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# Variation in carbon fixation and water use efficiency among date palm cultivars grown in arid zone

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**Abstract**

Seven commercial cultivars of date palm (Halawy, Khadrawy, Shamran, Zahidi, Medjool, Khuneizi and Khalas) were evaluated on the basis of physiological parameters. The net photosynthetic rate, transpiration, stomatal conductance and internal $CO_2$ concentration were estimated using LI-6200 Infra Red Gas Analyzer. The values of carboxylation efficiency and water use efficiency were computed. The results demonstrate that in date palm maximum rate of photosynthesis occurs during spathe emergence stage, which shows that probably this stage has a high sink demand. It was further noticed that higher rate of photosynthesis in date palm is on account of higher stomatal conductance. Inter-cultivars comparison revealed that cv. Halawy might have advantage over others in hot arid ecosystem, as this cultivar possesses high rate of photosynthesis, water use efficiency and carboxylation efficiency.

**Key words:** *Arid ecosystem , date palm, carboxylation efficiency, photosynthesis*

## Introduction

Date palm (*Phoenix dactylifera* L.) is a potential fruit tree of Indian arid ecosystem. Its nutritious fruits having high calorific value are eaten as raw dates (fresh khalal fruits), dry dates (*chuhhara*) and soft dates (tamar). It is suitable for cultivation on marginal lands even if irrigated with saline water. Because of tolerance to high salinity, aridity and maximum temperature (48°C), date palm is a hardy fruit tree of semi arid and arid regions. Various attempts have been made in past to evaluate the varietal characters of date palm cultivars on the basis of morphological parameters (Chandra *et al.*, 1990) isozyme patterns (Al-Helal, 1988; Al Jibouri and Adhan, 1990) and flavonoid spectrum (Ouafi *et al.*, 1988). However, the work on the growth and development particularly on photosynthetic efficiency of date palm cultivars is rare. Moreover, it has been pointed out that lower loss of water through foliar transpiration (Singh *et al.*, 1998) effectively control water loss by stomatal closure under water stress, higher intrinsic water use efficiency (Jones, 1992) and increase in content of hexose sugar and proline (Clifford *et al.*, 1997) are some of the important characterstics of drought tolerant plants such as ber.

Accordingly, the present study was undertaken with the aim to compare seven cultivars of date palm on the basis of physiological parameters with a view to identify most suitable cultivar, which can thrive best in arid ecosystem. The results thus obtained constitute the text of the present communication.

## Materials and methods

The study was conducted during the year 2001-2002 in the National Repository of Date palm at Central Institute for Arid Horticulture, Bikaner situated at 28.01° North latitude and 73.22° East longitude at an altitude of 234.70 meter above mean sea level. The soil of this region is sandy and low in organic matter. The uniform plants of seven commercial cultivars viz. Halawy, Khalas, Khuneizi, Medjool, Khadrawy, Zahidi and Shamran were selected for the study. The study was carried out on four-years old palm trees in three replications. The plants were maintained under normal cultural practices and irrigation was done at 15 days interval. For photosynthesis measurement, middle leaflet of expanded leaves were chosen at all stages on the same plant. The data on photosynthetic rate, transpiration, stomatal conductance was measured using LI-6200 Infra Red Gas Analyser (LICOR, USA). The observations were recorded between 10 to 11 h at all the four stages viz. vegetative growth, spathe emergence, fruit set and fruit development. The value for carboxylation efficiency was computed as ratio of photosynthetic rate to internal $CO_2$ concentration and water use efficiency as ratio of photosynthetic rate to transpiration as described by Das et al. (1999). Since the observations were taken in germplasm block, the data was statistically analyzed using CRD with the help of MSTAT software.

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## Results and discussion

### *Photosynthetic rate*

The results obtained on photosynthetic rate in seven cultivars of date palm are presented in Table 1. Perusal of data reveals that at vegetative stage cv. Shamran had significantly the highest net photosynthetic rate (15.46 μmol $m^{-2}$ $s^{-1}$) followed by Khalas and Halawy. At spathe emergence stage the maximum photosynthetic rate was observed in Shamran (16.09 μmol $m^{-2}$ $s^{-1}$) followed by Zahidi (15.34 μmol $m^{-2}$ $s^{-1}$) and Medjool. However, Khuneizi and Khalas cultivars had low rate at this stage. At fruit initiation stage the net photosynthetic rate was at par in Shamran, Halawy, Khuneizi and Medjool. Similarly at fruit development stage, the maximum net photosynthetic rate was in Zahidi (13.31 μmol $m^{-2}$ $s^{-1}$) followed by Khuneizi, Halawy and Khalas while lowest net photosynthetic rate was observed in cultivar Khadrawy. The significant observation which emerge from the present study is that the net photosynthetic rate in all the cultivars was highest at the spathe emergence stage. This illustrate that the plant has a high sink demand at this stage.

**Table 1.** Photosynthetic variation (μmol $m^{-2}$ $s^{-1}$) in date palm cultivars

| Variety | Stage | | | |
|---|---|---|---|---|
| | Vegetative growth | Spathe emergence | Fruit set | Fruit development |
| Halawy | 13.30 | 14.36 | 11.52 | 7.99 |
| Khadrawy | 12.39 | 13.55 | 7.48 | 5.93 |
| Shamran | 15.46 | 16.09 | 11.51 | 6.52 |
| Zahidi | 11.65 | 15.34 | 10.79 | 13.31 |
| Medjool | 12.22 | 14.74 | 11.23 | 7.17 |
| Khunezi | 10.69 | 12.48 | 11.93 | 8.19 |
| Khalas | 13.41 | 12.15 | 10.59 | 7.87 |
| C D at 5% | 0.571 | 0.964 | 0.844 | 2.19 |

The leaf $CO_2$ assimilation in date palm has been studied in past by Al-Whaibi (1988) where he compared the rates in cvs. Sukkeri and Osaila and reported that Osaila has 13% higher rate than cv. Sukkeri. The results are also in line with the above and demonstrate inter cultivar variations in photosynthetic rates. Thus, taking into consideration the stage at which plants have highest net photosynthetic rate (spathe emergence), the cultivars could be classified into 2 groups:

Group A- having higher net photosynthesis rate (more than 14 μmol $m^{-2}$ $s^{-1}$). (Halawy, Shamran, Zahidi, Medjool)

Group B- having low net photosynthetic rate (less than 14 μmol $m^{-2}$ $s^{-1}$). (Khadrawy, Khuneizi and Khalas)

### *Transpiration*

The data pertaining to transpiration rate in seven commercial cultivars of date palm are depicted in Table 2.

**Table 2.** Variation in transpiration rates (mmol $H_2O$ $m^{-2}$ $s^{-1}$) in date palm cultivars

| Variety | Stage | | | |
|---|---|---|---|---|
| | Vegetative growth | Spathe emergence | Fruit set | Fruit development |
| Halawy | 5.45 | 2.82 | 3.65 | 4.44 |
| Khadrawy | 5.49 | 2.74 | 5.89 | 5.54 |
| Shamran | 8.48 | 4.14 | 6.27 | 5.94 |
| Zahidi | 6.39 | 4.05 | 6.01 | 6.33 |
| Medjool | 6.11 | 4.11 | 5.39 | 5.94 |
| Khunezi | 5.46 | 3.78 | 6.24 | 4.85 |
| Khalas | 6.89 | 3.50 | 4.64 | 5.54 |
| C D at 5% | 0.091 | 0.054 | 0.079 | 0.073 |

Perusal of data reveals that at vegetative growth stage Shamran shows maximum transpiration rate (8.48 mmol $H_2O$ $m^{-2}$ $s^{-1}$) followed by Khalas, Zahidi and Medjool. The minimum value was recorded in cvs. Halawy and Khuneizi.

At spathe emergence stage, the transpiration rate was low in all the cultivars. The maximum rate was observed in Shamran and Medjool and lowest was in cvs. Khadrawy and Halawy showing thereby that the plant of Khadrawy and Halawy are able to conserve water under low moisture availability by reducing their transpiration rate. Similar pattern was observed at fruit initiation and fruit development stages also.

### *Stomatal conductance*

The data on stomatal conductance in seven cultivars at different growth stages are presented in Table 3. Perusal of data reveals that at vegetative growth stage the stomatal conductance in cvs. Shamran, Zahidi and Medjool were high whereas Khadrawy showed least value (4.411 cm $s^{-1}$). However at all other stages the date palm plants maintained lower rate of stomatal conductance ( <4.0 cm $s^{-1}$) as compared to vegetative growth stage. This is illustrated by the fact that at spathe emergence stage the highest value recorded was 3.997 cm $s^{-1}$ in cv. Shamran. The same cultivar showed highest stomatal conductance (3.88 cm $s^{-1}$) at fruit

**Table 3.** Variation in stomatal conductance in date palm cultivars (cm $s^{-1}$)

| Variety | Stage | | | |
|---|---|---|---|---|
| | Vegetative growth | Spathe emergence | Fruit set | Fruit development |
| Halawy | 5.178 | 3.568 | 2.579 | 2.035 |
| Khadrawy | 4.441 | 2.640 | 2.708 | 1.983 |
| Shamran | 6.849 | 3.997 | 3.88 | 2.041 |
| Zahidi | 6.529 | 3.922 | 3.298 | 2.850 |
| Medjool | 6.083 | 3.868 | 2.490 | 2.696 |
| Khunezi | 4.488 | 3.588 | 3.824 | 2.216 |
| Khalas | 4.518 | 3.564 | 3.600 | 3.686 |
| C D at 5% | 1.151 | 0.392 | 0.407 | 0.788 |

initiation stage and cv. Khalas (3.68 cm $s^{-1}$) at fruit development stage.

The studies conducted by Al-Whaibi (1988) have demonstrated that higher rate of photosynthesis and water use efficiency of date palm cv. Osaila is on account of high stomatal conductance. In this study also it has been observed that cultivars having higher rate of $CO_2$ assimilation and transpiration also have higher rate of stomatal conductance. For instance at spathe emergence stage, cv. Shamran showed has highest rate of net photosynthesis (16.09 µmol $m^{-2}$ $s^{-1}$), high transpiration rate (4.14 mmol $H_2O$ $m^{-2}$ $s^{-1}$) and high rate of stomatal conductance too (3.997 cm $s^{-1}$). Thus, it indicates that the high rate of photosynthesis in date palm cultivars is on account of higher stomatal conductance. This finding is in accordance with the results reported by Al-Whaibi (1988).

***Carboxylation efficiency***

The data on carboxylation efficiency was calculated using the net photosynthetic rate and internal $CO_2$ concentration. The results demonstrate that at vegetative growth stage the maximum carboxylation efficiency was recorded in cvs. Shamran and Halawy followed by Khalas, Khadrawy and Medjool. At spathe emergence stage, the maximum carboxylation efficiency was observed in cv. Shamran and Halawy followed by Zahidi. Similarly, at fruit initiation stage, the maximum carboxylation efficiency was recorded in Shamran followed by Khuneizi and Halawy. Similar results were also obtained at fruit development stage (Table 4).

**Table 4.** Variation in carboxylation efficiency in date palm cultivars

| Variety | Stage | | | |
|---|---|---|---|---|
| | Vegetative growth | Spathe emergence | Fruit set | Fruit development |
| Halawy | 0.0511 | 0.0501 | 0.0426 | 0.0294 |
| Khadrawy | 0.0468 | 0.0432 | 0.0271 | 0.0213 |
| Shamran | 0.0598 | 0.0517 | 0.0434 | 0.0231 |
| Zahidi | 0.0400 | 0.0489 | 0.0405 | 0.0467 |
| Medjool | 0.0459 | 0.0400 | 0.0419 | 0.0263 |
| Khunezi | 0.0373 | 0.0425 | 0.0440 | 0.0302 |
| Khalas | 0.0483 | 0.0392 | 0.0403 | 0.0293 |
| C D at 5% | 0.0147 | 0.0031 | 0.0040 | 0.0031 |

Thus, on the basis of carboxylation efficiency at spathe emergence stage (since the photosynthetic rate was maximum at this stage), the cultivars can be classified into 2 groups viz.,

Group A- having carboxylation efficiency more than 0.045 (Halawy, Shamran, Zahidi)

Group B- having carboxylation efficiency less than 0.045 (Khadrawy, Medjool, Khuneizi and Khalas)

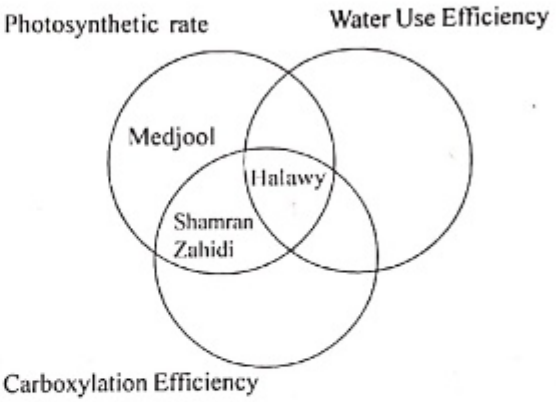


**Fig. 1.** Venne Diagram showing distribution of date palm cultivars on the basis of physiological parameters.

***Water use efficiency***

The data on water use efficiency in date palm cultivars at four growth stages is presented in Table 5. The data reveal that at vegetative growth stage cv. Halawy had the maximum water use efficiency (2.44 µmol $CO_2$ fixed/ mmol of $H_2O$ transpired) followed by Khadrawy (2.25 µmol $CO_2$ fixed/ mmol of $H_2O$ transpired ). At spathe emergence stage, the maximum water use efficiency was in cv. Halawy (5.09 µmol $CO_2$ fixed/ mmol of $H_2O$ transpired) followed by Khadrawy (4.94 µmol $CO_2$ fixed/ mmol of $H_2O$ transpired). All other cultivars showed value less than 4.0. At fruit initiation stage and fruit development stage, the water use efficiency was comparatively low in all the cultivars. At

**Table 5.** Variation in water use efficiency (µmol $CO_2$ fixed/ mmol of $H_2O$ transpired) in date palm cultivars

| Variety | Stage | | | |
|---|---|---|---|---|
| | Vegetative growth | Spathe emergence | Fruit set | Fruit development |
| Halawy | 2.44 | 5.09 | 3.15 | 1.79 |
| Khadrawy | 2.25 | 4.94 | 1.26 | 1.07 |
| Shamran | 1.82 | 3.88 | 1.83 | 1.09 |
| Zahidi | 1.82 | 3.78 | 1.79 | 2.10 |
| Medjool | 2.00 | 3.58 | 2.08 | 1.20 |
| Khunezi | 1.95 | 3.30 | 1.91 | 1.68 |
| Khalas | 1.94 | 3.47 | 2.28 | 1.42 |
| C D at 5% | 0.05 | 0.06 | 0.03 | 0.03 |

fruit initiation stage, the maximum water use efficiency was recorded in Halawy followed by Khalas and Medjool whereas at fruit development stage Zahidi demonstrated maximum water use efficiency.

