

Full Length Research Paper

## New fruit and seed disorders in Papaya (*Carica papaya* L.) in India

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Systematic field screening was conducted in 14 important papaya germplasm lines to observe the severity of bumpy fruit incidence. The disease severity, fruit yield and economic losses due to physiological disorders were observed. Pune Selection-3 was most sensitive (64.6%) for the disorder while Pusa Selection Red was most tolerant (4.2%). The maximum yield was obtained in Pune Selection-3 (62 kg/plant) while lowest yield in Mokama Local (20 kg/plant). The lowest market acceptability and highest economic loss were also observed in Pune Selection-3 (Rs. 3.3/kg and 11, 21,580/ha, respectively) due to highest incidence of bumpy fruit disorder as compared to other germplasm. The highest frequency of deformed seeds/fruit (83.6%) and economic loss (Rs. 84,400/ha) under fruit production for market was noticed during February, while the lowest deformed seeds/fruit (2.7%) were observed during December. The maximum incidence of vivipary and white seed disorders were observed during May (13.4 and 75.7%, respectively) while least incidence was observed in February and March (10 and 5%, respectively). The increased incidence of vivipary was observed in harvested fruits from February to May with increasing average monthly temperature. The low and high temperatures during seed maturation period aggravate deformed and vivipary seeds, respectively.

**Key words:** *Carica papaya*, physiological disorders, bumpy, vivipary, white seeds.

### INTRODUCTION

Papaya (*Carica papaya* L.) belongs to the family Caricaceae, one of the most important fruits cultivated throughout the tropical and subtropical regions of the world (Anonymous, 2000). The natural habitat of papaya lies in tropical, central and South America. Papaya flourishes in the frost-free and humid areas of the tropics and subtropics. It is regarded as an excellent source of ascorbic acid, a good source of carotene, riboflavin and a fair source of iron, calcium, thiamin, niacin, pantothenic acid, vitamin B-6 and vitamin K. Each and every part of papaya plant from root to shoot is used for medicament purposes. Seeds are also rich source of amino acids; scented oil was extracted, used in treatment of sickle cell disease and poisoning related disorders (Saran and Choudhary, 2013). The challenges that Indian Agriculture

faces in the coming years remain enormous. Ensuring food and nutritional security and eliminating hunger, including hidden hunger, remain a high national priority. In order to effectively counter this demand, this crop will play an even more critical role in determining the productivity and food security. Papaya has gained more importance owing to its high palatability, early fruiting and highest productivity per unit area and multifarious uses like food, medicine and industrial input. It is cultivated in the world in an area of 3.83 lakh ha with a production of 8.05 million tones. In India, it is cultivated in 73,000 ha with a production of 23.17 lakh tones (Singh et al., 2010). The seed production in papaya with 100% genetic purity is difficult because of dioecious nature of the plant. Therefore, the seed should be produced either strictly

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under controlled condition or in an isolated area.

Under diverse agro-climatic conditions of North Bihar, the autumn sown crop is best suited for seed production (Ram and Ray, 1992; Singh et al., 2010). Quality seed production, market value and export of papaya fruit suffer from several limiting factors including physiological disorders. Different nutrient deficiencies of boron, zinc and sulphur and environmental stresses cause several physiological disorders such as bumpy fruit which may lead to deformed/discolored seeds. Bumpy fruit, deformed / discolored seeds, vivipary seeds (Saha, 2007; Saran et al., 2013a) and white seeds (disturbed sarcotesta) were identified as new physiological disorders of papaya under diverse agro-climatic conditions of India. Deformity first starts in young fruits, but symptoms become more severe over fruits close to physiological ripening or of older age. The bumpiness begins in areas on the fruit epidermis and is due to boron deficiency, stopping the fruit growth (Wang and Ko, 1975; Chen and Raveendranathan, 1984). In addition to this, infected tissue continues increasing in size and ends forming a protuberance or “bump”, similar to a ball. High incidence before maturity has also been a serious concern in papaya production.

During fruit and seed development period, proper temperature also plays important role. Keeping aforementioned facts in mind, the present study was conducted on the varietal screening for bumpiness; morphology and economics of bumpy fruits, deformed/discolored seeds, vivipary and white seeds (disturbed sarcotesta) and relationship between temperature and disorders (deformed seed and vivipary).

