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Field establishment of the mealy bug, *Rhizoecus amorphophalli* infested tubers of elephant foot yam, *Amorphophallus paeoniifolius*

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ABSTRACT
Elephant foot yam, *Amorphophallus paeoniifolius* is a popular tuber crop with high production potential. Corm or tuber is the storage organ and on harvest it is used as seed material or as vegetable. Storing the tubers for a longer period attracts several pests. Mealy bug, *Rhizoecus amorphophalli* is a noxious pest affecting the quality of tubers. Present study aims to check the field establishment of mealy bug infested tubers and analyze the quality of harvested tubers. Fully and partially infested as well as uninfested tubers of elephant foot yam were planted according to standard measures. Results showed that plants established from all categories of seed materials showed normal growth and vigor. Even though harvested tubers from all categories were completely devoid of mealy bug infestation, uninfested batch produced more yield. But, there was no marked variation in the quality parameters among harvested tubers of all categories.

Keywords: *Amorphophallus paeoniifolius*, Field establishment, Infestation, *Rhizoecus amorphophalli*, Tubers, Yield

1. Introduction

Tuber crops, a group of versatile crops cultivated in the tropical and subtropical countries, play a vital role in food security [1], and are the important staple or subsidiary food for one fifth of the world population. *Amorphophallus paeoniifolius* (Dennst.) Nicolson, commonly known as elephant foot yam (EFY), is a herbaceous, perennial, C_3 crop [2] of Southeast Asian origin and owing to the indisputable palatability, cooking quality, medical utility and therapeutic values of its tubers, it has been dubbed as “King of tubers” [3]. By attaining the status of cash crop in India, EFY has been traditionally cultivated in West Bengal, Andhra Pradesh, Tamil Nadu, Gujarat, Kerala, Bihar and Jharkhand. Production potential of EFY varies from 50-80 t/ha [4] in accordance with the improved cultural practices and quality planting materials ensuring high return to a tune of Rs. 140,000-175,000/ha [5].

On harvest, tubers are either marketed or stored as the seed material for next planting season. Infestation by a spectrum of insect pests at the time of storage is an emerging problem concerned with this tuber, as it causes qualitative and quantitative loss to the tubers. Two species of mealy bugs *viz*. *Pseudococcus longispinus* Targioni-Tozzetti and *Rhizoecus* sp., were previously recorded from EFY tubers [6]. During the last two decades, the mealy bug, *Rhizoecus amorphophalli* Betrem has emerged as a noxious pest infesting on stored EFY tubers [7, 8]. *R. amorphophalli* sucks cell sap from the tubers, and the severely infested deformed tubers find no place in market, nor are accepted for cooking. Mealy bug multiplication is rapid during the season with high temperature and less humidity and they spread all over the tubers with white powdery mealy substance disfiguring them [9].

Infestation of white scale insect, *Aspidiella hartii* Cockerell on tubers of major aroids perpetuates through seed tubers and affects the quality of harvested tubers [10]. Literature survey revealed that exhaustive work on mealy bugs of field crops has been documented, but reports are scanty on *R. amorphophalli*, despite the fact that it is a major pest on EFY tubers. The present study aims to study field establishment of mealy bug infested tubers and analyze the quality of harvested tubers.

1. Materials and Methods

2.1. Field establishment of mealy bug infested tubers

Tubers of elephant foot yam collected from the storage shed of Central Tuber Crops Research Institute (CTCRI), Sreekariyam were classified based on the intensity of infestation.

Tubers with infestation level below and above 40% were classified as "partially infested" and "fully infested" tubers, respectively. Uninfested tubers were run as control. The tubers were planted in Random Block Design (RBD) with a plot size of 10 × 4 m for each batch. The field management was done as per the package of practices recommended by CTCRI. On field, observation on the sprouting, plant height, girth and canopy spread was recorded at monthly intervals and the yield parameters were noted at harvest.

2.2. Biochemical analysis

Moisture content and other biochemical tests including starch, sugar, fibre and ash content of harvested tubers from all the three categories were done.

2.3. Moisture

Moisture content (MC) of the sample was measured on fresh weight basis by drying 10 g of the sample in a hot air oven at 105°C till constant weight was reached. It was calculated as the ratio of the weight of moisture evaporated to the initial weight of the sample and expressed as %.

2.4. Preparation of flour

Tubers after peeling were washed thoroughly in water to remove dirt and adhering impurities and sliced to 2-3 mm thickness and dried at 50°C. The dried sample was powdered using laboratory grinder (Cyclotech 1093 sample mill), and the flour was packed in polythene covers for biochemical analysis.

