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Studies on floral biology in jackfruit (*Artocarpus heterophyllus* L.) var Konkan prolific

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Abstract
Jackfruit (*Artocarpus heterophyllus* L.) is native to Southeast Asia (chromosome no. 2n = 4x =56). The jackfruit tree belongs to the family Moraceae. The study was undertaken entitled 'Studies on the floral biology and fruit development in jackfruit (*Artocarpus heterophyllus* Lam) var Konkan Prolific' during the year 2021-2022. The flowering period of jackfruit for male flowers starts on 23 October 2021 and ends on 2 June 2022 whereas for female flowers flowering season starts on 12 November 2021 and ends on 14 April 2022. Male spikes took an average of 47.4 days and female spikes took an average of 63 days for flower bud development from bud appearance. Maximum flowering (Both male and female) was seen in the month of February. Both male and female spikes took an average of 24.90 days between two successive spike openings and an average of 5.80 days from the initiation of spike opening to the shedding of the spathe. The male spikes took an average of 13.60 days for anthesis from spike opening. The pollens are available for an average of 11.90 days on a spike. The female spikes took an average of 12.70 days for the protrusion of the stigma from the spike opening. The duration required to fertilize stigmas on female spikes took an average of 26 days whereas for the fertilization of individual stigma it took an average of 22 days. Jackfruit took an average of 28.20 days for fruit set from stigma appearance.

Keywords: Protrusion, successive, fertilization, anthesis

Introduction
Jackfruit (*Artocarpus heterophyllus* L.) is native to Southeast Asia (Boning 2006) [2] (chromosome no. 2n = 4x =56). The jackfruit tree belongs to the family Moraceae along with other fruits-bearing plants like Fig (*Ficus carica*) and Mulberry (*Morus indica*) (Samadder, 1990; Hammerschlag and Litz, 1992) [5]. The jackfruit tree is mainly a lowland tropical tree and can be grown in subtropical areas. Jackfruit is also known as the largest tree-borne fruit in the. Apart from India, it is also cultivated in Bangladesh, Myanmar, Malaysia, Nepal, Thailand, Vietnam, China, Philippines, Indonesia and Sri Lanka. Except for temperate regions, jackfruit is found throughout India and it is known by various vernacular names like Kathal, Kantaka, Panasa, Jak and Jaca. India is blessed with wide jackfruit diversity regarding its maturity, fruit shape, fruit size, spine character, latex, flake size, colour, texture, taste and sweetness (Jagadeesh *et al*., 2007; Khan *et al*., 2010; Sindhu, 2012) [7, 8, 13]. India is believed to be the land of Jackfruit. For centuries jackfruit plays a significant role in Indian agriculture and culture. It is mainly grown as a shade crop and is available throughout the country. It is also known as "Poor man's food" (Rahman *et al.*, 1995) [11].

It is the monoecious tree bearing small, inconspicuous, and incomplete flowers in a separate inflorescence. There is only one stamen in the male flower and a bicarpellary, syncarpous gynoecium in the female flower (Hammerschlag and Litz, 1992) [5]. Jackfruit has a unique character of producing specialized reproductive shoots (footstalks). Female spikes are produced on footstalks whereas male spikes are produced on footstalks as well as on young branches of the tree. Male spikes are dull green, relatively elongated, and have long peduncles, whereas female spikes are green, stout, and granular with short peduncles. Female spikes bear hundreds of small sessile flowers with fleshy receptacles. Each flower is characterized by a perianth, stigma, and unilocular ovary. Male spikes also bear hundreds of small sessile flowers with single stamens. Unlike female spikes, male spikes do not grow continuously and start decaying with the completion of pollen dehiscence. It is anemophilous (Samaddar, 1990) [12].

Jackfruit produces multiple fruits (syncarp) with a green to yellow-brown exterior rind containing hexagonal bluntly conical carpel apices (spines). The perianth of the individual flowers becomes the fleshy pericarp and surrounds the seeds, each pericarp and seed being an individual fruit.

