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# Effect of Pollen Storage and Time of Pollination on Seed Yield and Quality of Hybrid Watermelon Arka Jyothi

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**Abstract** An investigation to study the effect of pollen storage and time of pollination on seed yield and quality of hybrid watermelon (*Citrullus lanatus* Thunb) Arka Jyothi was undertaken. The results revealed that pollen storage period exhibited marked influence on seed weight per fruit, percentage of filled seeds, seed germination and vigor index irrespective of pollination time. The fresh pollen dusted on female parent recorded significantly highest seed weight, filled seed, seed germination and vigor index (4.87 g, 87.21%, 85.83% and 19.68), respectively followed by one day stored pollens as against two days stored pollen (4.53 g, 79.22%, 72.83% and 1706), respectively. Whereas, significant variations were observed due to crossing time for various seed yield and quality components irrespective of pollen storage. The crossing of female buds at 6.00 to 7.00 am period recorded significantly and consistently highest seed weight (4.95 g), filled seed (84.26%), seed germination (82.49%) and vigor index (1891) and it was followed by 7:00 to 8:00 am crossing time. On the other hand, all these parameters were significantly lowest in 8.00 to 9.00 am crossing time irrespective of pollen storage period.

**Keywords** Watermelon, Pollen storage, Pollination time, Seed yield, Quality.

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## Introduction

Watermelon [*Citrullus lanatus* (Thunb)], an important annual fruit vegetable crop belongs to Cucurbitaceous family and is a native of tropical Africa. It is called in Hindi verbiage by several names as *Tarbool, Kalind, Tarbu* and *Jamaika* and in Kannada as *Kallangadi*. Watermelon fruit contains 95% water, 0.2% protein, 0.3% minerals and 3.3% carbohydrates per 100 g of fresh fruit weight. The seed contains about 35% protein and 50% of oil with high amount of amino acids apart from rich in iron content and it is used in preparation of several sweets and delicious foods. The color of watermelon fruits ranges from

**Table 1.** Effect of pollen storage period and time of pollination on number of crossed fruits per vine in hybrid watermelon Arka Jyothi.

| | Number of crossed fruits per vine | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I year | | | | II year | | | | Pooled | | | |
| Treatments | $T_1$ | $T_2$ | $T_3$ | Mean | $T_1$ | $T_2$ | $T_3$ | Mean | $T_1$ | $T_2$ | $T_3$ | Mean |
| $P_1$–Fresh pollen | 8.33 | 7.66 | 6.66 | 7.55 | 8.33 | 7.33 | 7.00 | 7.55 | 8.33 | 7.50 | 6.83 | 7.55 |
| $P_2$–One day stored pollen | 8.00 | 7.33 | 5.33 | 6.88 | 7.66 | 7.33 | 5.33 | 6.77 | 7.83 | 7.33 | 5.33 | 6.83 |
| $P_3$–Two day stored pollen | 5.00 | 4.33 | 4.00 | 4.44 | 4.66 | 4.00 | 3.33 | 4.00 | 4.83 | 4.16 | 3.66 | 4.22 |
| Mean | 7.11 | 6.44 | 5.33 | 6.29 | 6.88 | 6.22 | 5.22 | 6.11 | 7.00 | 6.33 | 5.27 | 6.20 |
| For comparing the mean of | SEm± | | CD at 5% | | SEm± | | CD at 5% | | SEm± | | CD at 5% | |
| P | 0.19 | | 0.57 | | 0.16 | | 0.50 | | 0.06 | | 0.19 | |
| T | 0.19 | | 0.57 | | 0.16 | | 0.50 | | 0.12 | | 0.36 | |
| P × T | 0.33 | | NS | | 0.29 | | NS | | 0.18 | | 0.52 | |

deep pink to pale pink fresh color with slightly reddish tinge containing mainly lycopene and anthocyanin pigments. It is often regarded as poor man's fruit but realished by millions of rich and poor, young and old people alike throughout the world. The ripe watermelon fruit juice is an excellent alternative to drinking water in desert region and is consumed as a refreshing cooling drink by adding a pinch of salt and black pepper to relieve thirstiness during hot summer months.

In watermelon hybrid seed production, the most productive and desirable seed yield could be obtained from the female parent if there is a perfect coincidence between pollen viability and stigma receptivity during pollination. Obviously, time of pollination plays a crucial role in deciding ultimate seed setting and yield of hybrid watermelon. Since, watermelon is a highly cross pollinated crop, crossing is done usually on the day of flower opening during early morning hours starting 6.00 am to 9.00 am and the ideal period needs to be standardized. Cost-effective watermelon hybrid seed could be produced commercially by using different techniques like hand emasculation, insect or manual pollination, regulation of sex expression by chemicals and growing conditions. Among these several techniques, the manual pinching of male flowers and manual pollination technique are found more efficient and cost effective in hybrid watermelon seed production. The success rate of seed setting by manual crossing depends mainly on effective transfer of viable pollen to the female flower buds during the flowering period. Usually, the fresh pollen used for pollination immediately after flower opening may