Inter cultivar comparison revealed that at all the stages Halawy showed the best water use efficiency. Accordingly, the cultivars could be classified into two groups on the basis of WUE at spathe emergence stage:

Group A- water use efficiency high (>4.0) cvs. Halawy and Khadrawy.

Group B- water use efficiency low (<4.0) cvs. Shamran, Zahidi, Medjool, Khuneizi and Khalas.

In our study, we compared all the seven cultivars on the basis of physiological parameters with a view to assess the cultivars which can grow successfuly in arid ecosystem. The criteria taken were high rate of photosynthesis along with low transpiration and high water use efficiency. Accordingly, the cultivars were classified into groups based on their performance in the field. It was observed that Halawy, Shamran and Zahidi are the cultivars which shows better physiological performance under arid ecosystem. Thus our findings suggests that Cvs. Halawy, Shamran and Zahidi can be cultivated in hot arid region of Rajasthan. Our findings are in line with those suggested by Chandra *et al.* (1990) while evaluating the date palm on the basis of yield and quality attributing characters who also recommended suitability of cv. Halawy for arid region.

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# Influence of seed moisture and storage conditions on seed quality parameters in bael

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**Abstract**

Viable seeds of bael (*Aegle marmelos* L.) are essentially required for raising rootstocks and propagation. The effect of seed moisture at various levels and their relationship with some physiological parameters was studied in bael. The overall result depicted conversely, less moisture contents (2 and 5%) in seeds influenced more germination percentage and vigour index under all conditions of storage that high moisture (10%) level in seeds which have been stored for three years at all storage temperatures have significantly influenced least survival rates. The electrical conductance and UV-absorbance were low with less moisture level in seeds. The importance of seed moisture and storage conditions is discussed in the paper.

**Key words:** *Bael, seed germination, vigour index, storage conditions, electrical conductivity, total proteins*

## Introduction

*A. marmelos* commonly known as bael is an important drought hardy plant commonly found in the arid and semi-arid tracts of the country. Although whole tree is considered medicinally important the fruits are specially used in Ayurvedic drug i.e, Rasayana. Seed germination, seedling vigour and slow growth of bael plants have been the problem under adverse environmental conditions. In order to formulate suitable seed treatment strategies for enhancing germination and further growth it is essential to have the basic information with reference to seed physiology under variable storage conditions. Seed longevity is mainly influenced by the environmental conditions such as storage temperature (which affects the rate of biochemical activities), moisture content of the seed and oxygen pressure. It has been generally observed in most of the crop species that generally cooler and dry conditions can prolong the life span of the seeds, while the ultimate effect of adverse environmental conditions is seed deterioration which causes the loss of viability and vigour. In the tropical and sub tropical conditions, under high ambient relative humidity, the seed take moisture from the environment resulting in high ambient temperature, hereby leading seed deterioration. It is therefore, necessary to develop appropriate storage regimes for the maintenance of quality seeds. Therefore, establishment of such methodology for this medicinal and fruit crop *Aegle marmelos* was the aim of present investigation and the results are discussed research work.

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## Materials and methods

Physiologically mature seeds of bael were received from Jawahar Lal Nehru Medicinal Plants Garden and Herbarium, Kothrud Pune, for long term conservation in the National Gene Bank at National Bureau of Plant Genetic Resources, Pusa Campus, New Delhi. The samples were processed and conserved at the National Gene Bank. The remaining seed samples were used for the present investigation. Small seed lots were prepared and conditioned to maintain different moisture contents of 2%, 5% and 10% using desiccants. To attain the moisture content of 2%, the seeds were kept in a dessicator containing sulphuric acid for ten days whereas, to achieve the moisture content of 10%, the seeds were kept in desiccator having water at 25°C for 2 days. However, to attain the moisture content of 5% the seeds were kept on silica gel in a dessicator. All the seed samples were subjected to long term (LTS), medium term (MTS) and ambient (AMB) storage at -20°C, 0°C and 25 ± °C respectively. Various physiological and biochemical parameters were studied in these conditioned and three year old naturally aged seed sample.

### *Germination percentage*

Twenty five seeds of each accession were placed for germination using the towel paper methods. This was done in four replications and incubated in a seed germinator maintained at a constant temperature of 30 ± 2°C. Seeds were considered as germinated after the emergence of radicle (1mm). The germination percentage was calculated after 15th day of incubation. (ISTA,1993).

### *Seedling vigour*

In this experiment 10 seeds were planted between towel papers and kept in the vigour stands which were maintained

at a constant temperature of 30°C in a germinator for 15 days. The root length and shoot length were recorded on 15th day and mean of ten seedlings was taken into consideration for accessing the vigour index.

***Vigour index***

Vigour index was calculated as the product of seedling vigour (root + shoot length) and germination percentage by following the formulae described by (Abdul Baki and Anderson, 1973).

Vigour Index = Germination% x Seedling length

***Leachate conductivity***

Ten seeds were weighed and soaked in 25ml of deionized water at 20°C for 16 hours. The electrical conductance was determined with a digital conductivity meter at cell costant of 1. The UV absorbance of the leachate was recorded at 264 nm and 280 nm (Table 2).

***Protein estimation***

Two gram seeds from each treatment were ground to fine powder and defatted for two days using chloroform, acetone and methanol mixture ( 2:1:1). The proteins were extracted from the defatted dry powder (10 mg) with 0.5 ml of phosphate buffer (pH 7.0) , mixed thoroughly and then centrifuged at 12000 rpm for 15 min. Supernatant was used as a source of protein and the results were expressed in terms of µg $g^{-1}$ of seeds. Protein content in each sample was estimated using Lowry's Folin test method (Lowry, *et al.*, 1951). Data from all the experiments were analyzed statistically using MSTAT software.

## Results and discussion

***Seed germination***

Freshly harvested seeds exhibited maximum germination potential but when the storage period was increased they lost vigour and eventually the ability to germinate as compared to initial stage.

In present study bael seeds in all storage conditions at high moisture content (10%) resulted in significantly low level of germination compared to the less moisture contents of 5% and 2%. The germination percentage decreased from 100 to 80 % at lower moisture content (2% and 5%) in comparison to control (Table 1 and 2). Whereas at higher moisture content (10%) the decrease was tremendous (30%) at all the storage conditions ( Table 2). Incase of other crops increased rate of seed deterioration has been reported in many orthodox species (pea) stored above and below the optimum moisture content at which maximum viability was observed (Vertucii and Roos, 1990) and Vertucii *et al.* (1994). In addition, increased aging rates have been noted in very dry and moist seeds stored at a high temperature (Hu *et al.*,1998). The present study also supports the same trend in *A. marmelos*.

**Table 1.** Various physical parameters in untreated seed

| Physical parameters | Units |
|---|---|
| Weight of 20 seeds (gm) | 1.18 |
| Initial moisture (%) | 4.0 |
| Germination (%) | 100 |
| Vigour Index | 1720 |
| Electric conductivity (µS $g^{-1}$ $ml^{-1}$) | 0.57 |
| O.D of leachate at 264 nm | 0.511 |
| O.D of leachate at 280 nm | 0.036 |

**Table 2.** Physiological and biochemical parameters of bael seeds in different storage conditions three year old seeds of *Aegle marmelos*

| Storage conditions/ (Moisture%) | | Germination percentage | Vigour Index | Electrical conductivity (µS $g^{-1}$ $ml^{-1}$) | UV Absorbance (at 264 nm) | Protein Content (µg $g^{-1}$ seed) |
|---|---|---|---|---|---|---|
| LTS (-20°C) | 2 | 100 | 1093 | 0.079 | 0.547 | 620 |
| | 5 | 81 | 1037 | 0.077 | 0.626 | 540 |
| | 10 | 29 | 516 | 0.176 | 0.862 | 540 |
| MTS(10°C) | 2 | 100 | 990 | 0.079 | 0.674 | 800 |
| | 5 | 90 | 897 | 0.077 | 0.697 | 500 |
| | 10 | 30 | 447 | 0.185 | 1.097 | 80 |
| AMB(25±5°) | 2 | 99 | 966 | 0.077 | 1.121 | 840 |
| | 5 | 80 | 888 | 0.044 | 1.220 | 450 |
| | 10 | 29 | 222 | 0.199 | 1.533 | 20 |
| Control | 2 | 97 | 1102 | 0.078 | 0.547 | 705 |
| | 5 | 80 | 1095 | 0.078 | 0.584 | 680 |
| | 10 | 79 | 995 | 0.078 | 0.574 | 700 |
| C D at 5% | | | | | | |
| Storage condition (A) | | 3.52 | 97.59 | 0.018 | 0.84 | 32.13 |
| Moisture content (B) | | 1.84 | 47.51 | 0.001 | 0.04 | 29.71 |
| AXB | | 3.69 | 95.01 | 0.015 | 0.07 | 59.42 |

LTS –Long term storage; MTS-medium term storage ; AMB- ambient temperature.

***Vigour index***

Loss of vigour is associated with seed deterioration. Loss in seedling vigour is reported to produce with loss of seed viability in a number of crops (Dey and Basu, 1982; Yadav *et al.*1987; Dharamlingam and Basu, 1990). In present studies decline in seedling vigour index proceeded with reduction in germination which is in conformity with the earlier results of Raghuveer Rao (1988). In *A. marmelos* maximum vigour index was observed at 2% moisture and stored under –20°C. In general it was observed that lower storage temperature and lower moisture content maintained good vigour and viability in comparison to ambient storage condition (25-28°C) and high moisture (10%) level

***Electrical conductivity***

Cell membrane is the most important site of a seed which appears to be adversely affected by seed deterioration or ageing (Ching and Schoolcraft, 1968, Harman and Mattick: 1972). Degradation changes in cellular membranes are some early events of seed ageing (Heydecker, 1972), it enhances solute leakage from imbibed seeds resulting in loss of viability and seed vigour ( Dadlani and Agrawal, 1985a). The increase in electrolyte leakage was associated with reduction in germination and vigour index under different storage conditions and various moistures levels . These results are in agreement with reports of Halder *et al.* (1981).The amount of seed leachate was positively correlated with increasing moisture content. In *A. marmelos* maximum electrolyte leakage was observed at 10 % moisture content and ambient storage condition. Therefore, it is essentially required to conserve the bael seeds under suitable conditions to maintain the seed viability.

***UV Absorbance of Leachate***

Results presented in the Table 2 demonstrate a positive correlation of UV absorbance at 264 nm and 280 nm under different storage conditions in *A.marmelos.* At 264 nm and 280 nm the minimum value was observed in the sample stored at –20 °C and 2% moisture content, whereas the ambient storage condition with 10% moisture content resulted in maximum absorbance of 1.530 in case of *A.marmelos.*

***Total seed protein***

Estimation of total seed protein content showed significant difference with respect to seed moisture content. Maximum seed protein content (840 µg $g^{-1}$ seed) was observed at 2% moisture level and stored at –20°C, whereas with increase in moisture content (10%) and stored at ambient conditions showed a gradual decline in total seed protein content (20 µg $g^{-1}$seed) .However, it was observed that this decrease was minimized from 620 to 540 µg $g^{-1}$ seed when the same moisture content of the seed lots were stored at lower temperatures of -20°C in *A. marmelos.*

It can be concluded from the above study that lower seed moisture favours high germination and seedling vigour when compared to high moisture content of the seeds. The best storage conditions for *A. marmelos* are low moisture content of 2-5% and storage temperature of 5 and -20°C for extending the seed longevity. Therefore, *A. marmelos* confirms to be an orthodox seed.

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# Influence of foliar application of plant growth regulators on quality of guava in winter season crop

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**Abstract**

Foliar spray of NAA (20, 40 and 60 ppm), 2, 4-D (10,15 and 20 ppm) and $GA_3$ (30, 60 and 90 ppm) was done on guava trees of cultivar 'Sardar' at fruit setting stage and repeated after one month. The chemical characteristics like T. S. S., reducing sugar, non-reducing sugar and total sugar were recorded maximum in treatment with NAA at 60 ppm viz. 15.45 %, 4.56 %, 3.12 % and 7.84 %, respectively. The minimum acidity of 0.395 % was also recorded in the same treatment. Whereas, the mean maximum ascorbic acid and pectin content were recorded in treatment with $GA_3$ at 90 ppm viz., 205.16 mg/100 g pulp and 0.80 %, respectively.

