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Identification of optimum drying temperature for pollen yield and viability in coconut varieties in coastal Andhra Pradesh

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Abstract

This study was carried out to investigate the effect of desiccation methods on pollen moisture content, pollen yield, percent of pollen viability, pollen germination and pollen tube length of coconut varieties grown in coastal Andhra Pradesh. In this study, four different varieties were subjected to various drying methods (drying at room temperature for 12 and 24 h, oven drying at 30ºC for 12 and 24 h, and oven drying at 40ºC for 12 and 24 h). Results showed a significant difference among treatments, varieties and the interaction between the desiccation methods and varieties. Chowghat Orange Dwarf (COD) staminate flowers dried at 40ºC for 24 h had less moisture content, whereas the maximum was in East Coast Tall (ECT) staminate flowers dried at room temperature for 12 h. Although staminate flowers dried in an oven at 40ºC for 24 h yielded more pollen, pollen viability %, pollen germination %, and pollen tube length were recorded maximum in staminate flowers dried in the oven at 40º for 12 h. Minimum pollen viability %, pollen germination % and pollen tube length were recorded in staminate flowers dried at room temperature for 24 h. This study demonstrates that desiccated staminate flowers contribute to an increase in pollen quantity by reducing moisture content. The resulting pollen can be effectively utilized in breeding programs throughout the year.

Key words: Coconut, desiccation methods, pollen moisture, pollen yield, pollen viability.

Introduction

Coconut (*Cocos nucifera* L. 2n=32) is a woody perennial monocotyledonous tree that belongs to the family Arecaceae. It is the most versatile among the world's 2700 species of palms (Harries, 1990). It is referred as *Kalpa Vriksha,* which means 'the tree that provides all the necessities of life (Ahuja *et al.*, 2014). It is mostly found in coastal areas up to 1000 meters above mean sea level (Harries, 2001). It is a tropical crop that is highly cross-pollinated and can only be propagated by seed. The production of high-quality seedling material is crucial, and there is an important gap between the supply and demand for planting materials, particularly for coconuts. Farmers have a strong demand for hybrid material because of its greater yields and features of intermediate plant growth. In coconut, hybrid material is created by crossing the Tall and Dwarf types using artificial crossing techniques (Veluru *et al.*, 2021).

Pollen obtained from the inflorescence of the selected male parental line is crucial during hybridization; hence, standard extraction techniques and the quality of the pollen play vital roles in the success rate (Liyanage, 1954). Although pollen is available in immense quantities, the collection and storage of pollen are beset with many difficulties. Earlier methods of pollen collection were based on gathering the pollen that fell off opened male flowers. Very little pollen could be obtained due to fewer opened flowers dropping off the spikelets without opening and shedding pollen. With pollen collection being limited to prepotent palms, a large quantity of pollen has to be collected to make maximum use of these proven palms for breeding purposes (Manthriratan, 1965). To address this issue, desiccation techniques are used to remove moisture and enhance pollen production. Typically, pollen is collected from fresh flowers, which tend to yield lower amounts of pollen (Srinivasu *et al.*, 2022)..

Attempts to increase the quantity of pollen that could be collected from each inflorescence are reported and these methods are based on the induced shedding of pollen by the use of moisture content, suitable temperature, or a combination of both on unopened male flowers (Whitehead, 1963). This process was modified to produce enormous amounts of viable pollen from a single inflorescence of a prepotent palm; 9.0 g of pollen could be harvested. Large quantities of viable pollen were obtained by drying desiccated anthers from unopened male flowers (Manthriratna, 1965). Consequently, the current study was conducted by employing various desiccation methods for pollen yield and viability of different coconut varieties. Parameters like pollen germination and pollen tube length were also studied which are affected by various desiccation methods in coconut varieties.

Material and methods

The experiment was conducted during 2021-2022 (November 2021 to June 2022) at the College of Horticulture, Venakataramannagudem, Dr. Y.S.R Horticultural University, West Godavari District, Andhra Pradesh, India in Factorial Completely Randomized Design (FCRD) with two factors, three replications and twenty-four treatment combinations.

Pollen of varieties *viz*., East Coast Tall, Philippines Ordinary Tall, Ganga Bondam Green Dwarf and Chowghat Orange Dwarf were used in the study.

Pollen extraction and pollen yield from dried staminate flowers: For the extraction of pollen from dried staminate flowers was first removed from the inflorescence of the respective palms. The staminate flowers sample (100 g) was were subjected to different drying treatments having various time durations. After incubation, the dried staminate flowers were put in a sieving apparatus, which consisted of two sieves of mesh size of 500 and 212 microns, respectively, gently shaken to extract and sift the pollen from its floral parts and collected in a bottom pan. Collected pollen were weighed and edpressed in g per 100 g of dried staminate flowers.