**Table 2.** Effect of pollen storage period and time of pollination on fruit set percentage in hybrid watermelon Arka Jyothi.

| | Fruit set (%) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I year | | | | II year | | | | Pooled | | | |
| Treatments | $T_1$ | $T_2$ | $T_3$ | Mean | $T_1$ | $T_2$ | $T_3$ | Mean | $T_1$ | $T_2$ | $T_3$ | Mean |
| $P_1$–Fresh pollen | 28.71 | 26.45 | 21.48 | 25.55 | 28.50 | 24.97 | 23.08 | 25.52 | 28.61 | 25.71 | 22.28 | 25.53 |
| $P_2$–One day stored pollen | 23.58 | 23.14 | 21.07 | 22.60 | 23.95 | 23.95 | 21.34 | 23.08 | 23.76 | 23.54 | 21.21 | 22.84 |
| $P_3$–Two day stored pollen | 17.67 | 15.12 | 14.04 | 15.61 | 17.02 | 13.96 | 11.90 | 14.29 | 17.35 | 14.54 | 12.97 | 14.95 |
| Mean | 23.32 | 21.57 | 18.86 | 21.25 | 23.16 | 20.96 | 18.77 | 20.96 | 23.24 | 21.27 | 18.82 | 21.11 |
| For comparing the mean of | SEm± | | CD at 5% | | SEm± | | CD at 5% | | SEm± | | CD at 5% | |
| P | 0.66 | | 1.97 | | 0.61 | | 1.83 | | 0.32 | | 0.99 | |
| T | 0.66 | | 1.97 | | 0.61 | | 1.83 | | 0.46 | | 1.34 | |
| P × T | 1.15 | | NS | | 1.07 | | NS | | 0.66 | | NS | |

**Table 3.** Effect of pollen storage period and time of pollination on fruit length at harvest in hybrid watermelon Arka Jyothi.

| | Fruit length at harvest (cm) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I year | | | | II year | | | | Pooled | | | |
| Treatments | $T_1$ | $T_2$ | $T_3$ | Mean | $T_1$ | $T_2$ | $T_3$ | Mean | $T_1$ | $T_2$ | $T_3$ | Mean |
| $P_1$–Fresh pollen | 28.33 | 28.23 | 27.93 | 28.16 | 28.40 | 28.26 | 27.86 | `28.17 | 28.36 | 28.25 | 27.90 | 28.17 |
| $P_2$–One day stored pollen | 28.26 | 28.03 | 27.76 | 28.02 | 28.20 | 28.06 | 27.70 | 27.98 | 28.23 | 28.05 | 27.73 | 28.00 |
| $P_3$–Two day stored pollen | 26.40 | 26.30 | 26.00 | 26.23 | 26.40 | 26.26 | 25.83 | 26.16 | 26.40 | 26.28 | 25.91 | 26.20 |
| Mean | 27.66 | 27.52 | 27.23 | 27.47 | 27.06 | 27.53 | 27.13 | 27.44 | 27.66 | 27.52 | 27.18 | 27.45 |

| For comparing the mean of | SEm± | CD at 5% | SEm± | CD at 5% | SEm± | CD at 5% |
|---|---|---|---|---|---|---|
| P | 0.06 | 0.19 | 0.07 | 0.20 | 0.01 | 0.09 |
| T | 0.06 | 0.19 | 0.07 | 0.20 | 0.04 | 0.14 |
| P × T | 0.11 | NS | 0.12 | NS | 0.07 | NS |

result in higher hybrid seed setting and yield compared to the stored pollen. Therefore, ideal time of crossing and effective pollen storage plays a decisive role in hybrid watermelon seed production which needs systematic investigation. Hence, the present study was taken up on pollen storage and crossing period on seed yield and quality of hybrid watermelon cv Arka Jyothi.

## Materials and Methods

Studies pertaining to pollination time and pollen storage period were conducted in hybrid watermelon Arka Jyothi at Agricultural Research Station, Kawadimatti (Zone 2). The required seed materials were obtained from the Division of Vegetable Crops, Indian Institute of Horticultural Research, Hesaragatta, Bengaluru. The block method of hybrid seed production was adopted for sowing of female and male parents in 3:1 planting ratio. Forceps, scalpel and needles were used for carrying out emasculation and pollination of female floral buds. Two ceramic cups, muslin cloth, plastic container, camel brush and scissors were used for collection of pollens from anthers of the male flowers and for dusting of pollens on stigmatic of surface emasculated female buds during crossing period. The experiment was laid out in randomized block design consisting of nine treatment combinations with two factors viz. pollen storage period is one factor; fresh pollen ($P_1$), one day old stored pollen ($P_2$) and two days old pollen ($P_3$), time of pollination as second factor; pollination at 6.00 to 7.00 am ($T_1$), pollination at 7.00 to 8.00 am and pollination at 8.00 to 9.00 am.