**Key words:** *Growth regulators, guava, chemical characterestics*

## Introduction

Guava (*Psidium guajava* L.) is the most important, highly productive, delicious and nutritious fruit of tropical and sub tropical regions. It is a good source of calcium and iron, fair source of phoshorus, and a rich source of vitamin C and pectin. It is enjoyed both as fresh as well as in procesed from. In north Indian agro-climatic conditions, guava flowers twice in a year i.e., April-May for rainy season crop and then, in August-September for winter season crop. Generally, fruit yield is more in rainy season crop as compared to winter season crop, but are poor in quality. In recent years, plant growth regulators like auxins, and gibbrellins have been extensively used for improving the quality of various fruits like ber (Masalkar and Wavhal, 1991), litchi (Brahmachari *et al.*, 1996), etc. Auxins as well as $GA_3$ have been found to accelerate the translocation of metabolites from other parts of the plant towards developing fruits. Keeping in view the above facts, an attempt was made to improve the quality of winter season crop of guava with pre-harvest application of plant growth regulators.

## Materials and methods

The studies were carried out at Instructional Farm, Development of Horticulture, Rajasthan College of Agriculture, Udaipur during two successive years i.e. 2004-05 and 2005-06 in which 14 years old guava (*Psidium guajava* L.) trees of cv. Sardar were selected. Three plant growth regulators with following concentrations were taken.

1. Naphthelene Acetic Acid (NAA)-20, 40 and 60 mg $l^{-1}$
2. 2, 4-Dichlorophenoxy Acetic Acid (2, 4-D)-10, 15, and 20 mg $l^{-1}$
3. Gibberellic acid ($GA_3$)- 30, 60 and 90 mg $l^{-1}$
4. Control-Distilled water spray.

One tree was kept as a unit with three replications in RBD. The selected trees were sprayed with different concentrations of NAA, 2, 4-D and $GA_3$ in first week of September and first week of October during the study period. The fruits were harvested at colour break stage with full maturity. To determine the fruit quality a sample of 10 fruits was taken from each tree and chemical analysis like TSS was determined with hand refractometer. Other chemical properties i.e., acidity and ascorbic acid were estimated following the procedures laid in A O A C (1990), pectin content (Ranganna, 1977), reducing sugar (Somogyi, 1952) and total sugar (Dubois *et al.*, 1951).

## Results and discussion

It is evident from the data (Table 1) that the mean highest TSS (15.45%), lowest acidity (0.395%) and maximum TSS /acid ratio (39.23) were recorded at 60 mg $l^{-1}$ NAA Similar beneficial effect on TSS, acidity and TSS/ acid ratio was also recorded by Vijaylakshmi and Srinivasan (2000) and Gupta and Brahamchari (2004) in mango. The increase in TSS of the juice of treated fruits may be due to the increasd mobilisation of carbohydrates from the source to sink (fruits) by auxin treatment, hydrolysis of polysaccharides, conversion of organic acids into soluble sugars. The reduction in acidity may be attributed to fast conservation of acids into sugars and their derivatives by reactions

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**Table 1.** Effect of plant growth regulators on TSS, acidity and TSS/ acid ratio of guava cv. 'Sardar'

| Treatments | TSS (%) | | | Acidity (%) | | | TSS/ Acid ratio | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2004-05 | 2005-06 | Pooled | 2004-05 | 2005-06 | Pooled | 2004-05 | 2005-06 | Pooled |
| Control | 12.46 | 10.90 | 11.68 | 0.59 | 0.63 | 0.610 | 21.12 | 17.32 | 19.22 |
| NAA 20 ppm | 15.40 | 13.88 | 14.64 | 0.40 | 0.41 | 0.405 | 38.54 | 33.88 | 36.21 |
| NAA 40 ppm | 15.32 | 14.88 | 15.10 | 0.39 | 0.41 | 0.400 | 39.30 | 36.31 | 37.81 |
| NAA 60 ppm | 15.80 | 15.10 | 15.45 | 0.38 | 0.41 | 0.395 | 41.58 | 36.88 | 39.23 |
| 2, 4-D 10 ppm | 13.60 | 11.40 | 12.50 | 0.51 | 0.55 | 0.530 | 26.71 | 20.73 | 23.72 |
| 2, 4-D 15 ppm | 13.90 | 13.74 | 13.82 | 0.40 | 0.42 | 0.410 | 34.73 | 32.73 | 33.73 |
| 2, 4-D 20 ppm | 14.62 | 12.54 | 13.58 | 0.44 | 0.48 | 0.460 | 33.32 | 26.13 | 29.72 |
| GA3 30 ppm | 13.78 | 11.66 | 12.72 | 0.49 | 0.48 | 0.485 | 28.15 | 24.30 | 26.23 |
| GA 3 60 ppm | 14.40 | 12.86 | 13.63 | 0.40 | 0.46 | 0.430 | 36.05 | 27.99 | 32.02 |
| GA3 90 ppm | 14.80 | 12.70 | 13.75 | 0.44 | 0.43 | 0.435 | 33.90 | 29.60 | 31.75 |
| C D at 5% | 0.79 | 0.25 | 0.40 | 0.029 | 0.030 | 0.020 | 2.32 | 1.76 | 1.40 |

**Table 2.** Effect of plant growth regulators on Ascorbic acid (Vitamin-C) and pectin content of guava cv. 'Sardar'

| Treatment | Ascorbic acid (mg/100g pulp) | | | Pectin content (%) | | |
|---|---|---|---|---|---|---|
| | 2004 -05 | 2005 -06 | Pooled | 2004 -05 | 2005 -06 | Pooled |
| Control | 174.40 | 173.76 | 174.08 | 0.62 | 0.60 | 0.61 |
| NAA 20 ppm | 197.35 | 195.45 | 196.40 | 0.68 | 0.71 | 0.70 |
| NAA 40 ppm | 201.95 | 203.15 | 202.55 | 0.79 | 0.77 | 0.78 |
| NAA 60 ppm | 204.78 | 203.00 | 203.89 | 0.80 | 0.79 | 0.80 |
| 2, 4-D 10 ppm | 196.42 | 195.52 | 195.97 | 0.67 | 0.61 | 0.64 |
| 2, 4-D 15 ppm | 199.00 | 200.30 | 199.65 | 0.71 | 0.73 | 0.72 |
| 2, 4-D 20 ppm | 198.24 | 200.18 | 199.21 | 0.70 | 0.71 | 0.71 |
| GA3 30 ppm | 200.37 | 198.55 | 199.46 | 0.73 | 0.71 | 0.72 |
| GA 3 60 ppm | 203.17 | 201.19 | 202.18 | 0.77 | 0.76 | 0.77 |
| GA3 90 ppm | 206.03 | 204.29 | 205.16 | 0.79 | 0.81 | 0.80 |
| C D at 5% | 6.62 | 5.80 | 4.25 | 0.05 | 0.05 | 0.03 |

involving reverse glycolytic pathways. Improvement in T S S/acid ratio could be attributed to increase in TSS content and reduced acid content under N. A. A. treatments. Similar results have also been reported by Yadav *et al.* (2001) in guava.

The data (Table 2) reveals that the application of plant growth regulator had significantly increased the ascorbic acid and pectin content of the guava fruit over control. Among the various plant growth regulator treatments, the mean maximum ascorbic acid of 205.16 mg/ 100 g pulp and pectin of 0.80 per cent were recorded at 90 ppm $GA_3$ treatment followed by 60 mg $l^{-1}$ NAA whereas, the minimum ascorbic acid (174.08 mg/ 100 g pulp) and pectin content (0.61%) were observed with control. The present results are in line with the findings of Brahmachari *et al.* (1997) in guava. The increase in ascorbic acid content might be due to catalytic influence of $GA_3$ on biosynthesis of ascorbic acid from sugar.

The data presented in Table 3 clearly indicate that the application of plant growth regulators significantly increased the sugar content (reducing, non-reducing and total sugar) of guava fruits. The highest reducing, non-reducing and total sugar content of 4.56, 3.12 and 7.84 per cent, respectively were recorded with 60 mg $l^{-1}$ NAA treatment, whereas the mean minimum reducing sugar (3.95%), non-reducing (2.28%) and total sugar (6.35%) were

**Table 3.** Effect of plant growth regulators on reducing, non-reducing and total sugar content of guava cv. 'Sardar'

| Treatments | Reducing sugar (%) | | | Non-reducing sugar (%) | | | Total sugar (%) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2004-05 | 2005-06 | Pooled | 2004-05 | 2005-06 | Pooled | 2004-05 | 2005-06 | Pooled |
| Control | 4.04 | 3.86 | 3.95 | 2.44 | 2.12 | 2.28 | 6.61 | 6.09 | 6.35 |
| NAA 20 ppm | 4.42 | 4.22 | 4.32 | 2.69 | 2.21 | 2.45 | 7.25 | 6.55 | 6.90 |
| NAA 40 ppm | 4.56 | 4.34 | 4.45 | 2.89 | 2.96 | 2.93 | 7.60 | 7.46 | 7.53 |
| NAA 60 ppm | 4.68 | 4.44 | 4.56 | 3.09 | 3.14 | 3.12 | 7.93 | 7.75 | 7.84 |
| 2, 4-D 10 ppm | 4.06 | 4.04 | 4.05 | 2.79 | 2.32 | 2.56 | 7.00 | 6.48 | 6.74 |
| 2, 4-D 15 ppm | 4.38 | 4.02 | 4.20 | 2.64 | 2.28 | 2.46 | 7.16 | 6.42 | 6.79 |
| 2, 4-D 30 ppm | 4.49 | 4.25 | 4.37 | 2.54 | 2.78 | 2.66 | 7.16 | 7.18 | 7.17 |
| GA3 30 ppm | 4.22 | 4.02 | 4.12 | 2.76 | 2.38 | 2.57 | 7.12 | 6.52 | 6.82 |
| GA 3 60 ppm | 4.55 | 4.31 | 4.43 | 2.76 | 2.57 | 2.66 | 7.45 | 7.02 | 7.24 |
| GA3 90 ppm | 4.42 | 4.32 | 4.37 | 3.09 | 2.63 | 2.86 | 7.67 | 7.09 | 7.38 |
| C D at 5% | 0.17 | 0.17 | 0.12 | 0.29 | 0.12 | 0.15 | 0.28 | 0.19 | 0.16 |

recorded at control. The possible reason for increase in sugar content is that NAA might have promoted hydrolysis of strach into sugars. Auxins have been found to accelerate the translocation of metabolites from other parts of the plant towards developing fruits. The present results are corroborated with the findings of Kher *et. al.* (2005) in guava and Singh *et al.* (1989) in ber.

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# Studies on physico mechanical properties of ber cultivars

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**Abstract**

Ber is an important fruit crop in the arid regions of Asia and Africa. Some physical and mechanical properties of six ber cultivars namely Umran, Ilaichi, Gola, Mundia, Goma kirthi and Banarasi karka were determined. The geometrical mean diameter of fruits varied from 2.65 to 4.85 cm. The sphericity varied from 0.73 to 0.88 among cultivars and the fruits of Gola were more spherical than the fruits of other cultivars. The surface area, volume, average weight and firmness of Umran fruits were significantly higher, 74.04 $cm^2$, 89.90 $cm^3$, 56.66 g and 6.80 N, respectively than the other fruits. The cutting strength of Goma kirti fruits was found to be better than the fruits of other cultivars.

**Key words:** *Ber cultivars, physical, mechanical properties*

## Introduction

Indian jujube or Ber *(Zizyphus mauritiana* L.) has moved from forest to commercial cultivation in warm arid regions of India, Pakistan, Bangladesh, Sri Lanka, central to southern Africa and in the northern part of Australia. The expansion mainly took place because of its hardy nature to withstand vagaries of nature and the commercial yield potential. Conventionally, ber is considered poor man's fruit but it is richer than apple in protein, phosphorus, calcium, carotene and vitamin C (Bakshi and Singh, 1974). India annually produces around 37,97,606 million tonnes fruits from an area of 61,279 ha (Sharma *et al.*, 2002). Fruits of ber are commonly used in Indian households as fresh fruit and also dehydrated for later use. Presently, about 90% of its production is consumed as fresh fruit. Although there seems to be a good potential for use of the fruit in the processing industry (Pareek, 2001), it has not been fully exploited to the extent it should have been exploited.

To explore the potential use of ber for processing, machines like grader, peeler, stone remover, etc. need to be designed for which, its physical properties must be known. Detailed studies on physical and mechanical properties of ber fruits have not been reported. Since the environmental factors influence the quality attributes, physical and mechanical properties of different cultivars may also differ depending upon maturing season. Thus, these studies were conducted to determine the physical and mechanical properties of matured ber fruits of different cultivars.

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## Materials and methods

Matured fruits of six different cultivars viz., Umran, Ilachi, Banarasi karka, Mundia, Gola and Goma kirti were used for the experiments in this study. In the selected six cultivars, Mundia and Gola were of early maturity (January - February), Banarasi karka and Goma kirti were of mid season (February) and Umran and Ilaichi were late maturing cultivars (March - April) (Vashistha, 2001). The fruits were harvested from the orchard of Central Institute of Post Harvest Engineering and Technology, Abohar, during January- April, 2004. Damaged and other undesirable fruits were sorted out and healthy fruits were selected for the study. Twenty fruits were randomly selected from each cultivar and the average values were calculated. The geometry and the relative size of the ber fruit are shown in Fig 1. The parameters such as linear dimensions, size, sphericity, surface area, firmness and cutting strength were determined.