2.5. Starch and sugar estimation

One gram of flour sample was mixed with 20 ml of 80% ethanol and kept overnight. It was filtered and to the filtrate 1 ml of concentrated HCl was added and kept for hydrolysis on a hot plate. The solution was made up to 25 ml and then titrated against a mixture of 5 ml potassium ferricyanide (1%) and 5 ml NaOH (2.5 N) to obtain the value of sugar. The residue was transferred into a conical flask and 20 ml of 2 N HCl was added and hydrolyzed. It was made up to 100 ml and titrated against a mixture of potassium ferricyanide (1%) and NaOH (2.5 N), mixed in the ratio 2:1 and the titer value (T) was observed. Starch and sugar were estimated as given below.

Starch content of flour samples = 90/T

Sugar content of flour samples = 12.5/T

2.6. Fibre

To 5 gram flour taken in a beaker, 200 ml of 1.25% H_2SO_4 was added. After boiling for 30 minutes, it was cooled and filtered using muslin cloth. To the residue collected 200 ml of 1.25% NaOH was added and boiled for 30 minutes. After filtering, the residue was taken in a pre weighed Petri dish and oven-dried at 105°C till the weight remained constant.

2.7. Ash

Flour samples were taken in a pre weighed crucible and the total weight was recorded. It was then placed in the muffle furnace at 500°C for 5 hours and on cooling at room temperature (32 °C) its weight was further taken. Amount of ash was represented as difference in final weight with respect to the weight of sample taken initially (5 g).

2.8. Textural properties of raw tubers

Tubers after peeling and washing were cut into 15 mm cubes using a hand slicer. These were cooked for 30 minutes in a boiling water bath placed with wire mesh baskets to prevent the samples from getting direct contact with the bottom part of the bath. Cooked samples were allowed to cool at room temperature before being analyzed with the texture analyser. Textural properties were determined using a TA HDi food texture analyser (Stable Microsystems, Surrey, UK) with built-in Texture Expert Exceed software.

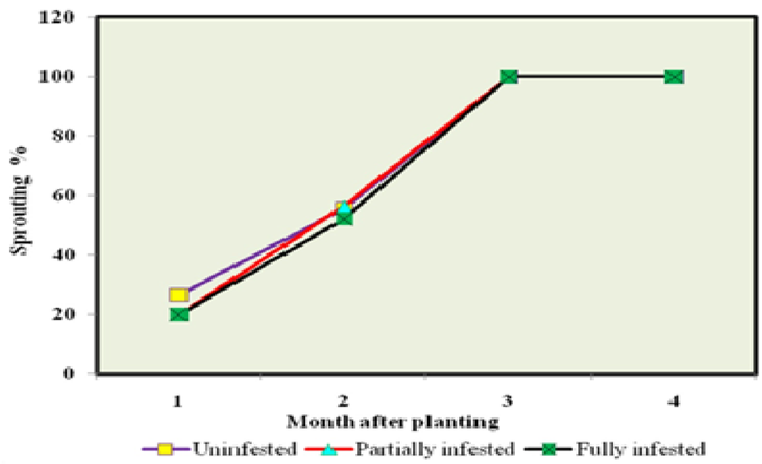
2.9. Textural properties of cooked tubers

Texture profile analysis (TPA) was carried out at a test speed of 2 mm/s for 25% compression with a time lag of 1s. From the TPA curve the following parameters were calculated [11]. Hardness (height of the force peak on the first compression cycle), adhesiveness (negative force area of the first compression), springiness (distance by which a food recovers its height during the time between the end of the first bite and the start of the second bite), cohesiveness (ratio of the positive force areas under the first and second compressions) and chewiness (energy required to masticate a food, being the product of hardness, cohesiveness and springiness).

2.10. Statistical analysis

Statistical analysis was done by analysis of variance (ANOVA) in a random block design and pair-wise comparison was carried out by Duncan's multiple range test (DMRT, p≤0.05) using SPSS 17.0.

Fig. 1: Effect of mealy bug infestation on sprouting of elephant foot yam tube



3. Results and Discussion

3.1. Sprouting and phenology

Sprouting percentage of the planted tubers is shown in Fig. 1. First month after planting, sprouting was 26.66% in the uninfested batch, whereas lower in the partially and fully infested batches, the same trend was noticed for the second month also and regardless of infestation, no seed failed to sprout during third month after planting.

Sprouting of elephant foot yam has been reported to be affected by various factors. Sprouting percentage was more with top cut portion of corm than the cut corms from lower half of the mother corm [12, 13]. Mulching improves sprouting, subsequent growth and yield. Moreover, treating cut pieces of corms from lower half with chemicals significantly improved sprouting and subsequently their growth and yield [2]. However, in the present study, all the selected seed materials were with top cut portion and mulching was done throughout the field. The seed materials were not chemically treated; nevertheless sprouting was high for the uninfested batch in the first two months after planting.