**Table 4.** Effect of pollen storage period and time of pollination on fruit girth at harvest (cm) in hybrid watermelon Arka Jyothi.

| | Fruit girth at harvest (cm) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I year | | | | II year | | | | Pooled | | | |
| Treatments | $T_1$ | $T_2$ | $T_3$ | Mean | $T_1$ | $T_2$ | $T_3$ | Mean | $T_1$ | $T_2$ | $T_3$ | Mean |
| $P_1$–Fresh pollen | 24.56 | 24.36 | 22.66 | 23.86 | 24.50 | 24.36 | 22.70 | 23.85 | 24.53 | 24.36 | 22.68 | 23.86 |
| $P_2$–One day stored pollen | 24.43 | 23.93 | 22.73 | 23.70 | 24.36 | 24.00 | 22.80 | 23.72 | 24.40 | 23.96 | 22.76 | 23.71 |
| $P_3$–Two day stored pollen | 22.53 | 22.40 | 22.20 | 22.37 | 22.60 | 22.43 | 22.23 | 22.42 | 22.56 | 22.41 | 22.21 | 22.40 |
| Mean | 23.84 | 23.56 | 22.53 | 23.31 | 23.82 | 23.60 | 22.57 | 23.33 | 23.83 | 23.58 | 22.55 | 23.32 |

| For comparing the mean of | SEm± | CD at 5% | SEm± | CD at 5% | SEm± | CD at 5% |
|---|---|---|---|---|---|---|
| P | 0.07 | 0.22 | 0.8 | 0.25 | 0.02 | 0.12 |
| T | 0.07 | 0.22 | 0.8 | 0.25 | 0.05 | 0.16 |
| P × T | 0.13 | 0.39 | 0.14 | 0.43 | 0.08 | 0.24 |

**Table 5.** Effect of pollen storage period and time of pollination on fruit yield per vine in hybrid watermelon Arka Jyothi.

| | Fruit yield per vine (kg) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I year | | | | II year | | | | Pooled | | | |
| Treatments | $T_1$ | $T_2$ | $T_3$ | Mean | $T_1$ | $T_2$ | $T_3$ | Mean | $T_1$ | $T_2$ | $T_3$ | Mean |
| $P_1$–Fresh pollen | 38.33 | 37.97 | 37.60 | 37.97 | 39.20 | 38.27 | 37.63 | 38.37 | 38.77 | 38.12 | 37.62 | 38.17 |
| $P_2$–One day stored pollen | 36.07 | 35.83 | 34.27 | 35.59 | 36.67 | 36.00 | 35.10 | 35.92 | 36.37 | 35.92 | 34.68 | 35.66 |
| $P_3$–Two day stored pollen | 36.07 | 34.23 | 33.33 | 34.54 | 36.23 | 35.07 | 33.30 | 34.87 | 36.15 | 34.65 | 33.32 | 34.71 |
| Mean | 36.82 | 36.01 | 35.07 | 35.96 | 37.37 | 36.44 | 35.34 | 36.38 | 37.09 | 36.23 | 35.21 | 36.17 |

| For comparing the mean of | SEm± | CD at 5% | SEm± | CD at 5% | SEm± | CD at 5% |
|---|---|---|---|---|---|---|
| P | 0.34 | 1.01 | 0.27 | 0.81 | 0.04 | 0.12 |
| T | 0.34 | 1.01 | 0.27 | 0.81 | 0.19 | 0.55 |
| P × T | 0.59 | 1.75 | 0.47 | 1.41 | 0.27 | NS |

## Pollen collection

At the start of blooming period in hybrid seed production, the male floral buds likely to open next day morning hours were selected in the male parental block and were bagged with brown paper bags in the previous evening hours. Such bagged male buds were collected in a polythene bag in the next day early morning hours. Pollen were extracted manually from the anthers of male floral buds and collected in the ceramic cup by using a camel brush. The extracted pollens were then transferred to glass vials for storage studies as listed under treatment schedule. The plastic vials were labeled properly and kept in a refrigerator at 10°C±1°C for one day and two days period. Subsequently, such stored pollen were used for crossing of emasculated female buds in the morning hours.

## Emasculation work

The emasculation work was carried out in the female parental block of hybrid watermelon experimental plot in the previous day evening hours. In the female IIHR-20 plants, emasculation was done manually by pinching off fully developed male flower buds from the vines and it was continued until last of male flower buds from the vines was removed. Further, only pistillate buds likely to open next day were bagged with butter paper bags for easy identification and were crossed manually with pollen of male parent in next day morning hour.