### *Determination of size and dimensions*

The linear dimensions, length (L) and diameter (D) were measured using a vernier caliper (least count - 0.01 cm). The size was calculated using the linear dimensions and were expressed in terms of geometrical mean diameter. Aydin and Ozcan (2002) and Demir *et al.*, (2002) have measured the linear dimensions in a similar manner to determine the size of the fruits. The geometrical mean diameter ($D_g$) was calculated using the following formula (Mohsenin, 1970):

$$D_g = (LD^2)^{1/3} \quad (1)$$

Sphericity expresses the shape character of the solid

relative to that of a sphere of the same volume. It is an index of roundness. According to Jain and Bal (1997), the degree of sphericity (o) can be expressed as follows:

$$o = D_g/L \qquad (2)$$

The linear dimensions were used to calculate the volume (V) and surface area (S) of the fruit by using the following equations (Mohsenin, 1970):

$$V = \pi D^2 L/4 \qquad (3)$$
$$S = \pi D_g^2 \qquad (4)$$

***Mass of single fruit***

The individual mass of fruits were weighed using an electronic balance of accuracy 0.001 g, make - citizen, Blue beacon enviro pvt ltd., Chandigarh, India.

***Determination of firmness and cutting strength***

The firmness of the fresh fruits was measured using the Texture Analyzer (TA-Hdi, Stable Microsystems, UK) with the 2 mm diameter stainless steel probe. The operating conditions were, pre-test speed 1.5 mm/s, test speed, 0.50 mm/s and post-test speed of 10.0 mm/s. The maximum value recorded by the probe while passing through the fruits, in Newton (N), was given as firmness. The firmness was measured in two places of each sample and average value was calculated. The cutting strength was also determined using the Texture Analyser, with a knife edge probe with blade set. The operating conditions were kept as that of used during measurement of firmness.

## Results and discussion

The inter-cultivar differences in physical properties of ber fruits are given in Table 1.

***Fruit dimensions***

The data shows that the difference in major dimension (length) and minor dimension (diameter) are less in some cultivars like Gola, Umran and Ilaichi. The geometrical mean diameter of the selected fruits varied from 2.65 cm to 4.85 cm. The late season cultivar of Umran is of bigger size and Ilaichi is the smallest fruit.

***Sphericity, volume and surface area***

The sphericity of the fruits varied from 0.73 to 0.88 . The fruit of the cultivars Gola, Illaichi and Umran has sphericity of more than 0.85, which shows that the fruits developed uniformly in both the axes. The fruits of Goma kirthi, Mundia and Banarasi karka developed more in lengthwise. These data will be useful in designing a ber grader. The surface area and average weight of Umran fruits were higher (74.04 $cm^2$ and 54.66 g) followed by Goma kirti cultivar. The volume of ber fruits calculated by equation 3 varied from 15.1 to 89.9 $cm^3$ for different cultivars.

***Mass of single fruit***

The average weight of fruits varied from 10 to 55g. The late season cultivar of Umran was found to be of bigger size having maximum weight. The early maturing cultivars of Gola and Mundia had less average weight than other cultivars, viz., Goma kirthi, Banarasi karka and Umran.

***Firmness and cutting strength***

The late season cultivar of Umran had the highest (6.80 N) firmness and the early season cultivar Gola had the lowest (2.9 N) firmness (Table 2). The firmness of middle and late season cultivars were higher than the early season varieties. The fruits of *Gola* and *Mundia* were softest among all the cultivars. The varied firmness of ber fruits maturing in different period may be due to its genetic character. The early maturing fruits may be susceptible to injuries while harvesting and grading since the strength was very less. It can be implied from the firmness that the middle and late season cultivar fruits can be transported for long distances with less damage. The ripening season of the fruits doesn't have any effect on the cutting strength (Table 2). The cutting strength varied from 28.2 to 59.3 N. The cutting strength of cultivars Goma kirthi, Umran and Mundia was high (45.8 - 59.3 N) when compared to other fruits.

**Table 1.** Physical properties of ber fruits

| Sl. No. | Cultivar | Length (cm) | Diameter (cm) | Geo. Mean dia (cm) | Sphericity | Volume ($cm^3$) | Surface area ($cm^2$) | Average wt. (g) |
|---|---|---|---|---|---|---|---|---|
| 1. | Gola | 4.31 (±0.23) | 3.55 (±0.10) | 3.79 (±0.12) | 0.88 (±0.03) | 42.85 (±4.3) | 45.23 (± 2.96) | 27.78 (±2.85) |
| 2. | Mundia | 4.33 (± 0.29) | 2.72 (±0.13) | 3.17 (±0.16) | 0.73 (± 0.02) | 25.35 (±4.03) | 31.73 (±3.26) | 15.90 (±2.24) |
| 3. | Goma kirti | 5.72 (±0.36) | 4.11 (±0.32) | 4.58 (±0.25) | 0.80 (±0.05) | 76.14 (± 12.62) | 66.14 (±7.28) | 44.74 (±5.59) |
| 4. | Banarasi karaka | 5.76 (±0.25) | 3.82 (±0.18) | 4.38 (±0.18) | 0.76 (±0.02) | 66.10 (±8.50) | 60.23 (±5.11) | 40.69 (±4.85) |
| 5. | Ilaichi | 3.05 (±0.22) | 2.48 (±0.27) | 2.65 (±0.26) | 0.87 (±0.02) | 15.05 (±4.39) | 22.32 (±4.34) | 9.87 (±2.69) |
| 6 | Umran | 5.67 (±0.32) | 4.50 (±0.18) | 4.85 (±0.09) | 0.86 (±0.05) | 89.90 (±4.77) | 74.04 (±2.62) | 54.66 (±2.44) |

Values in parenthesis are standard deviations

**Table 2.** Mechanical properties of ber fruits

| Sl. No. | Cultivar | Firmness (N) | Cutting strength (N) |
|---|---|---|---|
| 1 | Gola | 2. 92 (±0.47) | 33.0 (±6.50) |
| 2 | Mundia | 3. 52 (±0.21) | 45.8 (± 5.20) |
| 3 | Goma kirti | 5.83 (±0.26) | 59.3 (±3.60) |
| 4 | Banarasi karka | 4. 60 (±0.53) | 28. 2 (±4. 20) |
| 5 | Umran | 6. 80 (±0.62) | 57. 5 (±2. 00) |

Values in parenthesis are standard deviations

From the study it is concluded that the late season cultivar of Umran was found to be of bigger size compared to other fruits while the average geometric mean diameter, surface area, volume, average weight and firmness of Umran fruit were 4.85 cm, 74.04 $cm^2$, 89.90 $cm^3$, 56.66 g and 6.80 N, respectively.The ripening season of ber fruits slightly influenced the firmness of the fruits. The early maturing fruits were found to be less firm than the late varieties. Since the firmness is high, the fruits of Umran, Goma kirti and Ilaichi can be used for transportation to longer distances and storage.

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# Studies on the effect of drip irrigation and mulching on leaf nutrient status, yield and quality of aonla

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**Abstract**

The experiment was conducted to study the effect of drip irrigation and mulches on water use efficiency and productivity of aonla cv. Narendra Aonla-10 (NA-10). There were four irrigation regimes in terms of IW/CPE ratios of 1.0, 0.8, 0.6 and 0.4 and three types of mulches, namely black polythene, paddy straw and control (no mulch). The results indicated that aonla plants drip irrigated at 0.6 IW/CPE had higher leaf nitrogen status as compared to higher and lower levels of irrigation. Leaf nitrogen, potassium, calcium and magnesium were higher in paddy straw mulched trees, while phosphorus content was higher under polythene mulching. Fruits attained significantly higher fruit length, diameter, weight and volume at 1.0 IW/CPE. The higher levels of irrigation, viz., 0.8 and 1.0 IW/CPE improved fruit size but drip irrigation at 0.6 IW/CPE coupled with black polythene mulching resulted in optimum fruit yield and quality parameters such as total sugar content, ascorbic acid and acidity contents of aonla cv. NA-10. Thus, it helps in cutting down the water requirement of aonla to 0.6 IW/CPE (60% evaporation replenishment) with drip irrigation and black polythene mulching for optimum fruit yield and quality.

**Key words:** *aonla, leaf nutrient status, drip irrigation, mulching, yield and quality*

## Introduction

Aonla (*Emblica officinalis* Gaertn) is a hardy, prolific bearer and medicinally valuable fruit, which grows successfully in a variety of degraded lands, viz., saline, sodic, coastal ares and ravines, etc. (Pathak *et al.*, 2003). It also seems a tree suitable for fruit tree based agroforestry systems especially in degraded lands of arid and semiarid regions (Pathak and Saroj, 1999; Ram Newaj *et al.*, 2006). During last few decades, the area under aonla has increased in various parts of India in general, and waste and marginal lands in particular. In such lands, paucity of irrigation water and poor fertility ststus of the soil are the major constraints limiting crop production. Besides, water has become a scarce resource with increasing urbanization, burgeoning population pressure and input-intensive crop production. Attempts made in India on drip irrigation have shown 40-60 per cent economy in water use (Agarwal and Agarwal, 2005). Similarly, mulching imparts manifold advantages viz., moisture conservation, suppression of weed growth, maintenance of soil fertility and regulation of soil temperature. In the present investigation, attempts were been made to study the effect of different drip irrigation levels and mulches on leaf nutrient status, fruit yield and quality of aonla.

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## Materials and methods

The experiment was conducted at the experimental farm of Department of Horticulture, Narendra Deva University of Agriculture and Technology, Kumarganj for two consecutive years, using eight year old uniform growing plantation of aonla cultivar Narendra Aonla-10. There were four irrigation regimes in terms of IW/CPE ratio, viz., IW/CPE value of 1.0 ($I_1$), 0.8 ($I_2$), 0.6 ($I_3$) and 0.4 ($I_4$)and three types of mulches, namely, black polythene ($M_1$), paddy straw ($M_2$) and control/no mulch ($M_3$), thus making twelve treatment combinations. The experiment was laid out in randomized block design. The soil of the experimental plot was silty loam and sodic with pH 8.86, ESP 30.49, EC 3.7 dS $m^{-1}$ and organic carbon content of 0.21%. Initial leaf nutrient status of aonla was 2.07% nitrogen (N), 0.28% phosphorus (P), 1.43% potassium (K), 2.19% calcium (Ca) and 0.17% magnesium (Mg). The irrigation water was applied through drip method and scheduling of irrigation was done based on pan evaporation. Pan evaporation was recorded daily with the help of class 'A' pan evaporimeter. Rainfall less than or equal to the pan evaporation loss during the day was considered effective. The amount of water required for irrigation was computed as the ratio of Irrigation Water (IW) over Cumulative Pan Evaporation (CPE) at third day interval. Black polythene sheet of 400 gauge of 4.0 m x 4.0 m size was unrolled on the surface of tree basin with its corners

and sides stitched by stacking pins and their outer side tagged in soil to avoid rolling and splitting due to strong winds. A 10-cm thick layer of paddy straw @ 20 kg paddy straw plant$^{-1}$ was spread in the tree basin for mulching. Tree basins were left unmulched under control. The mulches were placed after fertilizer application, irrigation and weeding of the experimental plots to ensure the uniform moisture content. Trees were supplied with uniform doses of manures and fertilizers in two split doses i.e., half at the time of mulching and rest half in the last week of August.

The observations were recorded on leaf nutrient status with respect to nitrogen, phosphorus, potassium, calcium and magnesium, fruit yield and fruit quality parameters, viz., fruit length, diameter, weight, volume, total sugars, ascorbic acid and acidity. As regards leaf nutrient analysis, aonla leaves were randomly taken from mid portion of shoots at termination of experiment. Nitrogen was determined by micro-Kjeldahl method as advocated by Peach and Tracey (1956). Phosphorus was estimated by wet digestion method developing vanadomoybdo colour as suggested by Richards (1954). Potassium content was analysed by wet digestion using flame photometer as suggested by Jackson (1973), while calcium and magnesium contents were estimated by the methods suggested by Chang and Bray (1951). Fruit length and diameter were recorded using Vernier calliper, while fruit volume was recorded by water displacement method. Total sugar contents were analysed by Fehling solution method as advocated by Lane and Eynon (1943). Titrable acidity was recorded by titration against NaOH solution, while ascorbic acid content was estimated as per procedure given in AOAC (1970). Data for two years were pooled and analysed statistically as per methods given by Panse *et al.* (1985).

## Results and discussion

### *Leaf nutrient status of aonla*

Data pertaining to leaf nutrient status (Table 1) indicate that aonla plants irrigated at $I_3$ (0.6 IW/CPE) level recorded highest nitrogen content (2.52%) followed by $I_2$, $I_4$ and $I_1$. The minimum nitrogen content (2.11%) was noted in $I_1$. However, treatment pairs $I_2$ and $I_4$; $I_1$ and $I_4$ were statistically akin. Mulching showed significant effect on nitrogen content of aonla leaves. The maximum nitrogen (2.35%) was recorded in response to paddy straw mulch followed by black polythene (2.31%) and control (2.18%). However, $M_1$ and $M_2$ were statistically at par. The interaction between two factors was found significant in respect of leaf nitrogen content, varying from 2.08 to 2.81 per cent with the maximum nitrogen in $I_3M_2$ followed by $I_2M_2$, $I_3M_1$, $I_4M_1$, $I_3M_3$. Phosphorus content of aonla leaves was significantly affected by irrigation regimes and mulching. Highest phosphorus content (0.38%) was recorded at $I_2$ irrigation level followed by $I_3$ (0.37%), $I_4$ (0.36%) and $I_1$ (0.35%) irrigation regime. However, treatment pairs $I_2$ and $I_3$; $I_1$ and $I_4$ did not differ significantly. Mulching also significantly influenced the phosphorus content of leaves with significantly maximum phosphorus content (0.43 %) under black polythene mulched trees followed by paddy straw mulching and control. There is non-significant effect of interaction of these two factors on phosphorus content of aonla leaves. The significantly highest leaf potassium content (1.98%) was obtained under $I_2$ irrigation regime and the lowest was recorded in $I_4$ (1.74%). Mulching materials had significant effect on potassium content of aonla leaves. Mulching with paddy straw ($M_2$) had highest potassium (2.15%) content in leaves followed by trees under black polythene mulching and control (no mulching). The interaction of irrigation regimes and mulching had significantly influenced the potassium content in leaves. The maximum potassium (2.26%) was recorded in $I_2M_2$ followed by $I_3M_2$, $I_1M_2$, $I_4M_2$, $I_2M_1$ and so on.