Significant variation in plant growth was noticed in the first month after planting among different treatments. Maximum height, girth of pseudostem and canopy spread was recorded for the plants raised from uninfested tubers (Table 1). However this difference was statistically not significant ($p \leq 0.05$) for the 2 month old plants (Table 2). During the later stages of development, partially and fully infested plants reached their vigor which was at par with the vigor of plants developed from the uninfested tubers (Table 3 and 4).

The growth of the plant is related to the sprouting of the seed materials. It was already proved that improved sprouting leads to increased growth of the plant [14]. Similar observation was recorded in present study also; the delay in sprouting was reflected in the growth of the plants especially for the infested batches in the first two months.

Table 1: Growth parameters of the elephant foot yam raised from fully, partially and uninfested seed material during first and second month after planting

Infestation level of seed material	Month after planting					
	1			2		
	Height (cm)	Girth (cm)	Canopy spread (cm)	Height (cm)	Girth (cm)	Canopy spread (cm)
Fully	10.50±3.15[ab]	3.50±0.34[ab]	22.00±4.45[ab]	10.29±2.51[a]	4.26±0.54[a]	27.22±6.30[a]
Partially	5.50±1.33[a]	3.33±0.21[a]	11.50±3.50[a]	11.41±1.82[a]	4.26±0.41[a]	21.25±2.69[a]
Uninfested	20.00±5.42[b]	5.20±0.79[b]	35.40±3.29[b]	16.90±3.95[a]	5.10±0.68[a]	34.80±7.76[a]

Values with the same superscript (column wise) do not differ significantly ($P \leq 0.05$)

Table 2: Growth parameters of the elephant foot yam raised from fully, partially and uninfested seed material during third and fourth month after planting

Infestation level of seed material	Month after planting					
	3			4		
	Height (cm)	Girth (cm)	Canopy spread (cm)	Height (cm)	Girth (cm)	Canopy spread (cm)
Fully	38.30±3.32[a]	7.46±0.43[a]	59.30±3.40[b]	50.46±4.37[a]	10.10±0.37[b]	74.73±3.86[b]
Partially	31.40±2.94[a]	6.80±0.44[a]	44.82±3.59[a]	49.00±3.15[a]	8.71±0.42[a]	61.00±2.82[a]
Uninfested	36.40±3.31[a]	7.91±0.39[a]	52.73±3.76[ab]	52.00±3.31[a]	11.02±0.32[b]	71.83±3.17[b]

Values with the same superscript (column wise) do not differ significantly ($P \leq 0.05$)

Table 3: Growth parameters of the elephant foot yam raised from fully, partially and uninfested seed material during fifth and sixth month after planting

Infestation level of seed material	Month after planting					
	5			6		
	Height (cm)	Girth (cm)	Canopy spread (cm)	Height (cm)	Girth (cm)	Canopy spread (cm)
Fully	61.93±4.28[a]	11.34±0.32[b]	86.62±2.90[a]	67.40±4.09[a]	11.64±0.20[b]	90.60±2.95[a]
Partially	61.45±3.52[a]	10.10±0.32[a]	72.00±2.75[b]	67.42±3.38[a]	10.53±0.25[a]	78.46±2.73[b]
Uninfested	69.44±3.12[a]	11.8±0.20[b]	85.73±2.19[b]	77.34±2.57[a]	12.10±0.16[b]	89.60±1.85[b]

Values with the same superscript (column wise) do not differ significantly ($P \leq 0.05$)

Table 4: Growth parameters of the elephant foot yam raised from fully, partially and uninfested seed material during seventh and eighth month after planting

Infestation level of seed material	Month after planting					
	7			8		
	Height (cm)	Girth (cm)	Canopy spread (cm)	Height (cm)	Girth (cm)	Canopy spread (cm)
Fully	71.62±4.09[a]	11.86±0.2[b]	93.06±3.08[b]	75.84±4.32[a]	12.04±0.15[b]	96.12±3.24[b]
Partially	71.10±3.54[a]	10.82±0.23[a]	80.68±2.73[a]	74.10±3.42[a]	11.96±0.20[a]	80.86±2.80[a]
Uninfested	80.56±2.62[a]	12.13±0.23[b]	90.00±2.12[b]	81.83±2.53[a]	12.10±0.19[b]	90.31±2.00[b]

Values with the same superscript (column wise) do not differ significantly ($P \leq 0.05$)

3.2. Yield of harvested tubers

On harvest, the tubers from all treatments were found free from mealy bug infestation which was further ascertained by microscopic observations. The scale insect, *A. hartii* multiplies in field and their infestation is perpetuates through seed material. Present investigation proved that even though mealy bug infested tubers of elephant foot yam were planted, the infestation did not perpetuate through seed tubers. As reported earlier, the root mealy bugs, *R. hibisci*, *R. kondonsis* were rarely observed in field conditions [15, 16].