## MATERIALS AND METHODS

The investigations were carried out at Indian Agricultural Research Institute Regional Station Pusa, Samastipur, Bihar (India) (elevation 52 m; latitude 25.98°N and longitude 85.67°E). The details of different experiments conducted are given as follows:

### Screening of papaya germplasm

Screening of ten papaya germplasm lines was carried out during 2011 and 2012 for different physiological disorders. The plants selected were of uniform age (14 months). Ten plants of each germplasm line were randomly chosen for observations on bumpy fruit at fruit maturity. Each tree represented a replication and ten times replicated. Four germplasm lines, namely, Pune Selection-3, Pusa Dwarf, Pusa Nanha and Pusa Selection Red were studied for bumpy fruit incidence. Each tree of different selected germplasm was observed carefully and numbers of damaged fruits were recorded at weekly intervals. The values of different observations obtained from these trees were averaged to get the mean value. The bumpy fruit severity was calculated by own formular as given as follows:

$$\text{Disease severity (\%)} = \frac{\text{Disease category scale} \times \text{Number of plants} + \text{Disease category scale} \times \text{Number of plants}}{\text{Higher category scale} \times \text{Total number of plants}} \times 100$$

The observations on fruit yield were recorded to compare the yield of affected and non-affected trees of each germplasm in selected

orchard of uniform age (first crop). The yield of ten normal plants was recorded for estimating average fruit yield (kg/tree). A survey was carried out during the year; 2008 to 2013. The data on rates of fruits/kg was collected for normal and bumpy fruits to work out the market acceptability. The rates of bumpy and normal fruits of papaya were collected from the fruit sellers. The economic loss was calculated by working out the difference between gross return from normal and bumpy fruits as rupees per hectare during study years. An economic loss was estimated by calculating the difference between normal and diseased (bumpy) plants yield per unit area and it was multiplied by the market rate of fruits. The data presented are the pooled mean of two years. The statistical analysis of the data was carried out using standard statistical procedures.

### Studies on morphological and quantitative traits

The observations were recorded from December, 2008 to May, 2013. The average monthly temperature was recorded from IARI RS Pusa observatory. Morphological observations were recorded for fruit surface, seed attachment, seed color, seed surface, sarcotesta, removal of sarcotesta and vivipary in both varieties namely, Pusa Dwarf and Pune Selection-3. The fruits of Pusa Dwarf were observed with vivipary and morphological observation for fruit surface, seed attachment, seed color, seed surface, seed size, sarcotesta and removal of sarcotesta during fruit harvesting (initiation of colour turning stage) and seed extraction. The data were also recorded on the total number of seeds/fruit, number of normal seeds/fruit, number of deformed seeds/fruit, white seeds/fruit, vivipary seeds/fruit, deformed seeds (%), seed harvest (%) and economic losses (Rs/ha) in Pusa Dwarf at seed crop harvesting (December to May) due to deformed seed disorder in autumn crop. Each fruit was cut into two equal halves for observing the incidence. The deformed/discolored seeds were recorded by counting the seeds in different categories. An economic loss was estimated by calculating the seed yield per unit area in kilograms.

Loss was estimated by observing seed harvest (normal and deformed percent) in particular months and multiplied by our sale price (at Rs. 40,000/kg). Relationship between average monthly temperatures, time of fruit harvest and seed disorders, namely, deformed seed and vivipary seeds from December to May were shown during the study years.

## RESULTS

### Field screening of papaya cultivars

The field screening results had divulged that among all the selected germplasm, the bumpy fruit was significantly higher in Pune Selection-3 (64.6%), Pune Selection-2 (45.6%) and Pune Selection-1 (41.7%) followed by Co-7 (35.2%) and Pusa Dwarf (25%) while Pusa Selection Red (4.2%) was least affected. The maximum yield was obtained in Pune Selection-3 (62 kg/plant) followed by Pusa Selection Red (57.8 kg/plant), while lowest in Mokama Local (20 kg/plant) and Co-2 (22 kg/plant). The lowest market acceptability and highest economic losses were also observed in Pune Selection-3 (Rs 3.3/kg and Rs11, 21,580/ha), respectively due to highest incidence of bumpy fruit disorder as compare to other germplasm (Table 1).