**Table 1.** Leaf nutrient status in aonla leaves in response to drip irrigation and mulching

| Mulches | Leaf nutrient status in aonla at different irrigation levels | | | | |
|---|---|---|---|---|---|
| | **Nitrogen (%)** | | | | |
| | $I_1$ | $I_2$ | $I_3$ | $I_4$ | Mean |
| $M_1$ | 2.15 | 2.32 | 2.39 | 2.39 | 2.31 |
| $M_2$ | 2.11 | 2.39 | 2.81 | 2.10 | 2.35 |
| $M_3$ | 2.08 | 2.18 | 2.36 | 2.11 | 2.18 |
| Mean | 2.11 | 2.30 | 2.52 | 2.20 | |
| C D at 5% | Irrigation (I)–0.108; Mulching (M) – 0.093; I X M-0.186 | | | | |
| | **Phosphorus (%)** | | | | |
| $M_1$ | 0.41 | 0.45 | 0.44 | 0.42 | 0.43 |
| $M_2$ | 0.30 | 0.34 | 0.32 | 0.31 | 0.32 |
| $M_3$ | 0.34 | 0.35 | 0.34 | 0.34 | 0.34 |
| Mean | 0.35 | 0.38 | 0.37 | 0.36 | |
| C D at 5% | Irrigation (I) - 0.013; Mulching (M) –0.011; I X M - NS | | | | |
| | **Potassium (%)** | | | | |
| $M_1$ | 1.88 | 2.00 | 1.89 | 1.59 | 1.84 |
| $M_2$ | 2.10 | 2.26 | 2.15 | 2.13 | 2.16 |
| $M_3$ | 1.50 | 1.69 | 1.64 | 1.51 | 1.59 |
| Mean | 1.83 | 1.98 | 1.89 | 1.74 | |
| C D at 5% | Irrigation (I) - 0.038; Mulching (M) - 0.032; I X M – 0.065 | | | | |
| | **Calcium (%)** | | | | |
| $M_1$ | 2.11 | 2.30 | 2.17 | 1.66 | 2.06 |
| $M_2$ | 2.42 | 2.20 | 2.17 | 1.79 | 2.15 |
| $M_3$ | 2.04 | 2.05 | 1.65 | 1.60 | 1.84 |
| Mean | 2.19 | 2.18 | 2.00 | 1.68 | |
| CD (at 5%) | Irrigation (I) – 0.034; Mulching (M) – 0.035; I X M – 0.550 | | | | |
| | **Magnesium (%)** | | | | |
| $M_1$ | 0.27 | 0.29 | 0.28 | 0.24 | 0.27 |
| $M_2$ | 0.33 | 0.35 | 0.32 | 0.31 | 0.33 |
| $M_3$ | 0.21 | 0.24 | 0.23 | 0.21 | 0.22 |
| Mean | 0.27 | 0.29 | 0.28 | 0.25 | |
| C D at 5% | Irrigation (I) – 0.015; Mulching (M) – 0.013; I X M - NS | | | | |

Maximum calcium content (2.19%) was recorded under $I_1$ irrigation regime followed by $I_2$ and $I_3$ (Table 1), while the minimum content was in trees irrigated at 0.4 IW/CPE ($I_4$). However, $I_1$ and $I_2$ irrigation regimes were statistically at par in respect of leaf calcium content. Among different mulches used in the experiment, maximum calcium content (2.15%) in aonla leaves was recorded with paddy straw mulched aonla trees followed by black polythene mulching (2.06%) and control (1.84%). The interaction effects of irrigation regimes and mulches were also significant in respect of calcium content, varying from 1.60 to 2.42 per cent in different treatment combinations. The significantly maximum calcium content (2.42%) was recorded under $I_1M_2$ followed by $I_2M_1$, $I_2M_2$, $I_3M_1$, $I_1M_3$ and minimum (1.60%) was recorded in $I_4M_3$. Drip irrigation regimes and mulching significantly influenced magnesium content in aonla leaves. Maximum magnesium content (0.29%) was observed under $I_2$ irrigation level followed by $I_3$, $I_1$ and $I_4$. However, $I_2$ and $I_3$ ; and $I_1$ and $I_3$ irrigation regimes were found statistically at par. Among mulching treatments, the magnesium content (0.33%) was significantly highest under paddy straw mulching followed by black polythene and control.

Higher leaf nitrogen status in aonla leaves at $I_3$ (0.6 IW/CPE) may be attributed to restricted application of water which reduces leaching of nutrients from root zone (Purser, 1993). The findings are in agreement with Hegde and Srinivas (1989), and Ahmed (1994). The concentration of P, K and Mg was significantly higher with $I_2$ (0.8 IW/CPE). This may be due to leaching of salts from the root zone at this irrigation level resulting in increased availability of these plant nutrients. The results are in agreement with the findings of Elfving (1982) who also reported that trickle irrigation increased plant concentration nutrients because of better movement of nutrients in the soil solution and thereby ensured adequate nutrient availability to the plant. The findings are also in line with Neilsen (1995) in apple, Strabbioli and Turci (1995) in peach.

The assimilation and accumulation of Ca in aonla leaves was maximum (2.19%) at highest level ($I_1$) of irrigation, which decreased with reduced supply of irrigation water. It was due to the fact that the movement of Ca in plant was facilitated by higher amount of available soil water. It indicates that accumulation of Ca is unlike from that of N, P, K and Mg in leaves. The maximum accumulation of Ca recorded at higher level of irrigation ($I_1$) in the experiment is also supported by Duncan *et al.* (1992) and Bondok *et al.* (1995).

Among different mulches, paddy straw had beneficial effect on uptake of N, K, Ca and Mg followed by black polythene and control (no mulching). It might be due to higher moisture conservation better aeration and more soil nutrient concentrations obtained from partial decomposition of paddy straw. The findings are in conformity with Gupta and Gupta (1987), Mustaffa (1988) and Pinamonti *et al.* (1995). Phosphorus content in leaves was significantly higher in black polythene mulched aonla trees followed by control and paddy straw mulching. It may be ascribed to microbial imobilisation of P under the paddy straw mulch which lowered the absorption and translocation of phosphorus in plants. The results are in agreement with those of Mustaffa (1988) and Marumata *et al.* (1991). The interaction effects between irrigation and mulching with respect to leaf nutrient status had indicated that combination of both favourable factors i.e., drip irrigation and paddy straw mulching further increased concentration of N, K, Mg and Ca in leaves. The maximum nitrogen (2.81%) was under $I_1M_2$ while K and Mg contents were maximum in $I_2M_2$. Ca was maximum in $I_1M_2$ and maximum P was observed in $I_2M_1$. Bolding (1988) reported that leaf N content was lowest and leaf Ca content was highest with drip irrigation + potting compost in pear.

***Physical fruit characters and yield***

The physical fruit characters such as fruit length, diameter, weight and volume were significantly influenced by drip irrigation levels (Table 2). Maximum fruit length (3.91 cm), fruit diameter (4.66 cm), fruit weight (49.19 g) and fruit volume (48.29 $cm^3$) were observed at 1.0 IW/CPE followed by $I_2$, $I_3$ and $I_4$. This increase might be due to higher water application leading to larger fruit size. These results are in agreement with Hegde and Srinivas (1989) in banana. Since fruit weight is directly related to fruit yield, the highest fruit yield observed under 0.6 IW/CPE coincided with the reduced fruit size and weight. Higher yield with reduced fruit size was also recorded by Sepaskhah and Kashefipour (1994). Increased fruit volume with increasing water application was also recorded by Kumar and Bhojappa (1994). The physical fruit characters, viz. fruit length, weight and volume did not show any significant variations in response to different mulches. The interaction effect between irrigation levels and mulches with respect

**Table 2.** Effect of drip irrigation regimes and mulching on physical attributes of aonla

| Treatments | Physical attributes of aonla fruit in response to drip irrigation and mulching | | | |
|---|---|---|---|---|
| | Fruit length (cm) | Fruit diameter (cm) | Fruit weight (g) | Fruit volume ($cm^3$) |
| **Irrigation levels** | | | | |
| 1.0 IW/CPE ($I_1$) | 3.91 | 4.66 | 49.19 | 48.29 |
| 0.8 IW/CPE ($I_2$) | 3.82 | 4.46 | 47.89 | 47.46 |
| 0.6 IW/CPE $I_3$) | 3.69 | 4.43 | 47.00 | 46.28 |
| 0.4 IW/CPE ($I_4$) | 3.60 | 4.42 | 46.48 | 45.11 |
| C D at 5 % | 0.142 | 0.051 | 2.645 | 1.73 |
| **Mulches** | | | | |
| Black polythene ($M_1$) | 3.79 | 4.58 | 48.48 | 47.29 |
| Paddy Straw ($M_2$) | 3.79 | 4.48 | 47.31 | 46.78 |
| Control ($M_3$) | 3.69 | 4.43 | 47.13 | 46.29 |
| C D at 5% | NS | 0.058 | NS | NS |

to these parameters was also non-significant. Contrary to this, fruit diameter was significantly higher with black polythene mulch (4.58 cm) as compared to paddy straw and control. It may be due to reduced competition of grass, better conservation and utilization of soil moisture. Similar results were recorded by Mannini and Gallina (1987) in cucumber, Saini (1994) in ber and Chattopadhyay and Sarad Gurung (1996) in banana. The interaction effect with respect to fruit diameter exhibited significant variations with maximum fruit diameter with $I_1M_1$ (4.84 cm) followed by $I_4M_1$ (4.57 cm), $I_1M_3$ (4.52 cm) and $I_2M_2$ (4.48 cm). These findings are also in line with Welbaum *et al.* (1994).

As regards fruit yield, aonla plants irrigated at $I_3$ (IW/CPE = 0.6) recorded significantly higher fruit yield (43.96 kg/tree) followed by $I_4$, $I_2$ and $I_1$ (Table 3). Among mulch materials, use of black polythene resulted in significantly higher yield (44.53 kg/tree) followed by paddy straw mulching (39.50 kg/tree), while minimum yield (25.66 kg/tree) was obtained in control ($M_3$). Interaction between irrigation regimes and mulching showed significant influence with respect to fruit yield varying from 22.50 to 56.20 kg/tree. Maximum fruit yield (56.20 kg) was recorded under $I_4$ mulched with black polythene followed by $I_3M_1$, $I_3M_2$ and $I_2M_1$.

The higher yield at 0.6 IW/CPE might be due to efficient utilization of water and better nutrient uptake. The yield reduction both at higher irrigation levels (0.8 and 1.0 IW/CPE) and lower irrigation level (0.4 IW/CPE) might be due to unfavourable soil conditions in the root zone. At higher levels, plants get continued higher level which favours vegetative growth. In this case the poor fruit yield may be attributed to nutrient wash out from the feeding root zone. Furthermore, higher water application might lead to flower senescence and consequently lower fruit yield. However, poor yield at lower irrigation level (0.4 IW/CPE) might have resulted from water deficit leading to unavailability of water and nutrients (Sepaskhah and Kashefipour, 1994). Agarwal and Agarwal (2005) recorded 82.88% yield increase over control with 60% water application through drip coupled with plastic mulching.

**Table 3.** Fruit yield in aonla as influenced by drip irrigation and mulching

| Treatments | Fruit yield (kg/tree) | | | | |
|---|---|---|---|---|---|
| | $I_1$ | $I_2$ | $I_3$ | $I_4$ | Mean |
| M1 | 22.75 | 46.29 | 52.88 | 56.20 | 44.53 |
| M2 | 32.45 | 35.50 | 47.38 | 42.67 | 39.50 |
| M3 | 22.50 | 26.13 | 31.63 | 22.38 | 25.66 |
| Mean | 25.90 | 35.97 | 43.96 | 40.42 | |
| C D at 5% | I-2.362 | M-2.050 | I X M-4.090 | | |

Among mulching treatments, black polythene was found best for enhancing fruit yield followed by paddy straw. Better fruit yield with black polythene may be attributed to maintenance of optimum soil moisture (Agarwal and Agarwal, 2005), soil temperature (Wilhelm, 1979) and enhanced flowering duration (Hegde and Srinivas, 1990). These findings are in agreement with Pemovski *et al.* (1973) in grapes, Chadha and Pareek (1991) in mango, Agarwal and Agarwal (2005) in banana.

***Chemical fruit characters***

The fruit quality attributes, such as total sugars, ascorbic acid and acidity were significantly influenced by drip irrigation regimes and mulching (Table 4). Irrigation at 0.6 IW/CPE significantly improved the total sugar level of fruits followed by $I_2$, $I_1$ and $I_4$. However, treatment pairs, viz., $I_1$ and $I_2$; $I_1$ and $I_4$ were statistically at par. It might be due to fruit soluble sugar being negatively related to water availability, with a mild deficit showing highest percentage of total sugars. These results are in agreement with Goodwin and Jeric (1988), Coloptera (1989), Madrid *et al.* (1995). Among different mulches used in the experiment, total sugar was significantly highest with black polythene mulch (8.87 %) followed by paddy straw and control. The combined effect of drip irrigation and mulching did not cause significant variation amongst different treatment combinations. The higher total sugar content in response to black polythene mulch is attributed to better conservation and maintenance of soil moisture during fruit growth and development.