The fleshy aril along with the seed is called a bulb which varies in number size, colour, texture, and biochemical properties. The fruit axis is the modified mature inflorescence axis and is somewhat dome-shaped, rigid, and slightly fleshy (Pushpakumara, 2006) [10].

Materials and Methods

The field experiment took place at the Educational Research Farm, which is located at the Vice Chancellor Bungalow Plot College of Horticulture in Dapoli (M.S.) Dist. Ratnagiri, Maharashtra, India between November 2021 and June 2022. For this experiment, 10 years old firm fleshed jackfruit trees of var Konkan prolific were selected. 19 trees were selected for experimental purposes. Observation tables were drawn according to the stages of flowering, such as bud emergence, bud swelling all the way to female flower bud pollination completion or male flower bud decay. Along with the images, daily observations were also kept track of. Physical parameters were recorded by using descriptor for jackfruit by the International Plant Genetics Institute (Anonymous, 2000). The data from many observations during the study were statistically analyzed with the help of the method suggested by Panse and Sukhatme (1995), and basic statistics and means were taken for the comparison and interpretation of results. The analysis was carried out at Computer Cell, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli from 2021 to 2022.

Result and Discussion

1. Flowering period of jackfruit

The data presented in table 1 indicates that the flowering period and the peak flowering period of jackfruit (*Artocarpus heterophyllus* Lam.) var Konkan Prolific is different for male flowers and female flowers. For male flowers, the flowering season begins on 23 October 2021 and ends on 2 June 2022. Whereas, for female flowers, the flowering season begins on 15 November 2021 and ends on 22 April 2022. Peak flowering period for male flowers ranges from 28 December 2021 to 12 March 2022 whereas, for female flowers, it ranged from 12 January 2022 to 5 March 2022. However, there are some genotypic variations in the variety at the time of emergence of both male and female spikes as well as the flowering season of jackfruit, the peak flowering period for male and female flowers was higher than found by other authors the variation that occurs might be due to the genotypic variation in the flowering behavior of jackfruit varieties and agroclimatic conditions of the research location might be the reason for the difference in findings. Bawoor (2017) [3] reported differences in the flowering time of male and female spikes during the season.

Table 1: Flowering period and the peak flowering period of jackfruit (*Artocarpus heterophyllus* Lam.) var Konkan Prolific is different for male flowers and female flowers

Male flower			Female flower		
Initiation of the flowering season	Peak flowering period	End of the flowering season	Initiation of the flowering season	Peak flowering period	End of the flowering season
23 October 2021	28 December 2021 to 12 March 2022	2 June 2022	15 November 2021	12 January 2022 to 5 March 2022	22 April 2022

2. Days required for floral bud development

The data presented in Table 2 designate that the days required for floral bud development of male and female flowers of jackfruit (*Artocarpus heterophyllus* Lam.) var Konkan Prolific is different for male flowers and female flowers. The days required for male flowers for floral bud development in the present study ranged from 41 to 53 days with a mean of 47.7 days. Whereas, for female flower bud development it ranges from 59 to 68 days with a mean of 63 days. In the present study, the days required for floral bud development were higher than those found by other authors for the variation that occurs. Mannan *et al*., (1990) [9] and Azad (1989) [1] studied the flower bud development period in the months of October to February whereas the present study was done from November to March in Konkan agroclimatic conditions where the average temperature was lower. This low temperature and environmental conditions might be the reason for the differences in the findings. Mannan *et al*., (1990) [9]; Bawoor (2017) [3] recorded similar results in the floral bud development of jackfruit.