The both manual emasculation and dusting works were continued up to 15 days from the start of first anthesis day and subsequently all the floral buds emerging out beyond 15 days after crossing period were pinched off to ensure better growth and devel-

**Table 6.** Effect of pollen storage period and time of pollination on number of seeds per fruit in hybrid watermelon Arka Jyothi.

| | Number of seeds per fruit | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I year | | | | II year | | | | Pooled | | | |
| Treatments | $T_1$ | $T_2$ | $T_3$ | Mean | $T_1$ | $T_2$ | $T_3$ | Mean | $T_1$ | $T_2$ | $T_3$ | Mean |
| $P_1$–Fresh pollen | 58.67 | 57.33 | 55.00 | 57.00 | 58.67 | 57.67 | 55.33 | 57.22 | 58.67 | 57.50 | 55.17 | 57.11 |
| $P_2$–One day stored pollen | 54.00 | 51.67 | 47.67 | 51.11 | 54.33 | 51.67 | 47.70 | 51.22 | 54.17 | 51.67 | 47.67 | 51.17 |
| $P_3$–Two day stored pollen | 47.67 | 44.67 | 44.00 | 45.44 | 48.00 | 45.00 | 44.33 | 45.78 | 47.83 | 44.83 | 44.17 | 45.61 |
| Mean | 53.44 | 51.22 | 48.89 | 51.18 | 53.70 | 51.44 | 49.11 | 51.40 | 53.56 | 51.33 | 49.00 | 51.29 |

| For comparing the mean of | SEm± | CD at 5% | SEm± | CD at 5% | SEm± | CD at 5% |
|---|---|---|---|---|---|---|
| P | 0.41 | 1.23 | 0.52 | 1.56 | 0.29 | 0.98 |
| T | 0.41 | 1.23 | 0.52 | 1.56 | 0.31 | 0.90 |
| P × T | 0.72 | NS | 0.90 | NS | 0.44 | NS |

**Table 7.** Effect of pollen storage period and time of pollination on percentage of filled seeds in hybrid watermelon Arka Jyothi.

| | Percentage of filled seeds | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I year | | | | II year | | | | Pooled | | | |
| Treatments | $T_1$ | $T_2$ | $T_3$ | Mean | $T_1$ | $T_2$ | $T_3$ | Mean | $T_1$ | $T_2$ | $T_3$ | Mean |
| $P_1$–Fresh pollen | 87.60 | 86.93 | 86.90 | 87.14 | 87.53 | 87.37 | 86.90 | 87.27 | 87.57 | 87.15 | 86.90 | 87.21 |
| $P_2$–One day stored pollen | 84.73 | 83.27 | 80.63 | 82.88 | 84.90 | 83.33 | 80.12 | 82.78 | 84.81 | 83.30 | 80.38 | 82.83 |
| $P_3$–Two day stored pollen | 80.33 | 79.10 | 77.93 | 79.12 | 80.45 | 79.27 | 78.22 | 79.31 | 80.39 | 79.19 | 78.08 | 79.22 |
| Mean | 84.22 | 83.10 | 81.82 | 83.04 | 84.29 | 83.32 | 81.75 | 83.12 | 84.26 | 83.21 | 81.78 | 83.08 |
| For comparing the mean of | SEm± | | CD at 5% | | SEm± | | CD at 5% | | SEm± | | CD at 5% | |
| P | 0.27 | | 0.82 | | 0.30 | | 0.90 | | 0.03 | | 0.94 | |
| T | 0.27 | | 0.82 | | 0.30 | | 0.90 | | 0.18 | | 0.54 | |
| P × T | 0.48 | | 1.41 | | 0.52 | | 1.56 | | 0.26 | | 0.76 | |

opment of crossed fruits as well as hybrid seeds on the female parent.

Pollination (crossing) work

For purpose of crossing work, both fresh pollens and stored pollens extracted from floral buds of Crimson Red male variety were collected in small glass beakers. In the early morning hours of the crossing day, the butter paper bags were removed from the female flower buds and their stigma were gently dipped in male pollen mass. The dusted female buds were tagged with a label indicating crossing is done. The setting of crossed fruits was confirmed at 12 days after crossing. The both emasculation and dusting works were continued upto 15 days from the start of first anthesis day and the female and male buds emerging out beyond 15 days of crossing period were pinched off to ensure better growth and development of crossed fruits and hybrid seeds on the female parent.

In female parent block (IIHR-20), about five normal growing vines from each treatments were selected at random and tagged with a wax coated label for recording the observations on various biometric parameters as detailed below.

Number of crossed
fruits per vine

At 12 days after crossing, the number of crossed fruit set on each vine were counted on the five randomly tagged vines for each treatment and replications. Average was computed and expressed as number of crossed fruits per vine.

Fruit set (%) per vine

This observation was recorded at 12 days after crossing on female parent. The fruit set percentage was calculated based on total number of floral buds crossed and number of fruit set on each vine were counted and it was expressed as fruit set percentage by using the formula as below.

$$\text{Fruit set (\%) per vine} = \frac{\text{Total number of crossed fruits set per vine}}{\text{Total number of female buds crossed per vine}} \times 100$$

Fruit length (cm)

The distance between the two diagonally opposite edges of the fruit was considered as length of the water melon fruit. At harvest, it was measured on a metric scale from ten randomly selected crossed fruits for each treatments and average was expressed in centimeters.

