Content list available at http://epubs.icar.org.in, www.kiran.nic.in; ISSN: 0970-6429

Indian Journal of Hill Farming

June 2023, Volume 36, Issue 1, Page 01-06

Preliminary studies on the anomalous reproductive behaviours of Jackfruit (*Artocarpus heterophyllus* Lam.)

Heiplanmi Rymbai* • S.R. Assumi • H.D. Talang • V.K. Verma • Vanlalruati • D. Rymbai • M. Bilashini Devi • R.K. Akoijam • K.P. Biam • S. Hazarika

ICAR Research Complex for NEH Region, Umiam, Meghalaya – 793103

ARTICLE INFO

Article history:
Received: 31 August 2022
Revision: 13 January, 2023
Accepted: 19 January, 2023

Key words: *Artocarpus heterophyllus, Jackfruit, malformation, abnormality, economics*

DOI: 10.56678/iahf-2023.36.01.1

ABSTRACT

Jackfruit (*Artocarpus heterophyllus* Lam.) is an important fruit crop of the tropics and subtropics of Southeast Asia. A wide morphological diversity of jackfruit was observed in Meghalaya; however, it is still considered an underutilised fruit and its commercial cultivation is at a primitive stage. During an exploratory survey for the collection and evaluation of jackfruit germplasm, a unique abnormality in flowers and fruits was noted. Therefore, this study was aimed at understanding the anomalous reproductive behaviour of jackfruit. The results showed that the malformed sorosis appears stunted, compact, overcrowded, and light green in color. Furthermore, the fruits appeared to have developed separately, not as sorosis. The abnormalities are rare, but they had an adverse impact on yield (unaffected *vs.* affected trees) that was evidenced in surveyed villages, *i.e.*, Moobakhoon (81.02 *vs.* 51.33 number of fruits per tree) and Silkigre (63.67 *vs.* 44.25 number of fruits per tree). The extent of abnormality in the fruit (or flower) varied, from 20.55–37.78% in Moobakhoon to 15.15–47.37% in Silkigre. Trees free of such anomalies could generate an average economic return of Rs. 3240/- per tree; however, this was reduced to 66% (Rs. 1110/- per tree) in the case of affected trees. Though the cause of anomalous productive behaviour is not yet clearly understood, it may be due to improper pollination, developmental irregularities, insect-pest attacks, disease incidence, nutritional disorders, and hormonal imbalance. It is expected that the adoption of integrated management strategies may emerge as an effective solution to control these problems in jackfruit.

1. Introduction

Jackfruit (*Artocarpus heterophyllus* Lam., also known by its synonym, *Artocarpus integrifolia* L.) belongs to the family Moraceae. It is vernacularly referred to as Sohphan (*Khasi*), Sachram (Pnar), and Tebrong (Garo) in the state of Meghalaya. It is the largest and most recognised edible fruit-bearing tree that grows favourably in the tropics and subtropics of Southeast Asia. The Indo-Malayan region is considered to be the origin of this species (Barrau, 1976), specifically in the rainforest of the Western Ghats, India (Purseglove, 1968), and in Malaysia (Hensleigh and Holaway, 1988). The fruit species were then distributed to India, Bangladesh, Myanmar, Malaysia, Nepal, Thailand, Vietnam, China, the Philippines, Indonesia, and Sri Lanka. In addition, jackfruit is also found in Latin American, Caribbean nations such as Jamaica and East African countries including Uganda, Tanzania, and Mauritius. It is a rich source of carbohydrates, protein, potassium, calcium, and vitamins. The fruits are also known to possess antioxidants and medicinal properties. Therefore, it is called "poor man's food" in the Southeast Asia region (Swami et al., 2012). In Sri Lanka, due to its high carbohydrate content, the fruit is called "rice tree." In Meghalaya, jackfruit is a very dominant summer fruit crop and is growing abundantly in the low to mid-altitude of the tropical and warm subtropical parts. Almost all the standing trees of jackfruit are of seedling origin. The tender fruits arrived in the market during spring, i.e., March, for vegetable purposes and remain there until summer (August) as mature fruits for table purposes. However, ripened fruits are abundantly available during June-July. The market is largely