**Table 1.** Screening of different papaya germplasm lines.

Papaya germplasm	Bumpy fruit disease severity (%)	Fruit yield/plant (kg/tree)	Market acceptability (Rs/kg)		Economic loss (Rs/h)
			Normal	Abnormal	
Pusa Dwarf	25.0	41.0	8.3	5.1	3,54,240
Pusa Nanha	05.5	34.0	8.1	7.9	13,770
Pusa Delectious	11.0	44.0	8.1	6.2	2,25,720
Pusa Majesty	14.5	36.2	8.8	7.3	1,46,550
Pune Selection -1	41.7	54.0	10.0	7.1	4,22,820
Pune Selection -2	45.6	56.0	9.2	5.0	6,35,040
Pune Selection -3	64.6	62.0	10.0	3.3	1,121,580
Co-2	18.2	22.0	7.9	6.8	65,340
Co-6	25.0	40.0	8.7	7.2	1,62,000
Co-7	35.2	25.0	7.0	5.2	1,21,500
Pusa Selection Red	04.2	57.8	8.7	8.1	93,660
Pusa Papaya 2-8	09.1	43.0	10.0	7.5	2,90,250
Pusa Papaya Selection 1-11	07.4	41.0	9.7	9.0	77,490
Mokama Local	11.1	20.0	8.9	6.9	1,08,000
C.D. (P = 0.05)	1.9	8.4	1.6	1.3	8,988

**Table 2.** Morphological traits of normal and bumpy fruits in both 'Pune Selection-3' and 'Pusa Dwarf'.

Trait	Normal fruit	Bumpy fruit
Fruit surface	Smooth	Rough
Seed attachment	Loose	Tight
Seed color	Black	Brownish
Seed surface	Smooth	Rough
Sarcotesta	Shining	Disturbed
Removal of sarcotesta	Easily-removable	Non-removable
Deformed seeds	None	Almost

### Studies on morphological traits

There were visual differences in normal and bumpy fruits and seeds of Pune Selection-3 and Pusa Dwarf. Morphological observations of fruit and seed, namely, fruit surface, seed attachment, seed color, seed surface, sarcotesta, removal of sarcotesta and vivipary in normal fruit were smooth, loose, black, smooth, shining, easily removable and none while rough, tight, brownish, rough, disturbed, non-removable and almost in bumpy fruits, respectively, were observed in both cultivars (Table 2, Figures 1 and 2). The highest frequency of deformed seeds/fruit (83.6%) and economic loss (Rs. 84,400/ha) were recorded and noticed during February, whereas the lowest frequency of deformed seeds/fruit (2.7%) were observed during December. The lowest economic loss (Rs. 5,200/ha) was noticed in April (Table 3). A positive relationship between average monthly minimum temperature and deformed seeds (%) was observed from December to May during the years from 2008 to 2009 to 2013. The

increased incidence of deformed seeds was observed from December to February and decreased onward months harvested fruits with decreased and increase average monthly minimum temperature, respectively during study period. The maximum incidence was observed during February due to lower temperature during January which is seed maturity period for February harvest (Figure 3).

The vivipary fruits were also rough surfaced, while the normal fruits were smooth surfaced. The visual observations for vivipary were tight seed attachment, white seed color, rough seed surface, smaller size, disturbed sarcotesta and no need of removal of sarcotesta for seed germination, while just reverse of it was observed in case of normal seeds (Table 4 and Figure 4). Vivipary and white seeds (disturbed sarcotesta) are a serious economic problem only in Pusa Dwarf and the severity of damage varies with the harvesting/fruit maturity months. For vivipary and white seed disorders, the highest incidence were observed during May (13.4 and 75.7%, respectively), followed by April (8.1 and 66.3%, respectively), March (1.1 and 34.6%, respectively), and the lowest incidence was observed in February (0.0 and 10.0%, respectively). The maximum economic loss (Rs. 53,600/ha) was observed in April, while least during February (Rs. 16,800/ha) in autumn sown crop of Pusa Dwarf (Table 5). The higher incidence of these seed disorders during May harvested fruits might have got aggravated due to high temperature during seed maturation period. Positive relationship between average monthly maximum temperature and vivipary (%) was observed from December, 2008 to May, 2013. The incidence of vivipary was observed increased from February to May harvested fruits with increased average monthly maximum temperature during



Figure 1. Bumpy fruits of papaya.



Figure 2. Deformed and normal seeds in papaya cultivar, 'Pune Selection-3'.

Table 3. Average incidence and economic loss due to deformed seed disorder in autumn sown papaya cultivar, Pusa Dwarf during 2011 and 2012.