Fruit girth

The earlier selected ten fruits were cut vertically into two halves at the broadest point of the fruit by using

**Table 8.** Effect of pollen storage period and time of pollination on seed weight per fruit in hybrid watermelon Arka Jyothi.

| | Seed weight per fruit (g) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I year | | | | II year | | | | Pooled | | | |
| Treatments | $T_1$ | $T_2$ | $T_3$ | Mean | $T_1$ | $T_2$ | $T_3$ | Mean | $T_1$ | $T_2$ | $T_3$ | Mean |
| $P_1$–Fresh pollen | 5.00 | 4.90 | 4.63 | 4.84 | 5.10 | 4.93 | 4.66 | 4.90 | 5.05 | 4.91 | 4.65 | 4.87 |
| $P_2$–One day stored pollen | 4.96 | 4.73 | 4.43 | 4.71 | 4.93 | 4.76 | 4.40 | 4.70 | 4.95 | 4.75 | 4.41 | 4.70 |
| $P_3$–Two day stored pollen | 4.86 | 4.53 | 4.26 | 4.56 | 4.83 | 4.50 | 4.20 | 4.51 | 4.85 | 4.51 | 4.23 | 4.53 |
| Mean | 4.94 | 4.72 | 4.44 | 4.70 | 4.95 | 4.73 | 4.42 | 4.70 | 4.95 | 4.72 | 4.43 | 4.70 |
| For comparing the mean of | SEm± | | CD at 5% | | SEm± | | CD at 5% | | SEm± | | CD at 5% | |
| P | 0.05 | | 0.14 | | 0.03 | | 0.11 | | 0.01 | | 0.03 | |
| T | 0.05 | | 0.14 | | 0.03 | | 0.11 | | 0.02 | | 0.07 | |
| P × T | 0.08 | | 0.25 | | 0.06 | | 0.19 | | 0.03 | | NS | |

the sharp knife. The girth of the cut fruit was measured by using the metric scale. The average was expressed as fruit girth in centimeter.

Fruit yield (kg) per vine

All the fully ripened fruits harvested treatment wise from the five tagged vines and they were weighed using an electronic weighing balance and their average weight was expressed as fruit yield in kilograms per vine.

Total number of seeds per fruit

In each of the treatments, the five normal fruits from the tagged vines were chosen randomly and their seeds were extracted manually from the tagged fruits by slicing and squeezing method. The total number of matured and immatured seeds extracted from each fruits was counted manually and their mean was expressed as total number of seeds per fruit.

Percentage of filled seeds

Based on the number of matured and immature seeds obtained from the each fruits, the percentage of filled seeds was calculated treatment wise and replication wise by using the following formula.

$$\text{Filled seeds (\%)} = \frac{\text{Number of filled seeds obtained per fruit}}{\text{Number of filled + unfilled seeds obtained per fruit}} \times 100$$

**Table 9.** Effect of pollen storage period and time of pollination on seed yield (kg) per ha in hybrid watermelon Arka Jyothi.

| | Seed yield (kg/ha) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I year | | | | II year | | | | Pooled | | | |
| Treatments | $T_1$ | $T_2$ | $T_3$ | Mean | $T_1$ | $T_2$ | $T_3$ | Mean | $T_1$ | $T_2$ | $T_3$ | Mean |
| $P_1$–Fresh pollen | 83.97 | 82.93 | 65.90 | 77.60 | 84.33 | 83.00 | 83.00 | 83.44 | 84.15 | 82.97 | 74.45 | 80.52 |
| $P_2$–One day stored pollen | 78.97 | 76.60 | 74.37 | 76.64 | 79.44 | 76.33 | 74.55 | 76.77 | 79.20 | 76.47 | 74.46 | 76.71 |
| $P_3$–Two day stored pollen | 73.90 | 72.53 | 68.67 | 71.70 | 73.88 | 72.22 | 68.22 | 71.44 | 73.89 | 72.38 | 68.44 | 71.57 |
| Mean | 78.94 | 77.36 | 69.64 | 75.31 | 79.22 | 77.18 | 75.26 | 77.21 | 79.08 | 77.27 | 72.45 | 76.26 |
| For comparing the mean of | SEm± | | CD at 5% | | SEm± | | CD at 5% | | SEm± | | CD at 5% | |
| P | 0.64 | | NS | | 0.72 | | 2.15 | | 1.26 | | 7.69 | |
| T | 0.64 | | NS | | 0.72 | | 2.15 | | 1.65 | | NS | |
| P × T | 1.19 | | NS | | 1.25 | | NS | | 2.34 | | NS | |