**Table 4.** Chemical attributes of aonla as influenced by drip irrigation and mulching

| Treatments | $I_1$ | $I_2$ | $I_3$ | $I_4$ | Mean |
|---|---|---|---|---|---|
| | Total sugar (%) | | | | |
| M1 | 8.90 | 9.08 | 9.14 | 8.36 | 8.87 |
| M2 | 8.37 | 8.69 | 8.96 | 7.98 | 8.50 |
| M3 | 7.54 | 7.78 | 8.18 | 7.86 | 7.84 |
| Mean | 8.27 | 8.52 | 8.76 | 8.07 | |
| C D at 5% | I - 0.34 | M – 0.30 | I X M - NS | | |
| | Ascorbic acid (mg/100 g pulp) | | | | |
| M1 | 614.00 | 658.00 | 666.50 | 703.00 | 660.38 |
| M2 | 712.00 | 726.00 | 756.00 | 767.00 | 740.25 |
| M3 | 611.50 | 622.00 | 675.00 | 694.00 | 650.63 |
| Mean | 645.83 | 668.67 | 699.17 | 721.33 | |
| C D at 5% | I - 14.3 | M - 12.39 | I X M - 24.78 | | |
| | Acidity (%) | | | | |
| M1 | 3.69 | 3.94 | 3.93 | 3.99 | 3.89 |
| M2 | 3.87 | 4.02 | 4.03 | 4.25 | 4.04 |
| M3 | 3.59 | 3.45 | 3.89 | 3.91 | 3.71 |
| Mean | 3.72 | 3.80 | 3.95 | 4.05 | |
| C D at 5% | I - 0.14 | M - 0.12 | I X M - 0.24 | | |

Variations in ascorbic acid (vitamin C) and acidity contents were noted in response to various irrigation and mulching treatments (Table 4). Maximum ascorbic acid (721.33 mg/100 g pulp) was recorded at the irrigation regime $I_4$ (IW/CPE=0.4) followed by $I_3$ (699.17 mg/100g), $I_2$ and $I_1$. Among mulch materials, paddy straw mulch gave highest vitamin C content in fruits. Significant interaction effects were also recorded with in $I_4M_2$ (767 mg/100g) followed by $I_3M_2$ and $I_2M_2$.

Fruit acidity also varied significantly with different treatments. Maximum acidity was recorded under $I_4$ (4.05%) followed by $I_3$, $I_2$ and $I_1$. As regards mulching, paddy straw mulch resulted in highest fruit acidity (4.04 %) followed by $M_1$ and $M_3$. The interaction between irrigation and mulching was also significant with respect to fruit acidity. Maximum acidity was recorded with $I_4M_2$ (4.25%) followed by $I_1M_2$, $I_2M_2$, $I_4M_1$, $I_3M_1$.

The reduction in ascorbic acid and acidity content of fruits was recorded with increasing level of irrigation as it cause dilution of fruit juice with water. On the other hand, deficit in water increases electrical conductivity of soil leading to increase in fruit acidity. These findings are in agreement with Cruse *et al.* (1982) and Madrid *et al.* (1995).

The analysis indicates that aonla plants drip irrigated at 0.6 IW/CPE had higher leaf nitrogen status as compared to higher and lower levels of irrigation. Leaf nitrogen, potassium, calcium and magnesium were higher in paddy straw mulched trees, while phosphorus content was higher under polythene mulching. Fruits attained significantly higher fruit length, diameter, weight and volume at 1.0 IW/CPE. The higher levels of irrigation, viz., 0.8 and 1.0 IW/CPE improved fruit size but drip irrigation at 0.6 IW/CPE coupled with black polythene mulching resulted in optimum fruit yield and quality parameters such as total sugar content, ascorbic acid and acidity contents of aonla cv. NA-10. Thus, it helps in curtailing the water requirement of aonla to 0.6 IW/CPE (60 % evaporation replenishment) with drip irrigation and black polythene mulching for optimum fruit yield and quality.

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# Stability parameters in bottle gourd

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**Abstract**

The investigation was carried out to study the stability parameters for fruit yield and associated characters in bottle gourd. The material comprised of nine parents, 36 $F_1$ hybrids and one standard check. The environments were created by sowing the crop on the different dates at two different locations. The study revaled the presence of genotypes x environment interactions. The variance due to G x E (linear) was significant for all the traits indicating that major portion of G x E interaction were linear in nature and prediction of these traits was still possible. Based on the individual genotypes of adaptability, it is evident that three parental line and twelve hybrids recorded high mean performance alongwith non-significant deviation from regression. The hybrid Banswara Loca-1 x PSPL recorded below average regression coefficient (bi<1) while hybrid Long White Prolific x IC-92374 and Udaipur Local-1 x IC-92374 recorded above average coefficient indicating their better performance in poor and better environments, respectively. While, the parental line Banswara Local-1, Pusa Naveen and PSPL and nine hybrid showed regression coefficient around unity (bi=1) indicating their stability in varying environments.

**Key words:** *Stability, bottle gourd, genotypes x environment and hybrids*

## Introduction

To identify stable varieties/genotypes over different environments and to breed varieties separately for different regions of predictable environmental conditions, study of genotype x environment interactions was felt essential as a preliminary steps. An ideal crop variety is one that has a high mean yield but a low degree of fluctuations in performance, when grown over diverse environment. Due to high remunerative prices in domestic as well as external market, commercial cultivation of bottle gourd has increased in India. For evolving better and stable varieties for high quality yields, it is necessary to screen the available genotypes over a wide range of agro-climatic conditions for their commercial exploitation or effective utilization in breeding programme. Since, no detailed information is available the investigation could be of great significance to the breeders as well as growers.

## Materials and methods

The experimental material for analysis of G x E interaction comprised of nine diverse cultivars originated in different agro-climate of India alongwith their 36 $F_1$ hybrid (excluding reciprocals) and one standard check (Mahyco variety) of bottle gourd were evaluated under four environments created by sowing the experimental material on two different dates at two different locations. The experiment was conducted in a randomized block design with three replications. Each treatment consisted of a single row of accommodating ten plants. The rows were spaced at 3 m apart and plants at 1 m within the row. Observations were recorded from the randomly selected five plants leaving the border plants. The observations were recorded on days to open first male flower, days to open first female flower, node number to first male flower appearance, node number to first female flower appearance, number of male flowers/plant, number of female flowers/plant, number of branches/plant, vine length, days to first harvest, number of fruits/plant, fruit length, fruit girth, fruit weight and fruit yield/plant. The data were analyzed for stability parameters according to the method suggested by Eberhart and Russel (1966) and important yield characters are discussed in the text.

## Results and discussion

The pooled analysis of variance revealed that mean squares due to genotypes were highly significant for all the characters indicating the presence of adequate genetic variability in the experimental material. Significant mean squares due to environment and environment (linear) revealed variable environments for all the characters. Significant G x E interaction for all the traits indicated influence of environmental conditions on the genotypes studied. The variance due to G x E (linear) was significant for all the traits indicating that major portion of G x E interaction were linear in nature and prediction of these traits was still possible. Significant mean squares due to pooled deviation for all the traits indicated that genotypes

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differ considerable with respect to their stability and prediction of these attributes would be difficult (Table 1).

Finlay and Wilkinson (1963) considered linear regression slope as a measure of stability. However, Eberhart and Russel (1966) emphasized the need of considering both linear (bi) non-linear ($s^2$ d) components of genotype environment interactions in judging the phenotypic stability of a genotype. Later on, Samuel *et al.* (1970) and Paroda and Hayes (1971) advocated that linear regression could simply be regarded as a measure of response of a particular genotype, which infact is dependent largely on number of genotypes included in a particular study, whereas deviations from regression lines ($s^2d$) were considered as a better measure of stability, genotypes with lowest standard deviation being the most stable *vice versa*.

The mean performance (μi), the regression (bi) and deviation from regression ($s^2d$) components of G x E interaction are presented in the Table 2. The mean performance for female flower per plant among parental lines ranged from 11.35 (IC- 92353A) to 21.95 (Banswara local-1) while among the hybrids it ranged from 16.39 (Long White Prolific x IC-92353A) to 28.12 (Pusa Naveen x IC-92374) with over all mean of 21.03. One parental line and 14 hybrids recorded high mean performance alongwith non-significant deviation from regression ($s^2di=0$) indicating their better performance in better environments while one hybrid (Long White Prolific x PSPL) recorded below average regression co-efficient indicating better performance in poor environments. However, hybrids like Banswara Local-1 x Pusa Naveen, Banswara Local-1 x IC-92374, Long White Prolific X IC-92374, Pusa Naveen x Raichur Local-1, Pusa Naveen x PSPL, Raichur Local-1 x Udaipur Local-1, Raichur Local-1 x IC-92374, Udaipur Local-1 x PSPL and IC-92374 x PSPL recorded regression coefficient around unity (bi=1).

The mean performance for fruits per plant among parental lines ranged from 3.11 to 8.13 (IC-92374) while among hybrids it ranged from 4.29 to 13.83 (Pusa Naveen x IC-92374) with over all mean of 7.36. The hybrid namely Banswara Local-1 x Udaipur Local-1, Long White Prolific x IC-92374, Pusa Naveen x IC-92353A and Udaipur Local-1 x IC-92374 showed above average regression coefficient (bi>1) indicating their better performance in better environments. While parental line Pusa Naveen and IC-92374 and hybrid Banswara Local-1 x Pusa Naveen, Banswara Local-1 x Raichur Local-1, Long White Prolific x Udaipur Local-1, Pusa Naveen x Raichur Local-1, Pusa Naveen x Udaipur Local-1, Pusa Naveen x PSPL and IC-92374 x IC-42361 showed regression coefficient around unity (bi=1) indicating their stability in varying environments.

The mean performance for fruit yield per plant ranged from 1.49 to 6.93 among the parental lines while among the hybrids it ranged from 3.12 to 10.01 (Banswara Local-1 x IC-92374) with an over all mean of 5.97. Three parental lines (Banswara Local-1, Pusa Naveen and PSPL) and twelve hybrids recorded high mean performance alongwith non-significant deviation from regression. The hybrid Banswara Local-1 x PSPL recorded below average regression coefficient (bi<1) while hybrid Long White Prolific x IC-92374 and Udaipur Local-1 x IC-92374 recorded above average regression coefficient indicating their better performance in poor and better environments, respectively. Parental line Banaswara Local-1, Pusa Naveen and PSPL and hybrids Banswara Local-1 x Raichur Local-1, Long White Prolific x PSPL, Pusa Naveen x Raichur Local-1, Pusa Naveen x Udaipur Local-1, Pusa Naveen x IC-92374, Pusa Naveen x PSPL, Raichur Local-1 x IC-92374, Raichur Local-1 x PSPL and IC-92374 x IC-42361 showed regression coefficient around unity (bi=1) indicating their stability in varying environments. However, most of these crosses were also stable for yield contributing traits. In the present study, it is disappointing that the three crosses viz., Banswara Local-1 x IC-92374, Banswara Local-1 x Pusa Naveen and IC-92374 x PSPL showing significant economic heterosis

**Table 1.** Pooled analysis of variance for stability parameters of various characters over the environments in bottle gourd

| Source | d.f. | Mean squares | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Days to open first female flower | Node number to first female appearance | Number of female flower appearance | Days to first harvest | Number of fruit per plant | Fruit length | Fruit weight | Total fruit yield per plant |
| 1. Genotype (G) | 45 | 128.04** | 30.06** | 64.55 | 196.99** | 20.99** | 116.73** | 513.00** | 13.13** |
| 2. Environment (E) | 3 | 364.07** | 40.70** | 44.48 | 279.83** | 11.43** | 0.71** | 631.29** | 4.95** |
| 3. G×E | 135 | 5.26 •• | 1.16 •• | 1.96 •• | 6.68 •• | 0.31 •• | 1.05 •• | 500.78 •• | 0.21 •• |
| 4. G+( G×E) | 138 | 13.16++ | 2.02++ | 2.88++ | 12.62++ | 0.55++ | 1.04++ | 503.62++ | 0.31++ |
| 5. E (Linear) | 1 | 1092.21++ | 122.10++ | 133.45+ | 839.48++ | 34.29++ | 2.13++ | 1893.86++ | 14.86++ |
| 6. G×E (Linear) | 45 | 8.10++ | 2.05++ | 3.43++ | 8.41++ | 0.56++ | 1.30++ | 536.80++ | 0.32++ |
| 7. Pooled deviation | 92 | 3.90 •• | 0.69 •• | 1.19 •• | 5.69 •• | 0.17 •• | 0.91 •• | 472.28 •• | 0.15 •• |
| 8. Pooled error | 360 | 0.24 | 0.12 | 0.12 | 0.54 | 0.04 | 0.07 | 159.46 | 0.03 |

XX Significant at 1% when tested against GxE
++ Significant at 1% when tested against pooled deviation
•• Significant at 1% when tested against pooled error