Pollen moisture (%): The moisture content of pollen samples was determined using room-temperature drying techniques. The method involved the removal of moisture from a pollen sample at room temperature during a 24-hour drying period. 100 g of fresh pollen was placed in a clean, dry petri dish, weighed 50 g, and allowed 24 hours to dry before weighing the pollen. The percentage of moisture content of the pollen grain in the sample had been calculated using the formula below.

$$\text{Moisture content \%} = M_2\text{-}M_1 / M_2 \times 100$$

Where M_1 is the weight of the sample after drying and M_2 is the weight of the sample before drying

Pollen viability: To assess the viability of the pollen grains by a staining method, a pollen sample of approximately 0.02 g was placed on a slide, and a drop of 1% acetic carmine was added, followed by homogenization. The slide was then placed in a Petri dish (80 mm, Labomax Inc.) and incubated in a biological incubator at 35±1°C for 25-30 minutes. The slides were analyzed for the number of viable and nonviable pollen grains per quadrant using a microscope (model MAGCAM-DC3, Fluorescence Microscope with MagVision software) at 10x magnification and a digital camera (model MAGCAM-DC3, Magnus Analytics, New Delhi, India). The pollen grains that stained red with intact walls were considered viable (by the reaction of the presence of enzymatic activity), and those that were colorless or stained red with ruptured walls were considered nonviable.

$$\text{Percentage of viability} = \frac{\text{Number of viable pollens per sample}}{\text{Total number of pollens}} \times 100$$

Pollen germination: To assess the germination of the pollen grains by using *in vitro* germination method, a pollen sample of approximately 0.02 g were placed on Petri dishes containing 2 mL of culture medium of Lora *et al.* (2006). The Petri dishes (80 mm, Labomax Inc.) were kept in an incubator for 24 h at a temperature of 24±1°C. The Petri dishes were analyzed for the number of germinated pollen grains using a microscope (model MAGCAM-DC3, Fluorescence Microscope with MagVision software) at 10x magnification with a digital camera (model MAGCAM-DC3, Magnus Analytics, New Delhi, India).

Every time a fresh medium was prepared. Sucrose, boric acid, calcium nitrate, magnesium sulphate and potassium nitrate were dissolved in distilled water, which is boiled and smeared on clean micro slides. Pollen grains were scattered over the smear by using cotton and the slides were kept in a petri dish which was lined with moist filter paper for maintaining humidity inside the plate. Petri dishes were wrapped and kept for incubation for one h and 30 minutes. When the incubation time was over, slides were taken out from the petri dish to measure the tube length of pollen germinated on the media. Slide pictures were captured using a Fluorescence Microscope with the help of MagVision software. The germination percentage was calculated using the formula:

$$\text{Percentage of germination} = \frac{\text{Number of germinated pollens per sample}}{\text{Total number of pollens}} \times 100$$

Pollen tube length: The germination of the pollen, the tube length was measured using a fluorescence microscope with the help of MagVision software, and the average was calculated.

Statistical analysis: The data from the study was subjected to analysis in a Factorial Completely Randomized Design (FCRD) by DMRT using the SPSS 16.2 software.

Results and discussion

Pollen moisture content (%): The data pertaining to the effect of different drying/desiccation methods on pollen moisture content showed a significant difference, as presented in Table 1. The mean pollen moisture content ranged from 11.04±0.88% (pollen dried in oven at 40ºC for 24 h) to 18.28±2.45% (pollen dried at room temperature for 12 h). Among the different desiccation methods, the highest moisture content was recorded in pollen dried at room temperature for 12 h (18.28±2.45%) followed by room temperature for 24 h (16.72±2.22%). In contrast, the lowest was observed in pollen dried in the oven at 40ºC for 24 h (11.04±0.88%). Among the different varieties, the mean pollen moisture content ranged from 12.61±2.31% to 16.76±3.36%. The highest moisture content was registered in East Coast Tall (16.76±3.36%) followed by Philippines Ordinary Tall (15.06±2.87%) and the lowest moisture content was observed in Chowghat Orange Dwarf (12.61±2.31%) and Ganga Bondam Green Dwarf (13.48±2.25%). The interaction between cultivars/varieties and drying methods on pollen moisture content was found to be highly significant. Pollen moisture content ranged from a minimum of 10.02±0.44% in Chowghat Orange Dwarf pollen dried at 40ºC for 24 h to a maximum of 21.22±0.92% in East Coast Tall pollen dried at room temperature for 12 h.

In coconut, pollen collection and processing are important components for long-term storage (Hoekstra, 1995). The water content of pollen grains at the time of pollen dispersal varies among different cultivars, with the most recorded values in the range of 15 to 35% fresh weight (Heslop-Harrison, 1979). Ching and Slabaugh (1966) have shown that a relationship existed between pollen moisture content and loss of viability. They observed that when pollen contains more than 30% moisture content. Desiccation or drying of male flowers in the oven at 40ºC for 24 h was very effective for moisture reduction of pollen to 7.5% without losing its viability. The viability of desiccated coconut pollen stored in liquid nitrogen retained its viability as that of oven-dried pollen, whereas none survived when fresh pollen was cryopreserved. Hence, the moisture content of coconut pollen before storage in liquid nitrogen is crucial for maintaining its viability and fertility. A similar observation has been made by Hebbar *et al.* (2017) in coconut, Raja *et al.* (2001) in areca nut, Karipidis *et al.* (2007) in tomato and Daniel *et al.* (2002) in *Dioscorea* spp. Hebbar *et al.* (2017) stated that maximum moisture content in pollen was recorded when desiccated at 30ºC, positively impacting pollen viability

and fertility. This dehydration method maintains the optimum moisture content and is effective in preventing cell damage.