Table 2: The days required for floral bud development of male and female flowers of jackfruit (*Artocarpus heterophyllus* Lam.) var Konkan Prolific is different for male flowers and female flowers

Sample no.	The period required for male flower bud development	Days	The period required for female flower bud development	Days
1	16/2/2021 – 10/4/2021	53	23/10/2021 – 28/12/2021	66
2	16/2/2021 – 31/3/2021	43	23/10/2021 – 23/12/2021	61
3	16/2/2021 – 29/3/2021	41	2/11/2021 – 31/12/2021	59
4	16/2/2021 – 4/4/2021	47	13/11/2021 – 17/1/2022	65
5	16/2/2021 – 8/4/2021	51	11/11/2021 – 18/1/2022	68
6	16/2/2021 – 6/4/2021	49	8/11/2021 – 10/1/2022	63
7	16/2/2021 – 1/4/2021	44	8/11/2021 – 11/1/2022	64
8	16/2/2021 – 20/4/2021	48	15/12/2021 – 14/2/2022	60
9	16/2/2021 – 4/4/2021	47	13/11/2021 -17/1/2022	65
10	16/2/2021- 8/4/2021	51	23/10/2021 – 21/12/2021	59
	Mean	47.4	Mean	63
	Standard Error	1.21	Standard Error	0.98
	Standard Deviation	3.84	Standard Deviation	3.12
	Coefficient of Variance	14.71	Coefficient of Variance	9.77

3. Number of spikes per footstalk and leafy shoots

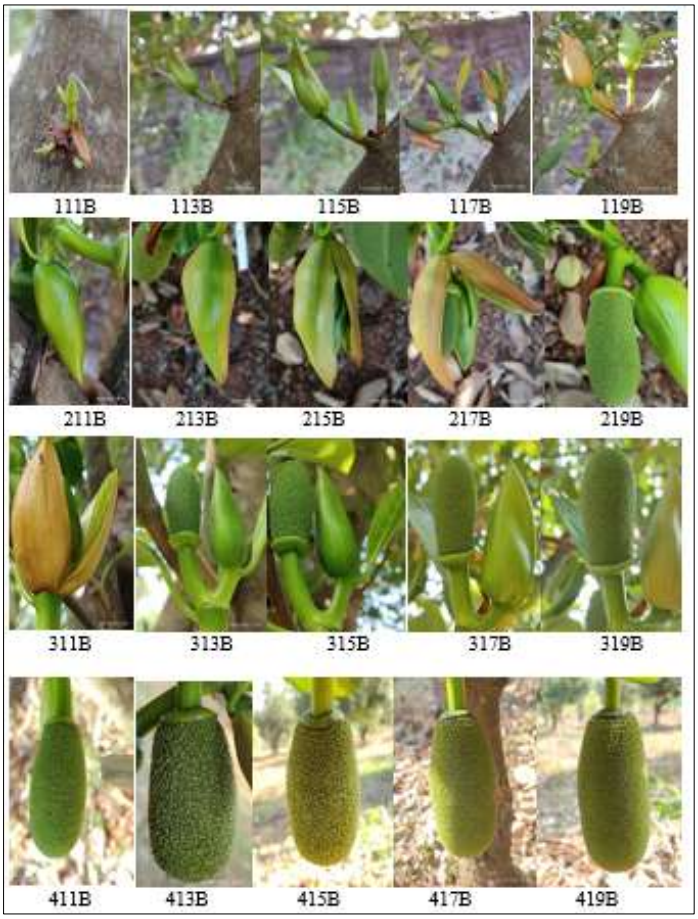
The data presented in Table 3 indicates that the number of spikes (male and female spikes) per footstalk and male spikes in leafy shoots of jackfruit (*Artocarpus heterophyllus* Lam.) var Konkan Prolific is different for male flowers and female flowers. The total number of (male and female) spikes varied among the selected jackfruit trees of var Konkan prolific, ranging from 38 to 125 spikes per tree with a mean of 65.5 spikes per plant (47.08 male spikes and 16.58 female spikes per plant). The number of spikes per footstalk and leafy shoots might be varied due to differences in the flowering behaviors of the jackfruit varieties and environmental conditions. Similar results in jackfruit were recorded by Haque and Majumder (2006).