**Table 2.** Estimates of stability parameters for various characters in bottle gourd

| S.No. | Entries | Days to first harvest | | | Number of fruits per plant | | | Total fruit yield yield per plant | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | μi | bi | $S^2di$ | μi | Bi | $S^2di$ | μi | bi | $S^2di$ |
| 1. | Banswara Local – 1 | 88.88 | 1.05 | 1.31* | 6.13 | 0.47 | 0.001 | 6.93 | 0.46 | -0.002 |
| 2. | Long White Prolific | 99.04 | 1.72 | 1.36* | 4.80 | 1.06 | -0.003 | 4.71 | 0.74 | 0.13** |
| 3. | Pusa Naveen | 87.13 | 1.12 | 2.49* | 7.47 | 0.41 | 0.01 | 6.80 | 0.33 | -0.02 |
| 4. | Raichur Local – 1 | 99.58 | 2.53 | 14.85** | 3.97 | -0.28 | 0.08 | 4.29 | -1.09* | 0.03 |
| 5. | Udaipur Local – 1 | 95.56 | 0.70 | 3.84** | 5.07 | 1.15 | 0.02 | 5.58 | 1.49 | 0.35** |
| 6. | IC-92353A | 104.97 | 0.92 | 18.99** | 3.12 | 0.38 | -0.02 | 1.49 | 0.56 | -0.02 |
| 7. | IC-92374 | 88.47 | 2.46 | 12.35** | 8.13 | 0.31 | 0.002 | 5.17 | -0.37** | -0.03 |
| 8. | IC-42361 | 109.27 | 0.71 | 4.88** | 3.14 | 0.61 | 0.14* | 2.23 | 0.78* | -0.03 |
| 9. | PSPL | 94.17 | 1.86 | 8.15** | 5.82 | 0.002 | 0.03 | 6.33 | -0.19 | 0.02 |
| 10. | Banswara Local – 1 x Long White Prolific | 96.28 | 0.72 | 6.21** | 7.74 | 0.30 | 0.78** | 7.40 | 0.09 | 0.57** |
| 11. | Banswara Local – 1 x Pusa Naveen | 82.28 | 0.38 | 0.62 | 9.41 | 0.24 | 0.07 | 9.24 | 1.23 | 0.16** |
| 12. | Banswara Local – 1 x Raichur Local – 1 | 93.30 | 0.43 | 4.27** | 6.54 | 1.08 | -0.03 | 6.81 | 1.68 | 0.02 |
| 13. | Banswara Local – 1 x Udaipur Local – 1 | 91.20 | 0.68 | 6.64** | 7.78 | 2.38** | -0.03 | 6.81 | 2.55 | 0.79** |
| 14. | Banswara Local – 1 x IC 92353A | 98.57 | 1.06 | 4.15** | 5.85 | 0.52 | 0.38** | 5.05 | 0.91 | 0.16** |
| 15. | Banswara Local – 1 x IC 92374 | 83.36 | 0.47 | -0.06 | 12.17 | 0.67 | 0.66** | 10.01 | 0.71 | 0.08* |
| 16. | Banswara Local – 1 x IC 42361 | 102.47 | 0.64 | 40.46** | 6.01 | 0.87 | 0.15* | 4.94 | 0.98 | 0.09* |
| 17. | Banswara Local – 1 x PSPL | 85.35 | 0.52 | 0.93 | 8.67 | 0.14 | 0.11* | 8.27 | -0.06* | -0.02 |
| 18. | Long White Prolific x Pusa Naveen | 84.91 | 0.83 | 3.92** | 9.78 | 1.48 | 0.65** | 6.50 | 0.87 | 0.57** |
| 19. | Long White Prolific x Raichur Local – 1 | 96.82 | 0.45 | 28.28** | 5.82 | 1.99 | 0.22** | 4.94 | 2.51 | 0.31** |
| 20. | Long White Prolific x Udaipur Local – 1 | 91.69 | 1.28 | 2.89** | 8.13 | 0.83 | -0.04 | 4.94 | -1.26 | 0.13** |
| 21. | Long White Prolific x IC- 92353A | 100.18 | 0.94 | 0.69 | 5.54 | 0.92 | 0.39** | 3.75 | 1.11 | 0.33** |
| 22. | Long White Prolific x IC- 92374 | 85.78 | 1.48 | 1.45* | 10.04 | 2.63* | -0.02 | 7.59 | 3.07* | 0.04 |
| 23. | Long White Prolific x IC- 42361 | 99.10 | 3.19 | 9.72** | 5.67 | 1.07 | 0.56** | 5.18 | 1.29 | 0.45** |
| 24. | Long White Prolific x PSPL | 89.82 | 0.38* | -0.19 | 7.20 | 1.40 | -0.01 | 6.85 | 0.60 | -0.01 |
| 25. | Pusa Naveen x Raichur Local – 1 | 84.64 | 0.66 | 0.59 | 9.68 | 0.41 | 0.02 | 6.57 | 0.96 | 0.02 |
| 26. | Pusa Naveen x Udaipur Local – 1 | 84.56 | 0.98 | 6.00** | 9.52 | 0.45 | -0.03 | 7.23 | 0.28 | 0.003 |
| 27. | Pusa Naveen x IC- 92353A | 93.70 | 1.08 | 3.61** | 8.01 | 1.61* | -0.03 | 5.29 | 1.95 | 0.18** |
| 28. | Pusa Naveen x IC- 92374 | 81.27 | 0.29* | -0.14 | 13.83 | 2.48 | 0.09* | 8.15 | 1.67 | -0.01 |
| 29. | Pusa Naveen x IC- 42361 | 93.49 | 1.08 | 3.59** | 8.41 | 1.86 | 0.36** | 6.54 | 2.11 | 0.08* |
| 30. | Pusa Naveen x PSPL | 82.95 | 0.55 | 2.67** | 8.64 | 0.51 | -0.001 | 8.16 | 0.44 | 0.44 |
| 31. | Raichur Local – 1 x Udaipur Local – 1 | 93.09 | 1.61 | 4.97 | 5.85 | -0.08 | 0.004 | 5.67 | 5.59** | -0.03 |
| 32. | Raichur Local – 1 x IC 92353A | 101.29 | 1.09 | 0.60 | 4.54 | 1.16 | 0.06 | 3.13 | 1.38 | 0.01 |
| 33. | Raichur Local – 1 x IC 92374 | 87.77 | 1.07 | 3.62** | 9.08 | 0.85 | -0.03 | 6.26 | 0.72 | -0.001 |
| 34. | Raichur Local – 1 x IC 42361 | 103.15 | 0.41 | 13.33** | 4.29 | 1.62* | -0.03 | 3.39 | 1.96* | -0.03 |
| 35. | Raichur Local – 1 x PSPL | 89.57 | 0.56 | 1.90** | 8.03 | 0.04 | 0.02 | 6.91 | -0.003 | -0.005 |
| 36. | Udaipur Local – 1 x IC- 92353A | 97.98 | 1.14 | 5.77** | 5.32 | 0.73 | 0.00 | 4.19 | 1.04 | 0.003 |
| 37. | Udaipur Local – 1 x IC- 92374 | 84.89 | 0.48 | -0.09 | 11.14 | 1.94** | -0.04 | 7.62 | 1.55* | -0.03 |
| 38. | Udaipur Local – 1 x IC- 42361 | 97.81 | 2.67 | 6.24** | 5.80 | 0.86 | 0.16** | 4.95 | 0.72 | 0.02 |
| 39. | Udaipur Local – 1 x PSPL | 90.71 | -0.03* | 0.37 | 8.08 | 1.22 | 0.01 | 6.96 | 1.02 | 0.29** |
| 40. | IC- 92353A x IC -92374 | 88.22 | 0.19 | 4.08** | 7.89 | 3.81* | 0.20** | 4.59 | 3.30* | 0.01 |
| 41. | IC- 92353A x IC- 42361 | 105.87 | 0.92 | 0.89 | 5.57 | 2.26 | 0.18** | 3.35 | 2.18 | 0.004 |
| 42. | IC- 92353A x PSPL | 90.89 | 0.50 | 0.32 | 7.06 | 2.64 | 0.59** | 4.49 | 2.18 | 0.16 |
| 43. | IC- 92374 x IC- 42361 | 88.07 | 1.63 | 0.38 | 9.62 | 0.30 | 0.01 | 7.56 | 0.03 | 0.01 |
| 44. | IC- 92374 x PSPL | 83.77 | 1.01 | 0.25 | 10.41 | 0.84 | 0.26** | 8.62 | 1.57 | 0.25** |
| 45. | IC- 42361 x PSPL | 94.06 | 0.52 | 0.03 | 7.13 | -0.02 | 0.05 | 5.70 | 1.57 | 0.08 |
| 46. | Check | 89.59 | 1.05 | -0.47 | 7.17 | 0.87 | -0.03 | 7.35 | 1.36 | 0.16** |
| | Pm (Xb) | 92.51 | 1.00 | 5.14 | 7.37 | 1.00 | 0.13 | 5.97 | 1.00 | 0.12 |
| | SE (b) | | 0.56 | | | 0.48 | | | 0.68 | |

for fruit yield/plant and its contributing characters none of the cross was stable in all the environments.

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# In vitro propagation of cactus pear

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**Abstract**

In this investigation an elite genotype of spineless cactus pear was selected for *in vitro* propagation. The effect of different levels of BA (0, 3.0, 6.0 and 9.0 mg $l^{-1}$) and NAA (0, 0.1 and 1.0 mg $l^{-1}$) alone and in combination were evaluated for *in vitro* culture establishment, axillary bud breaking, micro-shoot formation and root initiation. Early axillary bud breaking in cladode explant was induced with 9.0 mg BA $l^{-1}$ + 0.1 mg NAA $l^{-1}$ in 19.47 days, whereas all NAA concentrations failed to induce bud breaking in the explants. However, root initiation was noticed with NAA concentrations of 0.1 and 1.0 mg $l^{-1}$. Culture establishment in terms of percentage of explant with microshoot was maximum (80%) with 6.0 mg BA $l^{-1}$ + 0.1 mg NAA $l^{-1}$ as compared to minimum (26.67%) with 3.0 mg BA $l^{-1}$ and 1.0 mg NAA $l^{-1}$ treatment. All treatments of BA alone and in combination with NAA found to induce micro-shoots in single bud/areole of cladode explant. The proliferated micro-shoots were subjected for elongation treatment in order to obtain rootable length of micro-shoots. The elongated micro-shoots were further subjected to root formation under *in vitro* condition with different concentrations of NAA (0, 2.0, 4.0 and 6.0 mg $l^{-1}$) and IBA (2.0, 4.0 and 6.0 mg $l^{-1}$). Maximum number of roots was recorded with 6.0 mg IBA $l^{-1}$. Further the length of roots was also maximum (3.80 cm) with 6.0 mg IBA $l^{-1}$. The rooted plantlets were successfully acclimatized and approximately 92 per cent success obtained in potting mixture of vermiculite and cocopeat 3: 1 (v/v)

**Key words:** *Cactus pear, micropropagation, acclimatization*

## Introduction

The cactus pear (*Opuntia ficus-indica* (L) Mill) is native of Central American and Mexican region (Pareek *et al.*, 1998). Owing to presence of pricks on its body, cactus pear is commonly known as prickly pear and its edible fruit is called "tuna". In Mexico, the tender stems are used as vegetable (nopalitos) and sweet fruits are in demand in international market. In some countries cactus pear and their products serve various purposes such as the tender cladodes can be used to prepare vegetable, salad, pickle and as animal fodder (Singh and Felker, 1998). Use of nopales to cure diabetes has opened new vistas for its utilization in human health (Hagwood, 1990). The economic interest for cactus pear has remarkably increased during the last few years especially in the arid and semi-arid zones. However, one of the problems faced in increasing the area under cultivation of cactus pear rapidly is lack of suitable true-to-type planting material.

Propagation of cactus pear by seeds leads to several problems such as genetic segregation, a long juvenile phase, slow growth and lack of availability of true-to-type planting material and through vegetative means by cladodes produce limited plants which give poor survival in field due to foot rot disease infection.

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In view of the above, an attempt was made to multiply true to type plant material of cactus pear through tissue culture technique with an objective to develop *in vitro* micropropagation technique of thornless cactus pear and to develop successful micropropagation technique of cactus pear.

## Materials and methods

Explant material of spineless cladodes were taken from the pot grown plants of Cactus pear (*Opuntia ficus indica* (L.) Mill) from the Hi-Tech nursery of Central Institute for Arid Horticulture (CIAH), Bikaner and the experiment was conducted in CRD. The significance of various treatment effects was judged with the help of 'F' value (test) at 1%. The cladodes were harvested in the morning during the month of September and October 2006. The cladodes were thoroughly washed in detergent followed by running tap water and finally washed with autoclaved distilled water. The cladodes were then surface sterilized with 0.1% solution of $HgCl_2$ (W/V) for 5-6 minutes followed by washing with autoclaved distilled water for 6-8 times.

The culture medium was poured in conical flasks and test tubes for sterilization. Autoclaving was done for 15 minutes at 121°C and 15 p.s.i. (1.1 $kg^{-1}cm^2$) pressure. After autoclaving the media was stored in dark conditions for 48 hours at 25±2°C. The cultures were incubated in culture room at 26 ± 1°C and 16/8 hours photoperiod was provided.

To determine the influence of various concentrations of BA (0, 3, 6, 9 mg $l^{-1}$) and NAA (0, 0.1 and 1.0 mg $l^{-1}$), these were used alone and in various combinations. Murashige and Skoog (1962) medium was used as basal medium. Observations with respect to number of days taken for bud break, percentage of explants with shoots, mean number of shoot per explant and mean length of shoot were recorded. After bud breaking subculturing was done on fresh medium and observations were recorded after 21 days. To determine the influence of various concentrations of NAA and IAA on the elongation of proliferated micro-shoots, the micro-shoots were subjected for elongation phase and observations with respect to average shoot length (cm) were recorded after 30 days of micro-shoots inoculation.