*Corresponding author: rymbaihort@gmail.com

dominated by soft-flesh varieties, although sometimes they may be fibrous. Similarly, a wide diversity of jackfruit was observed in Meghalaya in terms of tree traits such as growth habit, shape, and leaf traits, and fruit traits including maturity, morphology (shape, size, spine character), and quality (latex behaviors, flake dimension, flake color, flake texture, sweetness, and taste). The consumption pattern of fruit was determined by stages of maturity; ripened fruits are used as dessert fruits, while immature fruits are used as vegetables. It is also used for fodder, timber, fuel, and medicinal and industrial products. In the ripe fruit, the fleshy aril (or flake) is the edible part, but the seeds are also edible after being boiled or used for pickle preparation. Despite having enormous potential for commercial cultivation of jackfruit, however, it is still considered an underutilised fruit crop, and its commercial adoption is still at a primitive stage. The main reason is the non-availability of quality planting materials and improved varieties. Therefore, the fruit trees are observed to be cultivated as semi-wild in the backyard garden, along the roadside, as border trees in orchards, as shade trees, etc. Furthermore, authors observed the occurrence of diseases such as soft rot of fruit, leaf spot, and jackfruit disorder; however, no systematic study has been conducted so far to resolve these issues under the prevailing climatic conditions of northeast India. In view of the limited availability of information on the scientific cultivation of jackfruit in Meghalaya, a preliminary assessment was made to understand the magnitude of the occurrence of abnormalities in the flowers and fruits of jackfruit under the prevailing climate of the state.

2. Material and methods

A survey was conducted during March–June, 2020–21, in 15 villages across three districts (West Jaintia Hills, Ri-Bhoi, and South Garo Hills), Meghalaya, to assess the occurrence of any peculiarity or abnormality in the flower and fruits of jackfruit. The abnormal flowers and fruits were found in trees aged 10 to 30 years and collected from the villages for observation at the Horticulture laboratory of the Institute. Interaction meetings with growers were organised in the villages to understand the farmers' perceptions of the problems. Observations were recorded for fruit yield, number of fruits per tree, % abnormality in flowers and fruits (number of malformed flowers or fruits divided by the total number of fruits or flowers obtained x 100), and net returns (gross returns – expenditure during the year). Gross returns were calculated by multiplying the number of marketable fruits per tree by the price of fruit in the local market (Rs. 35–60 per fruit), and total expenditure was calculated by adding labour costs for weeding and harvesting, as revealed by farmers, and transportation costs for fruits to market. The data on different parameters were analysed using analysis of variance (ANOVA) by employing SPSS version 26.0. Valid conclusions were drawn only on the basis of significant differences among the means of genotypes across locations (both infected and non-infected) at 0.05 level of probability.

3. Result and discussion

According to a survey and interactions, one of the newly emerging constraints for jackfruit production in the state of Meghalaya is the malformation of flowers and fruits. The malformation of flowers and fruits in jackfruit resembles the malformation in mango as shown in plate 1. It was observed that the affected inflorescences usually do not set fruit or, in the case of fruit setting, abort fruit shortly after they have set. The affected inflorescence appears stunted. When the infection starts at the fruit setting stage, the fruit setting may take place irregularly; however, the sorosis appears compact and overcrowded with a light green color. Furthermore, the fruits appeared to have developed separately, not as sorosis. The stunted, crowded, and compact symptoms may be similar to mango malformation (Rymbai and Rajesh, 2011), however, the pathological and nutritional aspects are yet to be ascertained. The occurrence of abnormal fruits and flowers was observed in Moobakhoon village of Jaintia Hills (25°38'37' N & 92°17'22' E, altitude 1041 m amsl) and Silkigre of Garo Hills, Meghalaya (25°15'31' N & 90°28'40' E, altitude 58 amsl). The period of such occurrence was observed during April-June. A significant difference in the yield loss and net return among the locations was noted (Table 1). The highest fruit yield was obtained in un-affected trees in both the locations (Moobakhoon, 81.00 number of fruits per tree; Silkigre, 63.67 number of fruits per tree), while the minimum yield was recorded in affected trees (51.33 number of fruits per tree in Moobakhoon; 44.25 number of fruits per tree in Silkigre). The malformation of flowers and fruits was recorded at 20.55–37.78% in Moobakhoon and at 15.15–47.37% in Silkigre. The economics of production were highest in unaffected trees (Rs. 3240.0/- per tree) at Moobakhoon and the lowest in affected trees at Silkigre (Rs. 1110.0/- per tree). This is because of the reduction in the number of marketable fruits and the poor consumer preference for the affected fruits.

The causes of the malformation of flowers and fruits are not yet clearly understood. Improper pollination, developmental irregularities, insect pests, weather fluctuations, and nutrient and hormone imbalances are all possible causes.

Improper pollination: Jackfruit is a monoecious species, producing separate female and male inflorescences on the same individual (Pushpakumara, 2006/2007). The plant bears male spikes in the periphery with non-synchronised anthesis periods. In the same plant, the periods of emergence of male and female spikes are different (Haque and Majumder, 2006).