Pollen yield (g/100g male staminate flowers): The effect of different drying methods on pollen yield was statistically significant and is presented in Table 1 and Fig. 1. Among the different drying methods, the mean pollen yield ranged from 0.61±0.23g to 1.06±0.15g. Maximum pollen yield was observed in pollen that was oven dried at 40º for 24 h (1.06±0.15g) followed by oven drying at 40º for 12 h (0.96±0.18g) as against 0.61±0.23g of pollen yield of staminate flowers dried at room temperature for 12 h. Significant findings were noticed among different cultivars with respect to the mean pollen yield that ranged from 0.66±0.19g to 1.03±0.15g. The highest pollen yield was recorded in Philippines Ordinary Tall (1.03±0.15g) followed by East Coast Tall (0.96±0.13g) and the lowest pollen yield was observed in Chowghat Orange Dwarf (0.66±0.19g). Interaction between cultivars/varieties and drying methods on pollen yield was found to be statistically significant. Maximum pollen yield was recorded in the Philippines Ordinary Tall pollen kept at oven drying at 40º C for 24 h (1.22±0.05g), and minimum was observed in Chowghat Orange Dwarf pollen kept at room temperature for 12 h (0.40±0.02g.). These results confirm the findings of Whitehead (1965) in coconut, who reported that West Coast Tall pollen kept in room temperature for 5 h followed by desiccation at 40ºC for 12 h yielded 1.17g/100g pollen. A similar observation was made by Wang *et al.* (2015) in litchi stated that maximum pollen yield was observed when anthers were dried with an electric air-blowing dryer at 35ºC for 24 h.

Percent viability: Table 2 shows that the different drying methods showed significant differences in pollen viability of different varieties. Among the different desiccation/drying methods, the mean pollen viability ranged from 54.57±6.74% to 81.95±8.99%. The highest pollen viability was recorded in the oven drying at 40ºC 12 hr (81.95±8.99%) followed by oven drying at 40ºC for 24 h (74.50±6.21%) and the lowest was recorded in pollen kept at room temperature for 24 h (54.57±6.74%) (Fig. 2). Among the different varieties, the mean pollen viability ranged from 59.42±9.90% to 75.53±10.79%. Maximum pollen viability was observed in East Coast Tall (75.53±10.79%) followed by Philippines Ordinary Tall (69.64±10.11%) as against the lowest pollen viability in Chowghat Orange Dwarf (59.42±9.90%). There was a significant interaction between varieties and drying methods

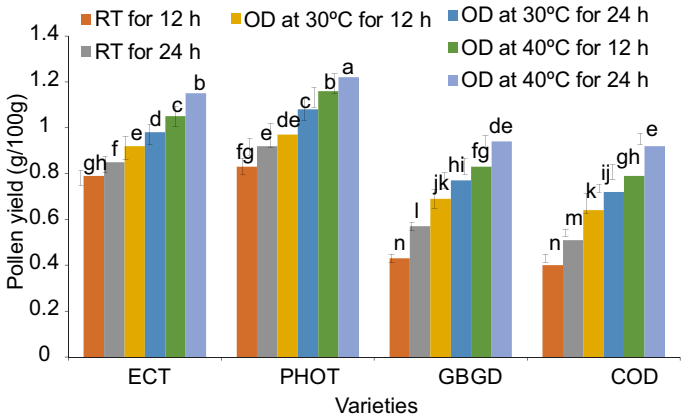

Fig. 1. Effect of different drying methods on pollen yield (g/100g) in different coconut varieties

for the *in vitro* pollen viability percentage. Maximum pollen viability percentage was observed in East Coast Tall pollen dried at 40ºC for 12 h (92.46±0.61%) followed by Philippines Ordinary Tall kept at 40ºC for 12 h (84.46±0.71%). In contrast, the minimum was recorded in Chowghat Orange dwarf kept at room temperature for 24 h (47.51±0.96%).

Pollen grains are known to possess high moisture content (Shivanna and Rangaswamy, 1992). Moisture condition predisposes organic materials to biodegradation by microorganisms (Hanna and Towill, 1995). The biological activity of these organisms makes storage and preservation challenging. The pollen stays viable during storage because its moisture content is lower in dried male flower pollen than in undried or fresh male flowers pollen for a longer length of time. Pollen viability may be negatively impacted if the moisture content of the pollen is reduced beyond a particular point. This observation agreed with earlier reports (Ekaratne and Senathirajah, 1983). Similar observations has been made by Towill and Walters (2000) in coconut, Welewanni and Bandupriya (2017) in coconut and Ugwoke *et al.* (2007) in oil palm stated that oven-dried male flower pollen at maximum temperature proved to be the most effective method for long term storge without losing viability.