Table 3: The number of spikes (male and female spikes) per footstalk and male spikes in leafy shoots of jackfruit (*Artocarpus heterophyllus* Lam.) var Konkan Prolific is different for male flowers and female flowers

Tree	No. of spikes (both male and female) in the footstalk		Total (male and female) spikes in footstalk	Male spikes in leafy shoots
	Male spike	Female spike		
1st row 3rd tree	57	19	86	31
1st-row 4th tree	76	25	101	29
2nd row 2nd tree	87	38	125	34
2nd row 3rd tree	36	12	48	42
2nd row 5th tree	27	5	32	63
3rd row 1st tree	48	19	67	45
3rd row 2nd tree	38	15	53	63
4th row 2nd tree	38	15	53	44
5th row 1st tree	57	25	82	46
5th row 2nd tree	44	9	53	47
5th row 3rd tree	37	11	48	47
6th row 3rd tree	20	6	38	18
Mean	47.08	16.58	65.50	42.42
Standard deviation	19.45	9.40	27.72	13.10
Coefficient of variance	378.45	88.45	768.63	171.72

4. Male and female flower ratio

The data presented in Table 4 shows that the male and female flower ratio of jackfruit (*Artocarpus heterophyllus* Lam.) var Konkan Prolific is different for male flowers and female flowers. The sex ratio was highest in the months of November to December among all the jackfruit trees under study. The ratio was lowest in the months of January to March. Maximum flowering (Both male and female) was seen in the month of February in all trees under study.



111B-Flower bud appearance
113B-Bud swelling
115B-Bud development
117B-Spike opening
119B-Footstalk developed
211B-Bud development
213B-Beginning of bract separation
111A-Flower bud appearance
113A-Bud swelling
115A-Bud development
117A-Spike opening
119A-Footstalk developed
211A-Bud development
213A-Beginning of bract separation
215B-Advance bract separation
217B-End of bract separation
219B-Female spike visible
311B-End of bract separation
313B-Female spike visible
315B-Beginning of female spike development
317B-Advanced female spike development
215A-Advance bract separation
217A- End of bract separation
219A- Male spike visible
411A-Beginning of anthesis of male spike
413A-Advance anthesis of male spike
415B-End of anthesis of male spike
417B-Beginning of the decay of male spike
319B-Fully developed female spike
411B-Protrusion of stigma
413B-Beginning of fertilization of stigmas
415B-Advance fertilization of stigmas
417B-End of fertilization of stigmas
419B-Fruit set
419B- Fully decay of male spike

The ratio was higher during the early part of the season. Then the ratio decreases sharply due to the increases in the female spike rate with the flowering season advancement. Variation in the sex ratio of jackfruit might be depending on the agroclimatic condition and the type of genotype of the study which might be the reason for the differences in the findings. Results recorded in jackfruit by Choudhury *et al*., (2018) has similarity to the present study.

Table 4: The male and female flower ratio of jackfruit (*Artocarpus heterophyllus* Lam.) var Konkan Prolific is different for male flowers and female flowers

Tree	Male to Female flower ratio			Male to Female flower ratio of season
	(Nov -Dec)	(Jan-Feb-March)	(April-May)	
1st row 3rd tree	22:0	4.90:1	1.5:1	4.63:1
1st-row 4th tree	4.37:1	5:1	2:1	4.20:1
1st row 5th tree	48:0	7.14:1	2.5:1	9.81:1
2nd row 2nd tree	42:0	3.25:1	1.04:1	3.04:1
2nd row 3rd tree	18:1	5.71:1	2:1	5.23:1
2nd row 5th tree	19:1	14:1	14:0	18.8:1
3rd row 1st tree	22:0	5.54:1	2.5:1	5.42:1
3rd row 2nd tree	19:0	6.87:1	3:1	6.73:1
4th row 2nd tree	14.5:1	4.2:1	2.75:1	5.12:1
4th row 3rd tree	6:0	11:1	10:1	12.66:1
5th row 1st tree	34:0	3.67:1	1.75:1	4.47:1
5th row 2nd tree	32:0	49:1	1.25:1	10.11:1
5th row 3rd tree	29:0	5:1	3.75:1	7:1
5th-row 4th tree	7:1	4.12:1	2.7:1	4.32:1
6th row 3rd tree	6:0	5:1	6:1	6.33:1
6th-row 4th tree	9:0	5.78:1	10:1	9:1
7th row 1st tree	44:0	2.12:1	4:1	3.47:1
7th-row 4th tree	35:0	1.97:1	1.89:1	2.64:1
9th row 3rd tree	15:1	2.18:1	2.0:1	2.79:1