**Table 10.** Effect of pollen storage period and time of pollination on 100 seed weight in hybrid watermelon Arka Jyothi.

| | 100 seed weight (g) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I year | | | | II year | | | | Pooled | | | |
| Treatments | $T_1$ | $T_2$ | $T_3$ | Mean | $T_1$ | $T_2$ | $T_3$ | Mean | $T_1$ | $T_2$ | $T_3$ | Mean |
| $P_1$–Fresh pollen | 7.93 | 7.90 | 7.80 | 7.87 | 7.93 | 7.76 | 7.63 | 7.78 | 7.93 | 7.83 | 7.71 | 7.82 |
| $P_2$–One day stored pollen | 7.70 | 7.53 | 7.43 | 7.55 | 7.76 | 7.63 | 7.46 | 7.62 | 7.73 | 7.58 | 7.45 | 7.58 |
| $P_3$–Two day stored pollen | 7.53 | 7.43 | 7.33 | 7.43 | 7.53 | 7.46 | 7.40 | 7.46 | 7.53 | 7.45 | 7.36 | 7.45 |
| Mean | 7.72 | 7.62 | 7.52 | 7.62 | 7.74 | 7.62 | 7.50 | 7.62 | 7.73 | 7.62 | 7.51 | 7.62 |
| For comparing the mean of | SEm± | | CD at 5% | | SEm± | | CD at 5% | | SEm± | | CD at 5% | |
| P | 0.04 | | 0.12 | | 0.03 | | 0.11 | | 0.04 | | 0.13 | |
| T | 0.04 | | 0.12 | | 0.03 | | 0.11 | | 0.02 | | 0.08 | |
| P × T | 0.07 | | NS | | 0.06 | | NS | | 0.04 | | NS | |

Seed weight (g) per fruit

The total number of seeds extracted from each fruit were weighed on an electronic precision balance and their average weight was expressed as seeds weight in grams per fruit.

Seed yield (kg)
per hectare

Based on the seed yield obtained from vines of the net plot area, the seed yield per hectare was calculated and expressed in killograms of seed yield per hectare. After harvest of the crop, seeds were extracted by fermentation method treatment combination wise and observations was recorded on seed quality parameters such as seed germination (%), seedling vigor index and seedling dry weight (mg) were taken as per the ISTA rules.

## Results and Discussion

Watermelon is mainly cross pollinated crop and it exhibits about 40% natural cross pollination depending upon agroclimatic conditions and varieties. The watermelon flower opens shortly after sunrise and remains open for only one day. The anthers dehisce usually before flower anthesis and pollen is usually sticky in nature adhering to anthers. The stigma is receptive throughout the day and favours natural cross pollination. The honey bees are the main pollen vectors for pollination of watermelon flowers which is an incidental activity carried out by them. In watermelon flower, anther dehiscence and stigma receptivity are influenced by dry temperature, humidity and other factors. These factors should be at optimum level during the flowering period in order to get maximum setting of hybrid seeds and yield in watermelon. In addition to this, the success of seed setting and yield in hybrid watermelon is decided by the amount of pollen mass deposited on the receptive stigma of the female parent during flowering period and it is directly related to the time of pollination (crossing) practiced. In case the female flower is crossed very early or very late, it may not give substantial seed setting resulting in poor seed yield. Further, period of pollen storage also plays a significant role on seed setting and yield in hybrid watermelon. The old pollens may not have desired viability and vigor to effect fertilization.

Period of pollen storage has shown significant influence on various seed yield and quality components, irrespective of pollination time in both the years. However, the analysis of pooled data exhibited marked differences with regard to effect of pollen storage period on number of crossed fruits per vine, fruit girth, seed weight per fruit, fruit weight and percentage of filled seeds irrespective of pollination time (Tables 1— 9). All these parameters were significantly highest (7.55, 23.86 cm, 4.87 kg, 7.75 kg and 87.21%), respectively in the fruits obtained from crossing with fresh pollen compared to two days stored pollens

**Table 11.** Effect of pollen storage period and time of pollination on germination percentage in hybrid watermelon Arka Jyothi.

| Treatments | Germination (%) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I year | | | | II year | | | | Pooled | | | |
| | $T_1$ | $T_2$ | $T_3$ | Mean | $T_1$ | $T_2$ | $T_3$ | Mean | $T_1$ | $T_2$ | $T_3$ | Mean |
| $P_1$–Fresh pollen | 87.33 | 86.00 | 83.67 | 85.66 | 88.33 | 86.67 | 83.00 | 86.00 | 87.83 | 86.33 | 83.33 | 85.83 |
| $P_2$–One day stored pollen | 86.33 | 83.67 | 82.00 | 84.00 | 86.33 | 85.00 | 82.33 | 84.56 | 86.33 | 84.33 | 82.17 | 84.28 |
| $P_3$–Two day stored pollen | 72.67 | 73.67 | 71.00 | 72.44 | 74.00 | 73.33 | 71.00 | 72.78 | 73.33 | 73.50 | 71.00 | 72.61 |
| Mean | 82.11 | 81.11 | 78.89 | 80.70 | 82.88 | 81.67 | 78.78 | 81.11 | 82.49 | 81.39 | 78.83 | 80.90 |
| For comparing the mean of | SEm± | | CD at 5% | | SEm± | | CD at 5% | | SEm± | | CD at 5% | |
| P | 0.31 | | 0.93 | | 9.34 | | 1.02 | | 0.11 | | 0.36 | |
| T | 0.31 | | 0.93 | | 9.34 | | 1.02 | | 0.22 | | 0.65 | |
| P × T | 0.54 | | NS | | 0.69 | | NS | | 0.32 | | NS | |