Percent germination: Mean pollen germination percentage of various varieties subjected to different drying methods ranged from 23.99±6.76% to 49.23±10.18% (Table 2). Among the different drying methods, the highest pollen germination percentage was recorded in pollen kept in oven drying at 40ºC 12 h (49.23±10.18%) followed by oven drying at 40ºC for 24 h (39.68±7.83%). In contrast, the lowest of 23.99±6.76% was observed in pollen kept at room temperature for 24 hr (Fig. 3). Among the different varieties, the mean pollen germination percentage ranged from 24.51±9.20% to 41.71±11.23%. Maximum pollen germination percentage was recorded in East Coast Tall (41.71±11.23%) followed by Philippines Ordinary Tall (37.50±10.22%), while minimum pollen germination percentage was observed in Chowghat Orange Dwarf (24.51±9.20%). A significant difference was noticed in the interaction between varieties and drying methods on pollen germination percentage (Table 2). It was clearly indicated that the maximum percent of pollen germination was noticed in East Coast Tall (59.75±1.00%) followed by Philippines Ordinary Tall pollen (55.98±0.60%) subjected to oven drying at 40ºC for 12 h. A minimum was observed in the pollen of Chowghat Orange Dwarf (16.44±0.6%) kept at room temperature for 24 h.

In vitro germination of pollen has been used as an important technique for assessment pollen viability and often affected by desiccation (Karun *et al.,* 2006). Consistent with the report of Karun *et al.* (2014) the coconut pollen collected from WCT (West Coast Tall) and COD (Chowghat Orange Dwarf) palms (desiccated) germinated with ranged from 24 to 32% and 30 to 31%. Similar observation has been made by Bernard *et al.* (1973) in coconut pollen. Ananda *et al.* (2017) stated that maximum germination percentage was found in fresh, oven dried pollen for 24 h. Higher temperatures may cause the rate of inversion to exceed the rate of utilization, which would raise the level of decreasing sugar. It has been observed that simple sugar serves as the primary energy source for pollen grains during germination (Hebbar *et al.,* 2018). There are reports in other palms like date palm (Mortazavi *et al.*, 2010), prunus

Table 1. Effect of different drying methods on pollen moisture content and pollen yield in different coconut varieties.

Drying methods	Pollen moisture (%)					Pollen yield (g/100 g staminate flowers)				
	ECT	PHOT	GBGD	COD	Mean	ECT	PHOT	GBGD	COD	Mean
RT (12 h)	21.22±0.92^{a} (22.21)	19.25±0.84^{b} (21.07)	16.98±0.74^{cd} (20.20)	15.68±0.68^{ef} (18.82)	18.28±2.45^{a} (20.57)	0.79±0.03^{gh}	0.83±0.03^{fg}	0.43±0.02^{n}	0.40±0.02^{n}	0.61±0.23^{f}
RT (24 h)	19.54±0.85^{b} (20.27)	17.45±0.76^{c} (19.79)	15.02±0.65^{fg} (19.03)	14.87±0.65^{fg} (18.44)	16.72±2.22^{b} (19.38)	0.85±0.04^{f}	0.92±0.04^{e}	0.57±0.03^{l}	0.51±0.03^{m}	0.71±0.20^{e}
OD at 30°C (12 h)	17.24±0.75^{cd} (27.41)	15.02±0.65^{fg} (26.01)	13.43±0.58^{hi} (24.32)	12.90±0.57^{ij} (23.31)	14.65±1.95^{c} (25.26)	0.92±0.04^{e}	0.97±0.04^{de}	0.69±0.03^{jk}	0.64±0.03^{k}	0.81±0.16^{d}
OD at 30°C (24 h)	16.25±0.71^{de} (26.22)	14.20±0.62^{gh} (24.67)	12.89±0.56^{ij} (22.79)	11.79±0.51^{jk} (22.66)	13.78±1.92^{d} (24.08)	0.98±0.04^{d}	1.08±0.04^{c}	0.77±0.03^{hi}	0.72±0.03^{ij}	0.89±0.17^{c}
OD at 40°C (12 h)	14.31±0.63^{gh} (24.51)	12.94±0.57^{ij} (22.79)	11.94±0.52^{jk} (21.48)	10.42±0.45^{lm} (21.03)	12.40±1.64^{e} (22.45)	1.05±0.04^{c}	1.16±0.05^{b}	0.83±0.03^{fg}	0.79±0.02^{gh}	0.96±0.18^{b}
OD at 40°C (24 h)	12.02±0.52^{jk} (23.76)	11.48±0.50^{kl} (22.12)	10.65±0.46^{lm} (21.02)	10.02±0.44^{m} (20.07)	11.04±0.88^{f} (21.74)	1.15±0.05^{b}	1.22±0.05^{a}	0.94±0.04^{de}	0.92±0.04e	1.06±0.15^{a}
Mean	16.76±3.36^{a} (24.72)	15.06±2.87^{b} (23.40)	13.48±2.25^{c} (22.00)	12.61±2.31^{d} (21.66)		0.96±0.13^{b}	1.03±0.15^{a}	0.71±0.18^{c}	0.66±0.19^{d}	
Factors			LSD					LSD		
DM			0.32					0.02		
Varieties			0.43					0.03		
DM×V			0.86					0.06		

*ECT-East Coast Tall, PHOT-Philippines Ordinary Tall, GBGD-Ganga Bondam Green Dwarf, COD-Chowghat Orange Dwarf, DM-Drying Methods and V-Varieties. *Mean values of parameters followed by the same letter are not significantly different according to the DMRT ($P \leq 0.05$).