5. Period required for spike opening and period required for two successive spike opening

The data presented in Table 5 indicates that the period required for spike opening and the period required for two successive spike openings of jackfruit (*Artocarpus heterophyllus* Lam.) var Konkan Prolific. Both male and female spikes took 5 to 8 days with a mean of 5.8 days from initiation of spike opening to the shedding of the spathe. Both male and female spikes took 15 to 35 days with an average of 24.9 days between two successive spike openings. In the present study, the spike opening to the shedding of spathe period was lower than found by other authors the variation that occurs might be due to the variation in the flowering behavior of jackfruit varieties and environmental conditions. Similar results were found by Azad (1989) [1] in jackfruit. While results recorded by Haque and Majumder (2006) which was not similar to the present finding.

Table 5: The period required for spike opening and the period required for two successive spike openings of jackfruit (*Artocarpus heterophyllus* Lam.) var Konkan Prolific

Sample no.	The period required for spike opening	Days	The period required for two successive spike opening	Days
1	9/1/2022 -13/1/2022	5	21/12/2021 – 5/1/2022	15
2	2/2/2022 – 6/2/2022	5	31/12/2021 -31/1/2022	30
3	13/1/2022–17/1/2022	5	17/1/2022 – 10/2/2022	24
4	28/12/2021–2/1/2022	6	14/1/2022 – 10/2/2022	27
5	31/12/2021–5/1/2022	6	17/1/2022 – 10/2/2022	24
6	6/1/2022 – 11/1/2022	6	26/1/2022 – 18/2/2022	23
7	27/12/2021–3/1/2022	8	13/1/2022 – 7/2/2022	25
8	21/12/2021- 27/12/2021	7	9/1/2022 – 13/2/2022	35
9	9/1/2022 – 13/1/2022	5	25/12/2022 -18/1/2022	24
10	5/1/2022 – 9/1/2022	5	9/1/2022 -31/1/2022	22
	Mean	5.80	Mean	24.90
	Standard Error	0.33	Standard Error	1.65
	Standard Deviation	1.03	Standard Deviation	5.22
	Coefficient of Variance	1.06	Coefficient of Variance	27.21

6. Days required for anthesia from spike opening and availability of pollen grains on a male spike

The data presented in Table 6 indicates the days required for anthesis from spike opening and availability of pollen grains on the male spike of jackfruit (*Artocarpus heterophyllus* Lam.) var Konkan Prolific. The protrusion of anther on the surface of the male spike after the spike opening out of the spathe ranged from 9 to 22 days have an average of 13.6 days. The availability of pollen grains on male flowers ranges from 9 to 15 days with an average of 11.9 days. The variation in period for anthesis of male spikes was different among the same jackfruit variety might be due to the positions of male spikes on the plant, variation in the flowering behavior of jackfruit varieties and environmental conditions. Azad (1989) [1] and Bawoor (2017) [3] recorded similar results in jackfruit.