This may lead to the possibility of improper pollination. An improperly pollinated flower resulted in no fruit setting or underdeveloped fruit, small fruit size, and irregular fruit shape. Furthermore, an unfertilized flower also leads to the development of malformed flowers and irregular fruit shapes (Sharma, 1964). Therefore, a deeper understanding of the malformation is essential for its proper management.

Developmental irregularities: The production of syncarp without pollination (Pushpakumara, 2006/2007) may also be the reason for the abnormal structure of the female inflorescence in jackfruit, besides other factors controlling flower and fruit malformation. Therefore, detailed anatomical and physiological studies are needed to establish a possible reason for malformation.

Insect-pests: Pathogen-infected jackfruit inflorescences have been reported to be abscised (Pushpakumara, 2006/2007). However, because of the infestation of insects on female inflorescences, few insect-attacked inflorescences develop into syncarps. Therefore, there is a possibility that these developed syncarps in the subsequent stage of development, become malformed.

Weather fluctuation: Our results showed that the symptoms appeared prominently during April–June, a period where temperatures and relative humidity shoot up, as indicated in figures 1 (1a & 2b). In addition, rainfall in the area of study also rises from 29.7–75.4 mm during March to 57.7–223.5 mm, 309.1–578 mm, and 432.3–463.5 mm during April, May, and June, respectively [Fig. 1 (1a&2a)]. Although regression analysis (r^2) showed a non-significant but positive relationship between malformation and weather parameters (Figure 2). However, the influence of weather factors on the occurrence of malformation in flowers and fruits cannot be ruled out. It has been reported that prolonged rainfall and high humidity affect the dehiscence of the anthers, causing them to drop completely from the spike (Pushpakumara, 2006/2007). While, during dry days, pollen is shed rapidly from the anthers, and thus clouds of pollen are produced by small physical disturbances, during wet days pollen is not easily shed from open anthers (Sambamurthi and Ramalingam, 1954).

Imbalance nutrient and hormones: The acidic soil may have imposed several nutritional limitations and stresses on the plants. Soil acidity induces an imbalance in the nutrition required for optimum plant growth. Aluminium and iron toxicity and the deficiency of basic cations (Ca, Mg, K) in the acidic soils of Meghalaya may be a few of the major constraints in targeting a high yield of crops (Sharma et al., 2006). It is well established that Ca^{2+} is a versatile signal and a vital messenger for various rapid cellular processes during responses to a wide range of endogenous and environmental signals. Among Ca^{2+} activating signals, auxin is a good candidate. However, under the constraints of limited calcium availability to the plants, there may be an adverse effect on endogenous hormones such as auxin, leading to hormonal stress (Vanneste and Friml, 2013). Therefore, plants are required to adjust their size, shape, and number of organs for coping and survivability.

Plate 1. Malformation in fruits of jackfruit

Management strategies

Bearing orchard: In order to manage the occurrence of anomalies in jackfruit flower and fruit more effectively, a combination of these approaches would be necessary.

i) Pruning: Jackfruit is a tropical fruit, and pruning is less responsive and rarely practiced. However, pruning strategies such as regular removal of infected parts, weak branches, parasitic plants, and a dense canopy may further improve yield and quality. Pruning of jackfruit plants should be done to the first lateral branches in the second year of their establishment (Crane et al., 2002). This will decelerate the upward growth and enhance the spreading of the canopy. After harvesting, remove the upright vigorous shoots and thin the inner canopy to allow for maximum sunlight penetration and air circulation, thereby reducing insect-pest and disease incidence (Crane et al., 2022). Furthermore, removal of old flowering shoots after harvest improves flowering and fruiting, while retention of only two fruits per footstalk during fruit thinning improves fruit size and quality.

ii) Spray of chemicals: In addition to pruning, a spray of the following compounds may control the malformation: a) Boron may stimulate the flow of hormones and improve pollen grain and pollen tube formation, as well as their elongation. It also increases the stickiness of the stigma when receiving the pollen grains. Thus, application of 15 g of boron per tree along with 10 kg of FYM and N:P:K:S:Zn at 920:200:250:85:20 g per tree per year was found effective for the correction of the deformed shape and size of a jackfruit (Halder et al., 2008). b) Spraying of NAA (200 ppm) before flowering. c) Spraying of Captan/Topson-M (1%) during flower initiation. d) Spraying of Zn (0.3%), Boron (0.3%), and Copper (0.3%) before and after flower initiation. e) Liming (2–5 kg per tree per year) in the tree basin

iii) Integrated management practice: Integrated management practises, viz., incorporation of organic matter into the soil, control of insects and diseases, irrigation management, balanced chemical fertilization, weed control, selection of resistant genotypes, and other cultural practices, may reduce the incidence of such abnormalities.