(4.22, 22.40 cm, 4.53 g, 7.04 kg and 79.22% respectively). The next higher values for all these parameters were observed in the one day stored pollens. The marked increase in various seed yield components noticed in fresh pollens followed by one day old as against two days old may be attributed to fact that the fresh pollens may have more number of viable pollens and also higher and longer pollen viability period compared to two day old pollens. This might have resulted in higher fruit setting and seed yield components. Irrespective of pollination time, two day old stored pollens recorded significantly the lowest values for seed yield components which may be attributed to the significant loss of pollen viability and also the shorter pollen viability period and it might have resulted in the poor seed setting and seed yield components compared to fresh pollen. These results are in agreement with findings of various studies. [1—3] which indicated that fresh pollen was more useful to get satisfactory seed set and yield in brinjal seed production compared to two days stored pollen.

With regard to pollination time, significant differences due to pollen storage period were seen for the various seed quality parameters studied such as 100 seed weight, seed germination (%) and seedling vigor index and seedling dry weight (Tables 10—13). In general, all these seed quality parameters were significantly higher in the seeds extracted from the fruits of fresh pollens used for crossing followed by one day pollens as against two day old pollens. The significant increase in seed quality indices noticed in the fresh pollens may be related to the higher seed weight coupled with bolder and well developed seeds obtained from the fruits of fresh pollens compared to those obtained from fruits of two day old pollens. These findings were also confirmed by the work of other research workers [1, 2, 4].

Significant variations were observed due to crossing times for various flowering, fruiting and seed yield components irrespective of the pollen storage. The crossing of female buds at 6.00 to 7.00 am period recorded significantly and consistently highest number of crossed fruits per vine, fruit set percentage, fruit girth, fruit length, fruit weight, fruit yield per vine, seed weight per fruit, filled seed percentage, number of seeds per fruit, seed yield per vine and it was followed by 7.00 to 8.00 am crossing time. On the other hand, all these parameters were significantly lowest in the 8.00 to 9.00 am crossing time irrespective of the pollen storage period. In this study, the highest number of crossed fruits per vine, fruit girth, fruit length, fruit weight, fruit yield per vine, filled seed percentage, number of seeds per fruit, seed weight per fruit, seed yield per vine noticed in 6.00 to 7.00 am crossing time may be ascribed to higher pollen viability and germination and also peak receptivity of stigma in the early morning hours (6.00 to 7.00 am) due to cool congenial weather condition prevailed. Obviously, these conditions might have favored in the effective fertilization and resulted in higher fruit setting and seed yield components. On the contrary, values for all the above parameters were the significantly lowest in the

**Table 12.** Effect of pollen storage period and time of pollination on seedling vigor index in hybrid watermelon Arka Jyothi.

| | Seedling vigor index | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I year | | | | II year | | | | Pooled | | | |
| Treatments | $T_1$ | $T_2$ | $T_3$ | Mean | $T_1$ | $T_2$ | $T_3$ | Mean | $T_1$ | $T_2$ | $T_3$ | Mean |
| $P_1$–Fresh pollen | 2052 | 1998 | 1846 | 1965 | 2083 | 1998 | 1834 | 1972 | 2067 | 1998 | 1839 | 1968 |
| $P_2$–One day stored pollen | 1991 | 1916 | 1798 | 1902 | 1999 | 1934 | 1803 | 1912 | 1995 | 1925 | 1800 | 1907 |
| $P_3$–Two day stored pollen | 1591 | 1571 | 1481 | 1548 | 1630 | 1576 | 1479 | 1561 | 1610 | 1573 | 1480 | 1554 |
| Mean | 1878 | 1828 | 1708 | 1805 | 1904 | 1836 | 1705 | 1815 | 1891 | 1832 | 1706 | 1810 |
| For comparing the mean of | SEm± | | CD at 5% | | SEm± | | CD at 5% | | SEm± | | CD at 5% | |
| P | 9.73 | | 28.92 | | 9.95 | | 29.59 | | 2.71 | | 8.16 | |
| T | 9.73 | | 28.92 | | 9.95 | | 29.57 | | 7.00 | | 20.17 | |
| P × T | 16.84 | | NS | | 17.24 | | NS | | 9.90 | | NS | |

fruits obtained from 8.00 to 9.00 am crossing time which might have caused loss of pollen viability, due to rise in day temperature, drying of stigmatic surface and rising sunlight as the day advanced. Hence, it resulted in poor pollen germination, fertilization, fruit setting and fruit yield components compared to those obtained from 6.00 to 7.00 am pollination time irrespective of pollen storage. These results are in agreement with the findings of other research scientists [1—6].