Month of harvest	Total number of seeds/fruit	Number of healthy seeds/fruit	Number of deformed seeds/fruit	Deformed seeds/fruit (%)	Economic loss (Rs/ha)
December	318.8	312.2	8.6	2.7	58,400.00
January	658.6	374.1	284.5	43.2	62,400.00
February	638.4	103.2	535.2	83.6	84,400.00
March	549.2	419.8	129.4	22.0	16,000.00
April	514	456.6	58.8	12.1	5,200.00
C.D. (P = 0.05)	31.653	4.646	25.369	2.7	1,466.18

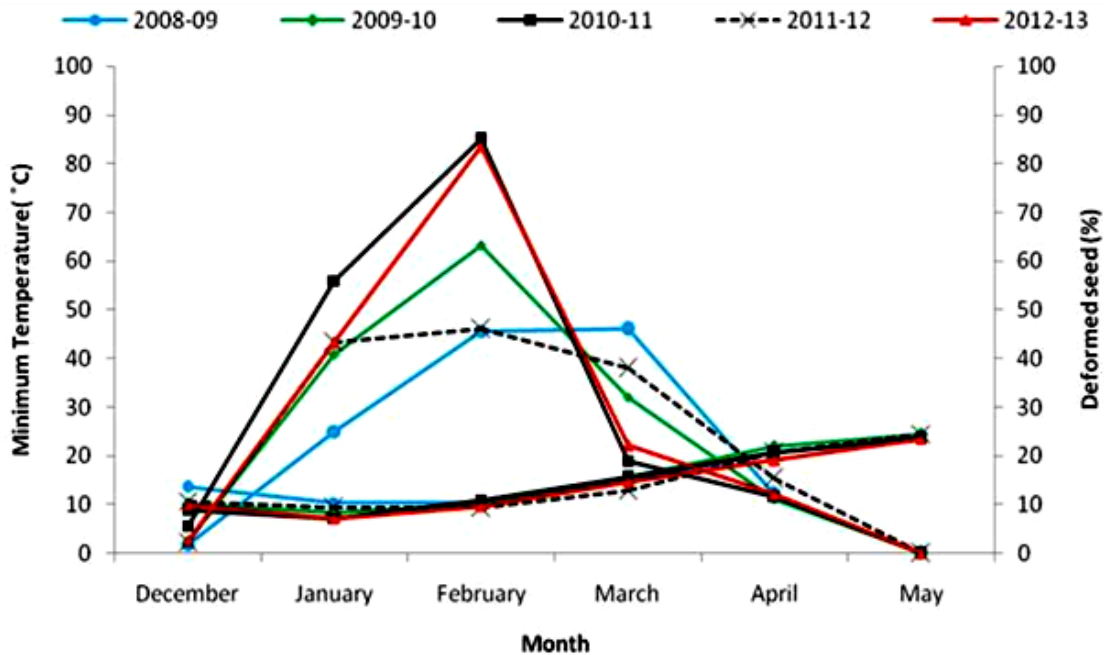


Figure 3. Relationship between average monthly minimum temperature and deformed seed (%).

Table 4. Morphological description of vivipary fruits of papaya cultivar, 'Pusa Dwarf'.

Observation	Normal fruit	Vivipary fruit
Fruit surface	Smooth	Rough
Seed attachment	Loose	Tight
Seed color	Black	White
Seed surface	Smooth	Rough
Seed size	Large	Small
Sarcotesta	Shining	Disturbed
Removal of sarcotesta	Easily-removable	Broken sarcotesta