New plantation: A new plantation should be established with insect- and pathogen-free nursery stock. The procurement of scion materials from affected orchards must be avoided, and the affected plants in the nursery should be culled and destroyed. A jackfruit nursery unit should not be established in or near the affected orchards.

4. Conclusion

Jackfruit is a very common fruit crop in Meghalaya, although it grows naturally as a semi-wild crop in the backyard. However, it has a great potential for commercialization due to its agro-climatic suitability and local preferences for its tastes and processed products. Lately, an incidence of flower and fruit malformation may affect the fruit production in the near future. Therefore, it is necessary to adopt management practises such as pruning practices, ensure proper pollination and fertilization, and adopt an integrated management package to prevent the incidence of flower and fruit malformation in jackfruit.

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Table 1. Fruit yield and economics impact of malformation in jackfruit production

Sites	**Fruit yield (Nos/tree)**	**Malformation (%)**	**Economics of production (Rs.)**
Moobakhoon - Affected	51.33	30.55	1466.67
Moobakhoon - Unaffected	81.02	0.00	3240.00
Silkigre - Affected	44.25	35.15	1110.00
Silkigre - Unaffected	63.67	0.00	2546.67
SE(d)	5.76	n.a.	249.02
C.D. (≥ 0.05)	14.37	n.a.	621.19

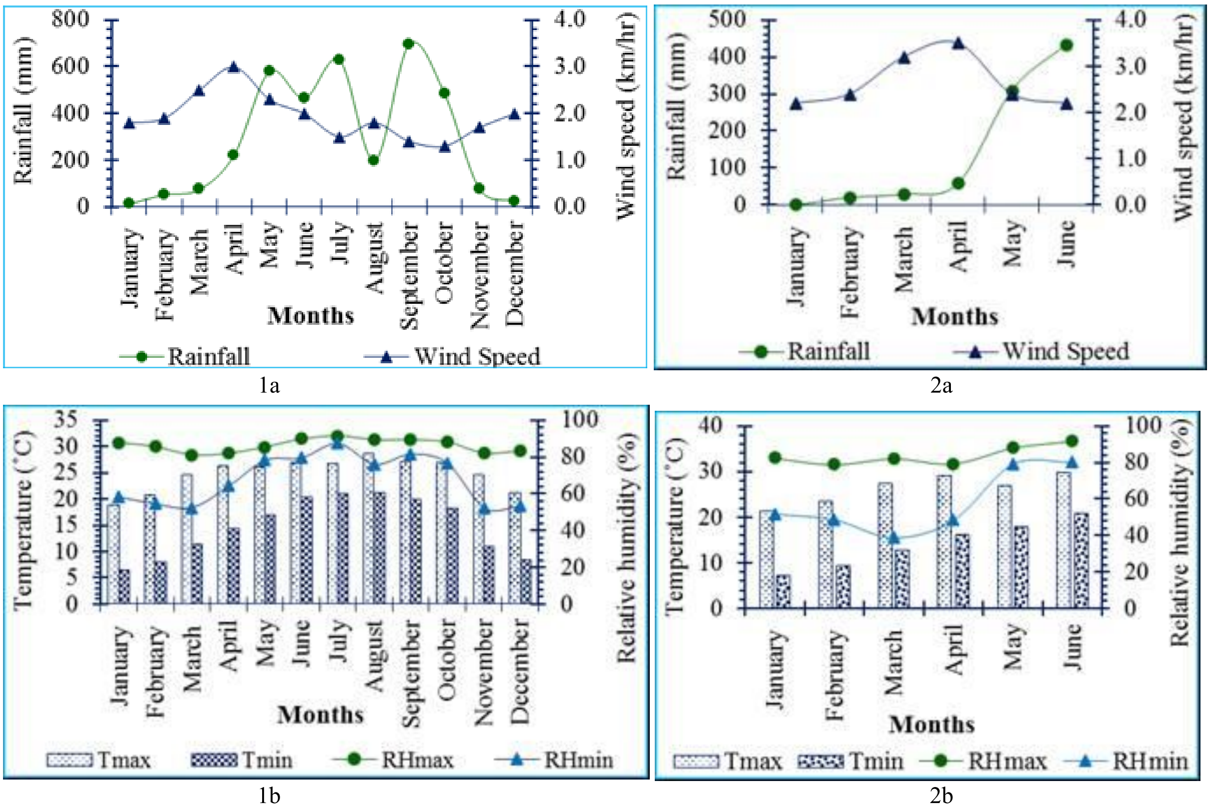

Figure 1. Weather characteristics (1a & 1b – 2020; 2a & 2b – 2021 during study period). Tmax -maximum temperature, Tmin – minimum temperature, RHmax – maximum relative humidity, RHmin – minimum relative humidity