Table 2. Effect of different drying methods on percent pollen viability and germination in different coconut varieties.

Drying methods	Percent viability (%)					Percent germination (%)				
	ECT	PHOT	GBGD	COD	Mean	ECT	PHOT	GBGD	COD	Mean
RT (12 h)	66.82±2.35^{fg} (54.81)	61.36±2.68^{i} (51.55)	57.12±0.84^{j} (49.07)	50.26±2.19^{k} (45.12)	58.89±6.99^{e} (50.14)	32.22±0.32^{g} (34.56)	30.61±1.15^{hi} (33.57)	21.70±0.42^{l} (27.75)	17.10±0.85^{n} (24.41)	25.41±7.22^{e} (30.07)
RT (24 h)	62.66±1.07^{hi} (52.31)	57.25±2.49^{j} (49.15)	50.85±1.66^{k} (45.46)	47.51±0.96^{k} (43.55)	54.57±6.74^{f} (47.62)	29.83±0.85^{ij} (33.09)	29.56±0.88^{ij} (32.91)	20.13±1.03^{m} (26.64)	16.44±0.68^{n} (23.90)	23.99±6.76^{f} (29.13)
OD at 30°C (12 h)	72.03±1.20^{e} (74.04)	67.57±0.60^{fg} (66.75)	50.26±2.19^{k} (62.66)	55.76±1.15^{j} (58.06)	61.41±10.12^{d} (65.38)	37.70±0.59^{e} (50.60)	31.72±1.40^{gh} (48.41)	24.15±0.39^{k} (40.53)	18.86±0.59^{m} (38.58)	28.11±8.29^{d} (44.53)
OD at 30°C (24 h)	77.63±0.90^{d} (64.58)	69.45±0.71^{ef} (61.82)	65.48±2.85^{gh} (56.86)	62.45±2.72^{hi} (55.87)	68.75±6.57^{c} (59.78)	41.46±1.09^{d} (44.58)	34.44±1.03^{f} (40.79)	28.60±1.28^{j} (35.83)	23.34±1.00^{k} (34.67)	31.96±7.79^{c} (38.58)
OD at 40°C (12 h)	92.46±0.61^{a} (61.58)	84.46±0.71^{b} (56.42)	78.88±3.44^{cd} (54.00)	72.02±3.14^{e} (52.19)	81.95±8.99^{a} (56.09)	59.75±1.00^{a} (40.06)	55.98±0.60^{b} (35.91)	42.27±1.40^{d} (32.31)	38.92±1.09^{e} (28.87)	49.23±10.18^{a} (34.29)
OD at 40°C (24 h)	81.61±1.00^{bc} (58.05)	77.73±1.05^{d} (55.26)	70.12±3.06^{ef} (45.12)	68.54±2.99^{efg} (48.28)	74.50±6.21^{b} (51.68)	49.31±0.77^{c} (37.86)	42.71±0.42^{d} (34.26)	34.31±0.81^{f} (29.72)	32.39±0.55^{g} (25.72)	39.68±7.83^{b} (31.81)
Mean	75.53±10.79^{a} (60.92)	69.64±10.11^{b} (56.82)	62.12±11.39^{c} (52.20)	59.42±9.90^{d} (50.51)		41.71±11.23^{a} (40.12)	37.50±10.22^{b} (37.64)	28.53±8.47^{c} (32.08)	24.51±9.20^{d} (29.36)	
Factors			LSD					LSD		
DM			0.84					0.37		
Varieties			1.03					0.46		
DM×V			2.07					0.92		

*ECT-East Coast Tall, PHOT-Philippines Ordinary Tall, GBGD-Ganga Bondam Green Dwarf, COD-Chowghat Orange Dwarf, DM-Drying Methods and V-Varieties. *Mean values of parameters followed by the same letter are not significantly different according to the DMRT ($P \leq 0.05$).