Table 6: The days required for anthesis from spike opening and availability of pollen grains on the male spike of jackfruit (*Artocarpus heterophyllus* Lam.) var Konkan Prolific

Sample no.	The period required for anthesis from male spike opening	Days	Period of availability of pollen grains on male spike	Days
1	31/12/21 – 14/1/2022	15	20/2/2021 - 6/3/2021	14
2	6/1/2022 – 19/1/2022	13	16/2/2021 – 1/3/2021	13
3	5/1/2022 – 14/1/2022	9	4/3/2021 – 12/3/2021	9
4	22/2/2022 – 3/3/2022	10	22/2/2021 – 3/3/2021	10
5	30/12/2021 – 13/1/2022	14	22/2/2021 – 7/3/2021	14
6	3/1/2022 – 17/1/2022	9	22/2/2021 – 2/3/2021	9
7	27/12/2021 – 11/1/2022	16	4/3/2021 – 13/3/2021	10
8	5/1/2022 – 18/1/2022	13	26/12/2021 – 8/1/2022	13
9	17/1/2022 – 31/1/2022	15	5/1/2022 – 19/1/2022	15
10	27/12/2021 – 17/1/2022	22	30/12/2021 – 11/1/2022	12
Mean		13.60	Mean	11.90
Standard Error		1.23	Standard Error	0.70
Standard Deviation		3.89	Standard Deviation	2.23
Coefficient of Variance		15.15	Coefficient of Variance	4.99

7. Time required from the female spike opening to the protrusion of the stigma, fertilization period of stigmas on a female spike and fertilization period of individual stigma on a female spike

The data presented in Table 7 indicates the time required from the female spike opening to the protrusion of the stigma, the fertilization period of stigmas on a female spike and the fertilization period of individual stigma on the female spike of jackfruit (*Artocarpus heterophyllus* Lam.) var Konkan Prolific. The period of protrusion of the stigma from the female spike opening ranged from 10 to 17 days with an average of 12.70 days. The fertilization period of stigmas varied from 22 to 34 days with an average value of 26.60. The duration required to fertilize individual stigma on a female spike ranged from 17 to 25 days with an average of 22 days. The variation in period required from female spike opening to the protrusion of stigma was different among the same jackfruit variety might be due to the positions of female

spikes on the plant and the size of the flower as well as variations in the climatic conditions. Similar results in jackfruit were recorded by Haque and Majumder (2006) and Choudhury *et al.*, (2018).

Table 7: The time required from the female spike opening to the protrusion of the stigma, the fertilization period of stigmas on a female spike and the fertilization period of individual stigma on the female spike of jackfruit (*Artocarpus heterophyllus* Lam.) var Konkan Prolific

Sample no.	The period required for protrusion of stigma on a female spike from opening	Days	Duration to fertilize stigmas on a female spike	Days	Duration required to fertilize individual stigma on a female spike	Days
1	14/1/2022-31/1/2022	17	2/2/2022 – 28/2/2022	27	10/2/2022 – 7/3/2022	25
2	18/1/2022 – 2/2/2022	15	10/2/2022 – 7/3/2022	26	10/2/2022 – 7/3/2022	25
3	19/1/2022- 31/1/2022	12	31/1/2022–23/2/2022	24	13/2/2022 – 7/3/2022	22
4	2/2/2022 – 13/2/2022	11	19/1/2022–10/2/2022	22	13/2/2022 – 7/3/2022	22
5	15/2/2022–28/2/2022	13	31/1/2022–24/2/2022	25	13/2/2022 – 9/3/2022	24
6	15/2/2022–28/2/2022	13	18/2/2022–22/3/2022	34	18/2/2022 – 7/3/2022	17
7	6/2/2022 – 18/2/2022	12	31/1/2022–28/2/2022	29	13/2/2022 – 3/3/2022	18
8	19/1/2022–31/1/2022	12	5/1/2022 – 31/1/2022	26	13/2/2022 – 3/3/2022	18
9	18/2/2022–28/2/2022	10	31/1/2022–28/2/2022	29	10/2/2022 – 7/3/2022	25
10	16/2/2022–28/2/2022	12	17/1/2022–10/2/2022	24	13/2/2022 – 9/3/2022	24
	Mean	12.70	Mean	26.60	Mean	22
	Standard Error	0.63	Standard Error	1.07	Standard Error	1.01
	Standard Deviation	2.00	Standard Deviation	3.40	Standard Deviation	3.19
	Coefficient of Variance	4.01	Coefficient of Variance	11.60	Coefficient of Variance	10.22

