foetida* [19]. In this study *Apis mellifera* was noted the most common pollination bee.

Floral morphology of passion flower is the barrier for self-pollination due to pollen not reaching the stigma. Except self-pollination (0% fruit set), manual pollination gave greater fruit set than natural pollination (about 55% vs. 44.6%), resulting in 90-g fruits (20% - 25% heavier than those of the control). Juice percentage and seed number were increased by hand pollination by about 40 and 10%. In general, cross pollinating at around 16.00 h gave the best results (Duarte and Sierra, 1997) [20] which was little contradictory with the present experiment. A high correlation between fruit weight and seed number, fruit length and diameter were noticed [21].

Though passion fruit (*P. edulis f. flavicarpa*) is capable of a very small degree of self-compatibility, cross-pollination results in increased fruit set, fruit weight, seed set, juice volume and juice sugar concentration. Although large bees such as *Xylocopa* spp. were expected as pollinators, honeybees (*A. mellifera*) were the only pollinators observed. The foraging habits of honeybees, not their size, may cause less than expected percentage fruit set [13]. Fruit set of passion fruit in the present study in open pollinated flowers was caused mainly by honey bees (data were not shown) which was supported by Hammer (1987) [13].

Hand pollination alone or in combination with GA3 increased fruit set, fruiting and fruit quality (weight, juice weight and TSS) compared with open pollination. Hand pollinated fruits contained more seeds than open pollinated fruits. Hand pollination decreased rind weight and total acidity content [14]. Seeds per fruit by hand pollination in the present study were observed highest (35.18) compared with self- and natural pollinations which were supported by Saleh and Zarad (1996) [14].

Nazrul *et al.* (2003) [16] in yellow passion fruit reported 30% fruit set by hand pollination. In the present investigation, fruit set percent was recorded maximum (20) during third flash by natural pollination mainly caused by *Apis mellifera*. In another study, Kishore *et al.* (2010) [19] mentioned 42.2% fruit set of yellow passion by using *A. mellifera* as a natural pollinator. Photoperiod

[22], air temperature [23], pesticides [24] and soil moisture are factors that determine the yield of yellow passion fruit. Due to high humidity in anther opening time, cell content of pollen grain contain high osmotic pressure as well as low resistance of their walls, reduced pollen viability as a result affect the frutification and fertilization percentage in pollination [12]. Biotic factors such as the physiological stages of the plant interfere with the frutification and seed production [25]. The biochemical pathways that control fruit setting and maturity in yellow passionfruit [15]. The low yield before and after third flash is due to the lack of flowering and fructification of the plant because of climatic conditions. Flowering of third flash during June-July, that time cause of rainfall and high humidity temperature was relatively low in summer time. Relatively low temperatures are suitable for flowering and fruit set, and moderately high temperatures are favorable for fruit growth and quality in purple passion fruit [26].

5. Conclusion

Finally, it can be concluded that, among the pollination methods (self-, natural and hand pollination), passion fruit produced maximum fruits pollinating flowers by hand. Hand pollination showed maximum fruits per plant at all flashes. Seeds per plant were recorded highest when flowers are pollinated by hand. Individual fruit weight was recorded maximum with naturally pollinated flower. Plants required minimum period day from anthesis to full maturity at third flash compared with other flashes. Plants produced longest fruit by natural pollination followed by hand pollination during third flash.

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