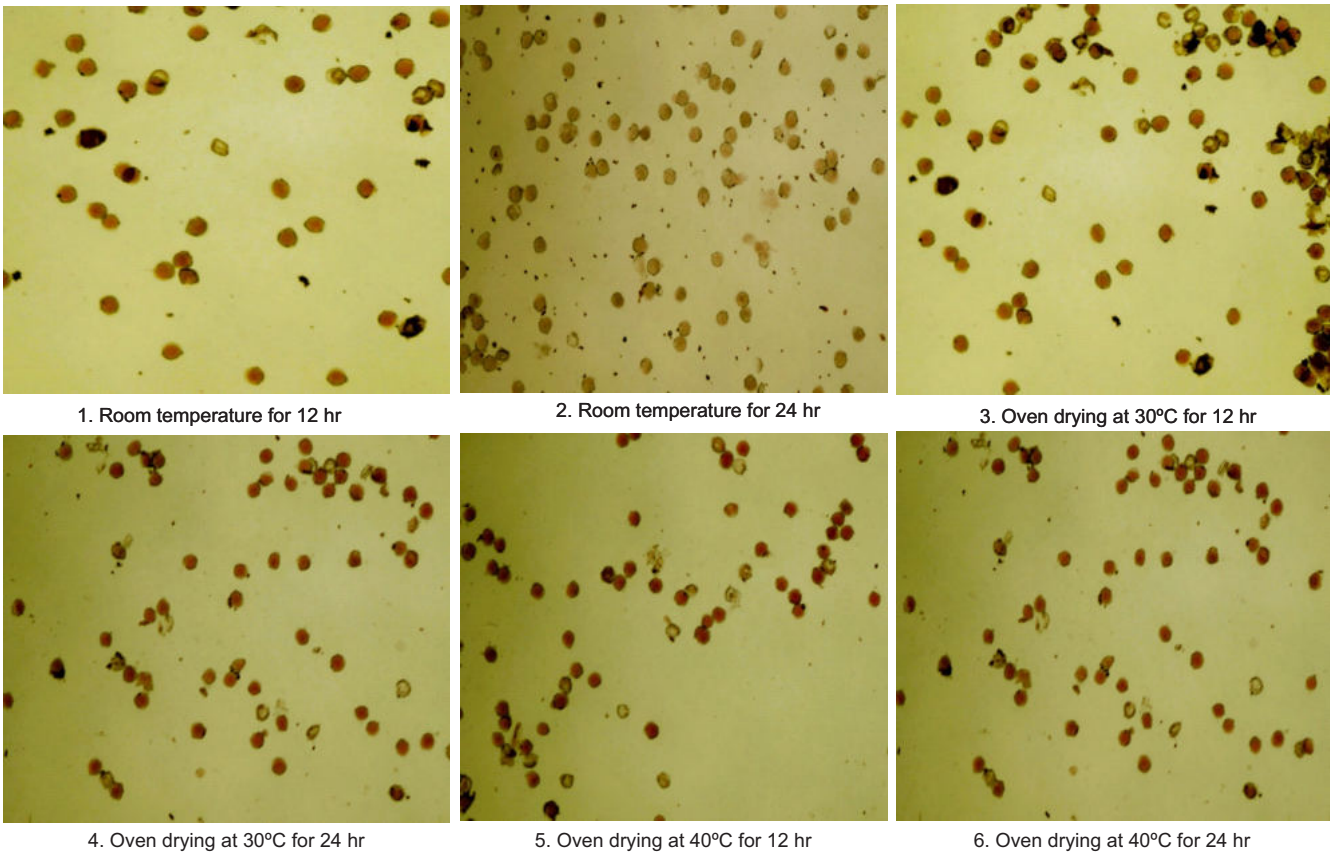

Fig. 2. Pollen viability as effected by different desiccation or drying methods

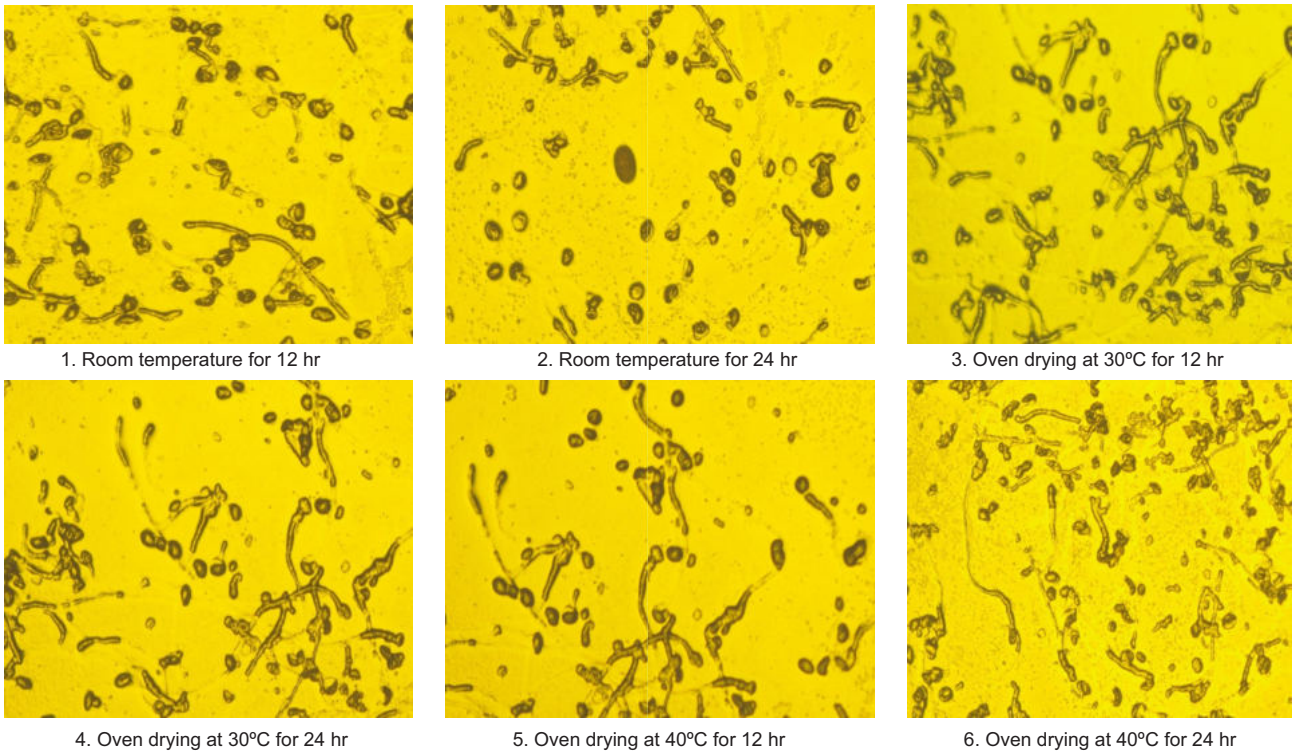

Fig. 3. Pollen germination as effected by different desiccation or drying methods

species (Sorkheh *et al.*, 2011) and oil palm (Tandon *et al.,* 2007; YouMbl *et al.*, 2015) for the effective desiccated pollen.

Pollen tube length (µm) as affected by different desiccation methods: The drying methods had a significant impact on the pollen tube length of different varieties, as observed in the *in vitro* germination of the pollen tubes. As shown in the Table 3 the mean pollen tube length under *in vitro* germination ranged from 131.57±5.44 µm to 215.28±12.66 µm among the different drying methods. The longest pollen tube length was observed in pollen kept in oven at 40ºC 12 h (215.89±12.66 µm) followed by oven drying of pollen at 40ºC for 24 h (183.89±9.53 µm) while the shortest of 131.57±5.44 µm was recorded in pollen kept at room