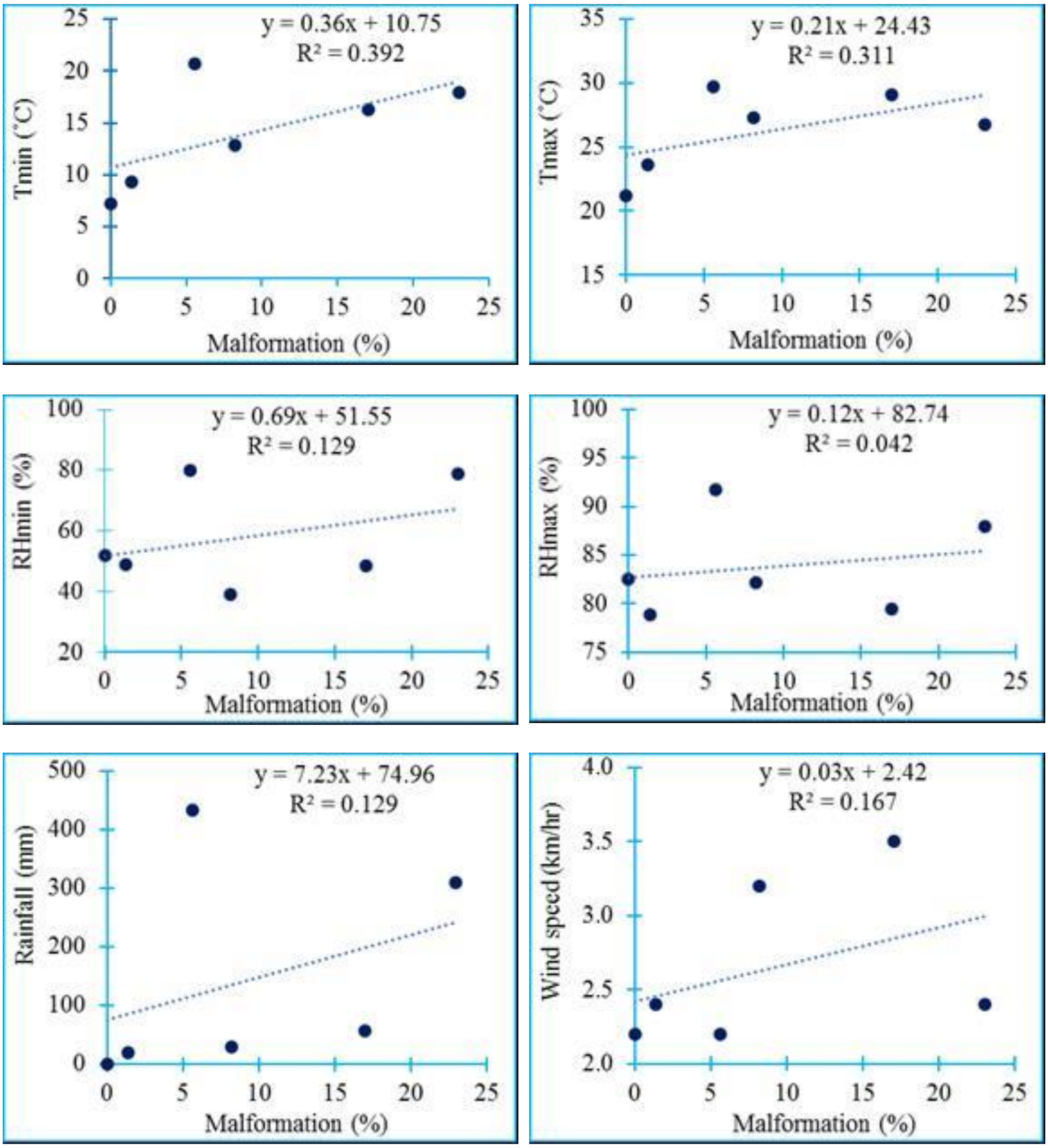

Figure 2. Relationship between occurrence of malformation and weather parameters. Tmax -maximum temperature, Tmin – minimum temperature, RHmax – maximum relative humidity, RHmin – minimum relative humidity