The seed quality parameters under the study exhibited marked differences due to crossing time irrespective of pollen storage. 100 seed weight, seed germination, seedling vigor index and seedling dry weight were significantly highest (7.73 g, 82.49%, 1891 and 20.39 mg, respectively) in the fruits of 6.00 to 7.090 am crossing time followed by 7.00 to 8.00 am crossing period as against those obtained from 8.00 to 9.00 am crossing period (7.51 g, 78.83%, 1706 and 18.36 mg, respectively). The superior seed quality parameters noticed in the 6.00 to 7.00 am crossing time may be due to higher fruit weight, number of seeds per fruit and seed weight per fruit as evident in this study and these might have further resulted in more number of heavier and bolder seeds contributing to better seed quality. On the other hand, the lower seed quality traits seen in the 8.00 to 9.00 am crossing period might be attributed to more number of immature, undersized and shriveled seeds obtained from fruits of the de-

**Table 13.** Effect of pollen storage period and time of pollination on dry weight of seedling in hybrid watermelon Arka Jyothi. NS – Non significant, $T_1$ : Pollination at 6.00 to 7.00 am, $T_2$ : Pollination at 7.00 to 8.00 am, $T_3$ : Pollination at 8.00 to 9.00 am.

| | Dry weight of seedling (mg) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I year | | | | II year | | | | Pooled | | | |
| Treatments | $T_1$ | $T_2$ | $T_3$ | Mean | $T_1$ | $T_2$ | $T_3$ | Mean | $T_1$ | $T_2$ | $T_3$ | Mean |
| $P_1$–Fresh pollen | 21.79 | 19.93 | 20.60 | 20.77 | 22.20 | 20.94 | 19.97 | 21.04 | 21.99 | 20.43 | 20.28 | 20.90 |
| $P_2$–One day stored pollen | 20.80 | 18.53 | 15.73 | 18.35 | 20.91 | 18.97 | 18.55 | 19.48 | 20.85 | 18.75 | 17.14 | 18.91 |
| $P_3$–Two day stored pollen | 18.33 | 17.46 | 17.80 | 17.86 | 18.37 | 17.93 | 17.53 | 17.94 | 18.35 | 17.69 | 17.66 | 17.90 |
| Mean | 20.30 | 18.64 | 18.04 | 18.99 | 20.49 | 19.28 | 18.68 | 19.49 | 20.39 | 18.96 | 18.36 | 19.24 |
| For comparing the mean of | SEm± | | CD at 5% | | SEm± | | CD at 5% | | SEm± | | CD at 5% | |
| P | 0.52 | | 1.56 | | 0.08 | | 0.24 | | 0.25 | | 0.78 | |
| T | 0.52 | | 1.56 | | 0.08 | | 0.24 | | 0.26 | | 0.76 | |
| P × T | 0.91 | | NS | | 0.14 | | NS | | 9.37 | | NS | |

layed pollination (8.00 to 9.00 am). These results are well supported with findings of similar studies in brinjal and tomato [1, 2].

These results indicated that crossing of flower buds at 6.00 to 7.00 am with fresh pollen was found to be ideal for watermelon hybrid seed production for getting higher fruit set percentage, fruit weight, seed number, seed weight, seed germination, vigor index and seedling dry weight compared to 8.00 to 9.00 am crossing period and two days stored pollens. The interaction effect between pollen storage period and crossing time (P × T) was found to be non-significant for most of the fruit, seed yield and quality parameters studied. In this study the consistently higher fruit set percentage, seed yield components and seed quality parameters were noticed in the fruits obtained from dusting of fresh pollens at 6.00 to 7.00 am due to higher retention of pollen viability and stigma receptivity period in the early morning hours compared to those obtained from dusting of two day old pollens at 8.00 to 9.00 am timing, where, the rising day temperature and dry condition might have caused significant loss in pollen viability as well as stigma receptivity. The results uphold the findings of earlier studies made by other scientists in various crops [1—5, 7, 8].

Seed weight per fruit, percentage of filled seeds, seed germination and vigor index were recorded consistently maximum values from fresh pollens crossed at 6.00 am to 7.00 am ($P_1T_1$) followed by one day old pollens crossed at 8.00 am to 9.00 am ($P_2T_2$) irrespective of crossing time. Hence, it is concluded that for the production of quality seeds and improved productivity of watermelon, fresh pollens could be used for pollination at 6.00 am to 7.00 am.

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