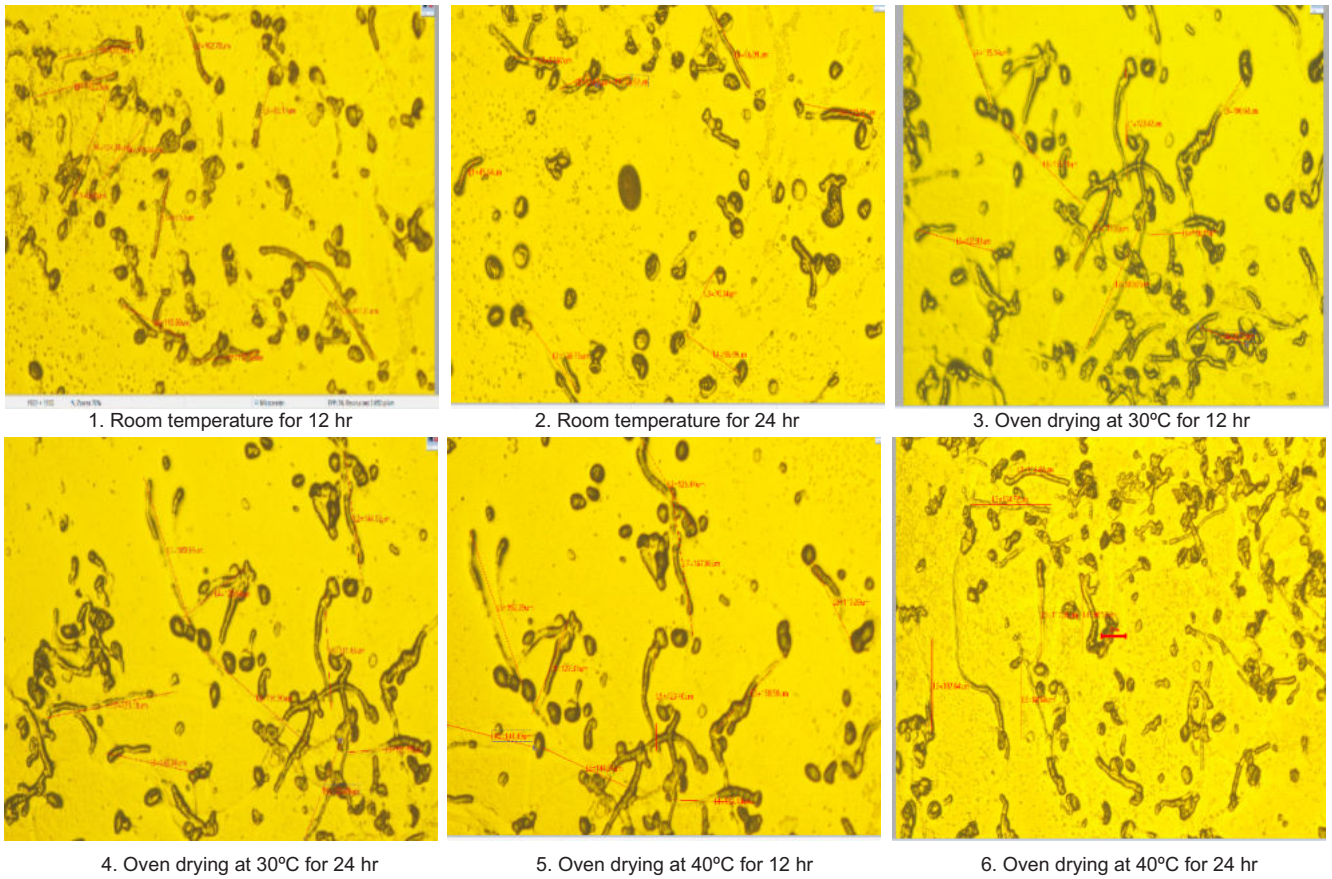

Fig. 4. Pollen tube length as effected by different desiccation or drying methods.

temperature for 24 h (Fig. 4). The mean pollen tube length under *in vitro* germination of pollen tube ranged from 153.33±29.66 µm to 173.94±35.04 µm in different varieties. It was clearly indicated that the longest pollen tube length was noticed in East Coast Tall (173.94±35.04 µm) followed by Philippines Ordinary Tall (169.90±33.04 µm) and the shortest length had been noticed in Chowghat Orange Dwarf (153.33±29.66 µm). There was a significant interaction between varieties and drying methods for the *in vitro* pollen tube length. Maximum pollen tube length under *in vitro* germination of pollen was recorded in East Coast Tall (230.15±10.03 µm) followed by Philippines Ordinary Tall (220.51±9.62 µm) pollen dried at 40ºC for 12 h whereas minimum was recorded in Chowghat Orange Dwarf pollen (125.14±0.67 µm) kept at room temperature at 24 h.

Pollen tube length showed a linear decrease with further changes in temperature. Maximum pollen tube length (267 µm) at 30ºC 7 h in MGD cultivar in Mexico and Sri Lanka, has been reported by earlier workers (Armendariz *et al.*, 2006; Ranasinghe *et al.*, 2010). In the present study, a mean maximum pollen tube length was obtained at 40ºC 12 h which is much higher than reported by others in coconut (Armendariz *et al.*, 2006; Ranasinghe *et al.*, 2010). This difference might be mainly due to the differences in the concentrations of nutrients in the germination media these studies and the maturity of the sampe. Similarly, Sorkheh *et al.* (2011) in prunus species, Gaaliche *et al.* (2013) in caprifig, Ananda *et al.* (2017) in Arecanut, Hebbar *et al.* (2018) and Machado *et al.* (2021) in coconut. Hebbar *et al.