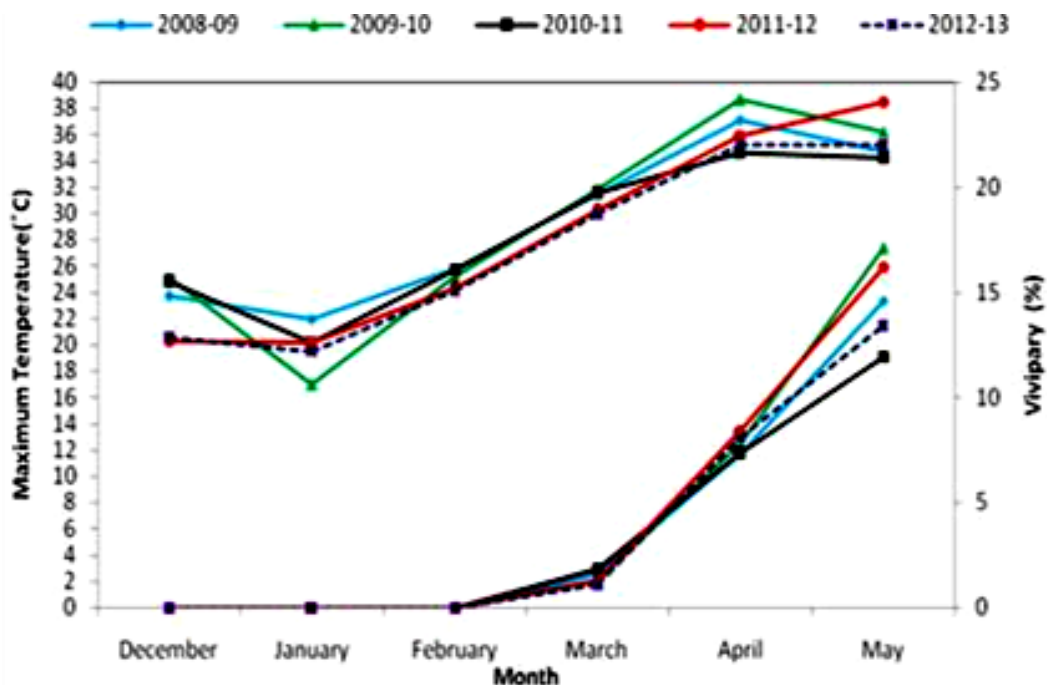


Figure 4. Normal, white and vivipary seeds in papaya cultivar, 'Pusa Dwarf'.



**Table 5.** Average incidence and economic loss due to vivipary and white seeds disorder (disturbed sarcotesta) in autumn sown papaya cultivar, 'Pusa Dwarf' during 2011 and 2012.

Month of harvest	Normal seeds (%)	Vivipary seeds (%)	White seeds (%)	Economic loss (Rs./ha)
February	90.0	0.0	10.0	16,800.00
March	64.4	1.1	34.6	42,800.00
April	25.7	8.1	66.3	53,600.00
May	11.0	13.4	75.7	21,600.00
C.D. (P = 0.05)	9.3	1.4	4.5	481.00



**Figure 5.** Relationship between average monthly maximum temperature and vivipary (%).

study period (Figure 5).

## DISCUSSION

Ram and Ray (1992) reported fruit yield in different papaya cultivars under agroclimatic conditions of North Bihar in autumn sown crop. Screening of different papaya varieties have been carried out against expression of boron deficiency symptoms by different workers (Wang and Ko, 1975; Chen and Raveendranathan, 1984) and fruit deformity has been found associated with boron deficiency. Visual differences in normal and bumpy fruits and seeds of Pune Selection-3 and Pusa Dwarf were observed. Similarly, the bumpy surface on the fruit epidermis at fruit maturity stage was also reported (Chen and Raveendranathan, 1984). The stress associated with bumpy fruits may aggravate deformed seed incidence in Pune Selection 3. Fruit and seed disorders in papaya cause high economic losses in seed production during

autumn-sown crop (Saran et al., 2013a). The economics of Pusa Dwarf seed production and seed yield has already been reported (Ram and Majumder, 1990; Sing et al., 2010). Similarly, the economic loss was maximum in April and least in February in autumn-sown crop of 'Pusa Dwarf' under seed production at North Eastern Plains Zone of India (Saran et al., 2013b). Under normal conditions, the seed yields are 60 to 75 kg/ha in dioecious varieties. The high incidence of deformed seeds in Pusa Dwarf may be due to lower temperature during seed maturation period (January) in autumn sown crop. The stress associated with bumpy fruits may aggravate the incidence in Pusa Dwarf. The natural occurrence of precocious germination has been reported in papaya (Balakrishnan et al., 1986). These observations have revealed that the temperature during seed maturation period play an important role.

The low and high temperatures during seed maturation period aggravate deformed and vivipary seeds, respectively.

## Conclusions

Fruit and seed disorders in papaya cause great economic losses in seed production during autumn sown crop. We observed that Pune Selection-3 and Pusa Dwarf were the most susceptible germplasm lines for bumpy fruit and deformed seed disorders, while vivipary and white seeds (disturbed sarcotesta) are a serious economic problem only in Pusa Dwarf. The incidence of deformed seeds was increased from December to February and decreased onward months harvested fruits and incidence of vivipary was increased from February to May harvested fruits with maximum temperature.

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