Although, infested batches produced acceptable tubers, the yield was significantly ($P \leq 0.05$) less than that of uninfested batch (Table 5). The average weight of fully infested tubers used for planting was 0.51 kg from which 2.01 kg of tubers were obtained at harvest, which is equivalent to 24.81 t/ha, whereas the yield from partially infested and uninfested plots was 24.07 and 38.94 t/ha, respectively.

Corm yield varied between 30.9 and 85.4 t/ha depending upon the variety and cultural practices particularly plant spacing and manurial practices [17, 18]. Present study revealed that even though uniform conditions were provided, infested seed material yielded significantly lower than uninfested seed material. But, irrespective of the yield reduction, the harvested tubers were acceptable and marketable.

Table 5: Yield of elephant foot yam raised by using infested and uninfested planting material

Infestation level of seed material	Average weight of seed materials		Average weight of harvested tubers	
	kg	t/ha	kg	t/ha
Fully infested	0.51[a]	6.29[a]	2.01±0.27[a]	24.81[a]
Partially infested	0.54[a]	6.66[a]	1.95±0.20[a]	24.07[a]
Uninfested	0.50[a]	6.17[a]	3.15±0.37[b]	38.94[b]

Values with the same superscript (column wise) do not differ significantly ($P \leq 0.05$)

3.3. Quality of harvested tubers

Moisture content showed a marked difference among the three categories of tubers harvested. Uninfested batch showed highest moisture content as shown in Table 6. Accordingly, when flour prepared from the harvested tubers was analyzed, it was found that ash and fibre content was high for infested batches which can be attributed to the comparatively low moisture content. Decreased moisture content of the tubers of *Dioscorea dumetorum* attributes to the increased ash and fibre content [19]. However, starch and sugar content was high for uninfested batch. Sucking pests feed the sugary juice from their host, and depletion of the sugar would be compensated from the reserved starch by hydrolysis [20]. All categories of tubers were free from mealy bug infestation at harvest. But mealy bug infestation during the time of planting contributes to intense loss in sugar content and consequent decline of starch in the infested tubers. This reduction would have reflected in the reduced starch and sugar content for the harvested tubers of infested categories (Table 6).

Table 6: Biochemical parameters of harvested tubers of elephant foot yam

Infestation level of seed materials	Fresh tuber	Flour			
	M C (%)	Ash (%)	Fibre (%)	Sugar (%)	Starch (%)
Uninfested	81.79	5.69	2.77	7.59	33.58
Partially infested	76.72	5.89	3.03	6.79	32.88
Fully infested	75.76	5.84	3.15	6.70	32.56

Hardness of the uninfested batch in both raw and cooked form was less as compared to other categories as shown in Table 7. Increase in fibre content contributes to the hardening phenomenon of the stored tubers. Moreover, it was already recorded that increased hardness of the tubers is due to the decreased moisture and starch content [21]. Reduced water content caused the cell wall polysaccharides to shrink, permitting greater interactions by means of hydrogen bonding and Van der Waals forces, resulting in cell rigidity in the form of thickening of cell walls and middle lamella in the cells of tubers and lignification of the tissues. Springiness of the tubers decreased with the increase in hardness while cohesiveness and chewiness was found to increase.

Table 7: Texture profile of uninfested and infested raw and cooked tubers of elephant foot yam

Infestation level of seed material	Hardness (N)		Springiness		Cohesiveness		Chewiness	
	Raw	Cooked	Raw	Cooked	Raw	Cooked	Raw	Cooked
Uninfested	421.57	40.92	1.2	0.81	0.19	0.13	95.07	4.32
Partially infested	475.79	45.22	1.15	0.56	0.25	0.14	109.79	5.05
Fully infested	484.14	53.83	1.04	0.4	0.26	0.17	122.78	7.56

4. Conclusion

Present study was carried out to assess the field establishment of mealy bug infested tubers which is first of this kind. Infested seed materials showed a delay in sprouting and it was reflected in their growth in first two months after planting. At harvest, it affected the yield and infested seed material produced lesser yield. However, infested seed material when planted was completely free from mealy bug incidence at harvest. The harvested tubers of infested categories were harder than the uninfested batches, but when cooked they did not show much variation in quality. Therefore, from the present study it can be recommended that infested tubers can be successfully used as seed material in the absence of uninfested tubers.

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