8. Duration from the appearance of stigma to fruit set

The data presented in table 8 shows the duration required to fruit set from stigma appearance on the female spike of jackfruit (*Artocarpus heterophyllus* Lam.) var Konkan Prolific. The days required for fruit set from stigma receptivity ranged from 24 to 31 with a mean of 28.4 days. The variation in the fruit set of jackfruit from stigma appearance might be due to the variation in the environmental conditions and positions of flowers on the plant. Similar results were found by Ullah and Haque (2008) [14] in jackfruit.

Table 8: The duration required to fruit set from stigma appearance on the female spike of jackfruit (*Artocarpus heterophyllus* Lam.) var Konkan Prolific

Sample no.	Period	Days
1	31/1/2022 - 27/2/2022	28
2	28/2/2022 - 28/3/2022	29
3	10/2/2022 - 13/3/2022	31
4	13/2/2022 - 13/3/2022	28
5	27/12/2021 - 19/1/2022	24
6	28/2/2022 - 28/3/2022	29
7	13/2/2022 - 13/3/2022	28
8	28/2/2022 - 28/3/2022	29
9	3/3/2022 - 2/4/2022	29
10	10/2/2022 - 9/3/2022	27
Mean		28.20
Standard Error		0.57
Standard Deviation		1.81
Coefficient of Variance		3.28

9. Fruit setting position of jackfruit on plant

The data presented in table 9 indicates the fruit setting positions of jackfruit (*Artocarpus heterophyllus* Lam.) var Konkan Prolific. The maximum number of fruit set on primary branches of jackfruit trees with a mean of 10.06 set fruits from the total mean of 20.13 set fruit. The variation in fruit setting positions of jackfruit might be due to the environmental conditions during the season. Similar results were found by Ullah and Haque (2008) [14] in jackfruit.

Table 9: The fruit setting positions of jackfruit (*Artocarpus heterophyllus* Lam.) var Konkan Prolific.

Tree	On trunk	Primary branch	Secondary branch	Tertiary branch	Total
1st row 3rd tree	2	8	7	2	19
1st-row 4th tree	2	15	6	2	25
1st row 5th tree	-	7	3	1	11
2nd row 2nd tree	3	18	13	9	43
2nd row 3rd tree	-	7	2	3	12
3rd row 1st tree	5	9	3	2	19
3rd row 2nd tree	-	8	6	1	15
4th row 2nd tree	2	6	5	3	16
5th row 1st tree	1	15	4	3	23
5th row 2nd tree	2	4	2	1	9
5th row 3rd tree	-	6	6	-	12

5th-row 4th tree	-	19	17	7	43
6th row 3rd tree	-	4	2	-	6
6th-row 4th tree	-	3	-	1	4
7th-row 4th tree	-	22	18	5	45
Mean	1.13	10.06	6.26	2.66	20.13
Standard Deviation	1.50	6.08	5.48	2.55	13.47
Coefficient of Variance	2.26	37.06	30.06	6.52	181.50

Conclusion

The results of the present study have provided some basic information on the floral biology and fruit development in jackfruit (*Artocarpus heterophyllus* Lam.) var Konkan prolific. Under Dapoli conditions, the flowering season of jackfruit (var Konkan Prolific) starts from 23 October 2021 to 2 June 2022. The average days required for male and female floral bud development were 47.7 and 63 days respectively. Stigmas on the female spike required an average of 26.60 days for fertilization and the average days for the fruit set noted was 28.20. There was variation in different aspects of the variety which might be due to the tree age, positions of flowers and fruits on the plant and agroclimatic conditions of the region.

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