* (2018) reported that significant variation among cultivars (COD & GBGD) and temperature interaction was significant effect on pollen tube length. The main reason that pollen tube length was affected by temperature, lies in its direct impact on metabolic processes and physiological functions within the pollen grain. There are several reports that showed varied response of cultivars to temperature for pollen tube length (Kakani *et al.*, 2002, 2005; Karim *et al.*, 2011). In Iranian almonds (*Prunus spp.*) Karim *et al.* (2011) reported variation for cardinal temperatures (T_{min}, T_{opt} and T_{max}) for pollen tube growth.

This study emphasizes substantial variations among treatments, varieties, and the interaction between desiccation methods and varieties in pollen characteristics. Remarkably, staminate

Table 3. Effect of different drying methods on pollen tube length in different coconut varieties

Drying methods	Pollen tube length (µm)				Mean
	ECT	PHOT	GBGD	COD	
RT (12 h)	145.48±6.34ghi	142.01±6.19^{hij}	134.39±4.74^{ikl}	128.4±2.28^{kl}	137.57±7.67^{e}
RT (24 h)	137.28±3.21ijk	134.62±1.03^{ijkl}	129.23±0.67^{kl}	125.14±0.67^{l}	131.57±5.44^{f}
OD at 30°C (12 h)	154.73±6.74fg	151.47±6.60^{fgh}	139.08±1.68^{ijk}	135.95±2.60^{ijkl}	145.31±9.19^{d}
OD at 30°C (24 h)	182.54±7.96de	180.25±7.86^{e}	158.91±3.60^{f}	155.63±1.37^{fg}	169.33±14.03^{c}
OD at 40°C (12 h)	230.15±10.03a	220.51±9.62^{ab}	210.98±6.97^{b}	200.66±8.74^{c}	215.58±12.66^{a}
OD at 40°C (24 h)	193.46±8.43c	190.54±8.31^{cd}	177.35±2.77^{e}	174.21±2.11^{e}	183.89±9.53^{b}
Mean	173.94±35.04^{a}	169.90±33.04^{b}	158.32±31.38^{c}	153.33±29.66^{d}	
Factors			LSD		
DM			3.94		
Varieties			4.83		
DM×V			8.12		

For abbreviation see Table 1

flowers (COD) subjected to drying in an oven at 40ºC for 24 h demonstrated lower moisture content and higher pollen yield. Whereas, pollen viability %, pollen germination % and pollen tube length were recorded maximum in staminate flowers dried in oven at 40º for 12 h.

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