To evaluate *in vitro* rooting response of micro-shoots, the proliferated micro-shoots of about 2-5 cm length obtained from *in vitro* raised explants were transferred to MS medium supplemented with various concentrations of IBA and NAA and time taken for induction of roots, per cent rooting, mean maximum length of root and number of roots/shoot were recorded 21 days after inoculation of microshoots

The rooted micro-shoots were taken out from the culture vessels and tried in different potting mixtures for successful establishment of plantlets. Initially, plantlets were kept under growth chamber and later on transferred to greenhouse (at temperature range of 28-30°C and humidity of 70-85%).

## Results and discussion

### *Effect of BA and NAA on axillary bud/areole breaking in cladode explant*

The number of days required for axillary bud breaking in cladode explants are presented in Table 1. The data revealed that different levels of BA and NAA resulted in significant variation on number of days taken for axillary bud breaking in inoculated cladode explants under *in vitro* condition. Significantly less number of days for axillary bud breaking (19.47) were observed in the cultures at $T_{11}$ (9.0 mg $l^{-1}$ BA + 0.1 mg $l^{-1}$ NAA) treatment followed by (19.87) days as compared to higher (35.46 days) at $T_4$ (3.0 mg $l^{-1}$ BA) treatment, whereas $T_1$ (control), $T_2$ (0.1 mg $l^{-1}$ NAA) and $T_3$ (1.0 mg $l^{-1}$ NAA) treatments failed to induce axillary bud breaking in explants.

The present results are in conformity with the findings of Mauseth (1977 and 1979). Further, Escobar *et al.* (1986) also reported that BA was necessary for axillary proliferation from pre-existing buds in the cactus *Opuntia amyclaea*. Similar results have also been noticed by Dabekaussen *et al.* (1991) and Mohamed-Yassen *et al.* (1995) in cactus *Sulcorebutia alba* Rausch and *Stepelia semota*, respectively. This shows that BA suppresses apical dominance and stimulates the lateral buds.

In the treatments without BA, all auxin concentrations failed to stimulate axillary bud initiation in the cladode explant. However, some explants exhibited root induction instead of shoot bud induction. This is due to physiological action of auxin in stimulation of root initiation.

### *Effect of BA and NAA on percentage of explants with shoots*

Data in Table 1 indicate significant effect of various levels of BA and NAA on the percentage of explants with shoots. It is clear from the data that different levels of BA and NAA produced a remarkable effect on the percentage of explant with shoots. The mean maximum percentage of explants with shoots (80%) were obtained in $T_8$ (6.0 mg $l^{-1}$ BA + 0.1 mg $l^{-1}$ NAA) and $T_{11}$ (9.0 mg $l^{-1}$ BA + 0.1 mg $l^{-1}$ NAA) treatment as compared to mean minimum (26.67%) in $T_6$ (3.0 mg $l^{-1}$ BA + 1.0 mg $l^{-1}$ NAA) treatment. Whereas, T1 (control), $T_2$ (0.1 mg $l^{-1}$ NAA) and $T_3$ (1.0 mg $l^{-1}$ NAA) treatments failed to induce shoot formation in the explant.

These results are in agreement with the findings of Escobar *et al.* (1986), Mohamed-Yaseen *et al.* (1995), Giusti *et al.* (2002) and Garcia-Saucedo *et al.* (2005). In cactus spp, they observed better establishment of explants under *in vitro* condition with proliferation of micro-shoots. The less percentage of explant with shoots was observed with 3.0 mg $l^{-1}$ BA + 1 mg $l^{-1}$ NAA treatment. This is due to higher concentration of NAA with respect to BA i.e., 1.0 mg $l^{-1}$ which might have suppressed stimulative effect of BA.

### *Effect of BA and NAA on number of shoot per explant*

The treatment without BA failed to induce shoot in the explants (Table1 ) whereas, in all the treatments of BA alone and in combination with NAA produced one shoot per explant. *In vitro* propagation, subculturing process generally enhances shoot proliferation and plays an important role in increasing number of shoots per explant (Giusti *et al.*, 2002). In this experiment, cultures were not subjected to repeated subculturing hence only one micro-shoot was observed per explant. Similar results were obtained by Juarez and Passera (2002) *in vitro* propagation of *Opuntia ellisiana* Griff.

### *Effect of BA and NAA on length of shoot per explant*

In the present study, all the BA concentrations along with NAA significantly influence the shoot length in the explants. The mean maximum shoot length (1.02 cm) was obtained in $T_{11}$ (9.0 mg $l^{-1}$ BA + 0.1 mg $l^{-1}$ NAA) treatment followed by (0.95 cm) in $T_8$ (6.0 mg $l^{-1}$ BA + 0.1 mg $l^{-1}$ NAA) treatment as compared to mean minimum shoot length (0.45 cm) in $T_6$ (3.0 mg $l^{-1}$ BA + 1.0 mg $l^{-1}$ NAA) treatment (Table 1). Maximum length of shoot as observed in BA treatments at higher concentrations are due to emergence of shoot earlier with higher concentration of BA. Minimum length of the shoots recorded under the treatments with minimum BA concentration and higher concentration of auxins might be due to the suppression of BA effect by the higher concentration of NAA in shoot growth. Starling (1985) also observed variable response of BA and NAA at different

**Table 1.** Effect of BA and NAA on the number of days taken for axillary bud breaking in explant and others parameters of shoot proliferation

| | Treatment combinations | Days taken for bud breaking in explant | Percentage of explant with shoots | Number of shoots per explant | Shoot length per explant (cm) |
|---|---|---|---|---|---|
| $T_1$ | BA +NAA (0.0 mg $l^{-1}$ + 0.0 mg $l^{-1}$) | 0.00 | 0.00 (0.00)* | 0.00 | 0.00 |
| $T_2$ | BA +NAA (0.0 mg $l^{-1}$ + 0.1 mg $l^{-1}$) | 0.00 | 0.00 (0.00) | 0.00 | 0.00 |
| $T_3$ | BA +NAA (0.0 mg $l^{-1}$ + 1.0 mg $l^{-1}$) | 0.00 | 0.00 (0.00) | 0.00 | 0.00 |
| $T_4$ | BA +NAA (3.0 mg $l^{-1}$ + 0.0 mg $l^{-1}$) | 35.47 | 46.67 (43.09) | 1.00 | 0.49 |
| $T_5$ | BA +NAA (3.0 mg $l^{-1}$ + 0.1 mg $l^{-1}$) | 31.67 | 73.33 (58.91) | 1.00 | 0.75 |
| $T_6$ | BA +NAA (3.0 mgl$^{-1}$ + 1.0 mg $l^{-1}$) | 32.33 | 26.67 (31.09) | 1.00 | 0.45 |
| $T_7$ | BA +NAA (6.00 mg $l^{-1}$ + 0.0 mg $l^{-1}$) | 29.47 | 66.67 (54.74) | 1.00 | 0.62 |
| $T_8$ | BA +NAA (6.0 mg $l^{-1}$ + 0.1 mg $l^{-1}$) | 28.47 | 80.00 (63.43) | 1.00 | 0.95 |
| $T_9$ | BA +NAA (6.0 mg $l^{-1}$ + 1.0 mg $l^{-1}$) | 23.47 | 53.33 (46.91) | 1.00 | 0.65 |
| $T_{10}$ | BA +NAA (9.0 mg $l^{-1}$ + 0.0 mg $l^{-1}$) | 21.60 | 53.33 (46.91) | 1.00 | 0.68 |
| $T_{11}$ | BA +NAA (9.0 mg $l^{-1}$ + 0.1 mg $l^{-1}$) | 19.47 | 80.00 (63.43) | 1.00 | 1.02 |
| $T_{12}$ | BA +NAA (9.0 mg $l^{-1}$ + 1.0 mg $l^{-1}$) | 19.87 | 66.67 (54.74) | 1.00 | 0.60 |
| | C D at 5% | | 0.21 | 9.06 | 0.06 |

0 indicates no bud break

concentration in shoot formation in a range of cacti and other succulents.

***Effect of different concentration of auxin on the shoot elongation***

The effects of various levels of NAA and IAA on shoot length in inoculated micro-shoots were studied. In this experiment, there were three concentration of NAA (0.5, 1.0 and 2.0 mg $l^{-1}$) and three concentration of IAA (0.5, 1.0 and 2.0 mg $l^{-1}$) along with control.

***Effect of NAA and IAA on shoot length during elongation period***

The data given in Table 2 show the effect of NAA and IAA on the elongation of proliferated micro-shoots. The length of shoot was significantly influenced by all the treatments of NAA and IAA as compared to control. A decrease in shoot length was noticed with increasing concentrations of auxins. It is evident from the data that the shoot length was inversely proportional to the various levels of auxins (NAA and IAA). The mean maximum elongation in shoot length (1.33 cm) was obtained in $T_5$ (0.5 mg $l^{-1}$ IAA) treatment followed by (0.63 cm) in $T_2$ (0.5 mg $l^{-1}$ NAA) treatment as compared to mean minimum shoot length (0.13 cm) in $T_1$ (control) treatment. Addition of auxin in the medium often mitigates the inhibitory effect of

**Table 2.** Effect of NAA and IAA on the length of micro-shoots during elongation phase

| | Treatments | Shoot length per explant (cm) |
|---|---|---|
| $T_1$ | Control | 0.13 |
| $T_2$ | NAA (0.5 mg $l^{-1}$) | 0.63 |
| $T_3$ | NAA (1.0 mg $l^{-1}$) | 0.47 |
| $T_4$ | NAA (2.0 mg $l^{-1}$) | 0.30 |
| $T_5$ | IAA (0.5 mg $l^{-1}$) | 1.33 |
| $T_6$ | IAA (1.0 mg $l^{-1}$) | 0.47 |
| $T_7$ | IAA (2.0 mg $l^{-1}$) | 0.23 |
| | C D at 5% | 0.09 |

cytokinin on shoot elongation, thus increasing the number of usable shoots of sufficient length for rooting. This is due to physiological action of NAA in cell division and stimulation of apical dominance in the micro-shoots and adventitious root formation including cell elongation.

***Rooting in micro-shoots***

After having successfully established the culture of cactus pear single areole cladodes followed by successful production of micro-shoots, the formation of roots on the micro-shoots formed an important part of the present investigation. Proliferated micro-shoots were subjected to root initiation the *in vitro* culture.

***Effect of IBA and NAA on root induction in micro-shoots***

The data given in Table 3 show the effect of IBA and NAA on root induction in micro-shoots.

In the present study the number of days taken for root induction under the influence of different IBA and NAA treatments were recorded and it was observed that earliest root induction (10.44 days) was recorded with $T_4$ (6.0 mg IBA $l^{-1}$) followed by (10.82 days) with $T_7$ (6.0 mg NAA $l^{-1}$) as compared to delayed rooting with $T_1$ (control) treatment. These results indicate that the higher concentration of auxins have better simulative influence on root initiation whereas lower concentration exhibited delayed rooting which may be due to in-sufficient quantity for root induction. Similar observations were reported by Mata-Rosas *et al.* (2001) with Mexican cactus *Turbinicarpus laui* and Jaurez and Passera (2002) with *Opuntia ellisiana* Griff.

***Effect of IBA and NAA on rooting percentage of micro-shoots***

The mean maximum rooting (100%) was obtained in $T_3$ (4.0 mg $l^{-1}$ IBA) and $T_6$ (4.0 mg $l^{-1}$ NAA) treatments,

**Table 3.** Effect of IBA and NAA on the various rooting parameters

| | Treatments | Root induction (Days) | Rooting per cent | Number of roots / micro-shoots | Length of the Root (cm) |
|---|---|---|---|---|---|
| $T_1$ | Control | 14.69 | 36.30 (37.05)* | 1.69 | 0.52 |
| $T_2$ | NAA (0.5 mg $l^{-1}$) | 12.15 | 80.00 (63.43) | 2.13 | 2.00 |
| $T_3$ | NAA (1.0 mg $l^{-1}$) | 11.13 | 100.00 (90.00) | 4.33 | 3.33 |
| $T_4$ | NAA (2.0 mg $l^{-1}$) | 10.44 | 66.67 (54.74) | 4.47 | 3.80 |
| $T_5$ | IAA (0.5 mg $l^{-1}$) | 12.42 | 93.33 (75.04) | 2.20 | 2.20 |
| $T_6$ | IAA (1.0 mg $l^{-1}$) | 11.68 | 100.00 (90.00) | 4.20 | 2.60 |
| $T_7$ | IAA (2.0 mg $l^{-1}$) | 10.82 | 93.33 (75.04) | 3.73 | 3.20 |
| | C D at 5% | 0.31 | 15.21 | 0.38 | 0.31 |

*Figures in parenthesis are angular transformed values

respectively and the mean minimum rooting (36.30%) was obtained in control (Table 3). Rooting percentage in micro-shoots was better with 4.0 mg $l^{-1}$ IBA and 4.0 mg $l^{-1}$ NAA. *In vitro* studies of Parez-Molphe-Balch *et al.* (2002) also support the present findings.

***Effect of IBA and NAA on number of roots per shoot***

The mean maximum numbers of roots (4.47) were recorded in $T_4$ (6.0 mg $l^{-1}$ IBA) treatment closely followed by $T_3$ (4.33) (4.0 mg $l^{-1}$ IBA) treatment as compared to mean minimum number of roots (1.69) in control (Table 3). The maximum numbers of roots per micro-shoot were recorded with higher concentration of IBA as compared to all treatments of NAA and control. These results are in confirmation of with Escobar *et al.* (1986), who also observed variable response of IBA and/or NAA at different concentration on root formation in a range of cacti and other succulents.

***Effect of IBA and NAA concentration on root length***

The data presented in the Table 3 show the effect of different concentration of auxin (IBA and NAA) fortified to ½ strength MS media. The mean maximum length of roots (3.80 cm) observed in $T_4$ (6.0 mg $l^{-1}$ IBA) treatment closely followed by (3.33 cm) in $T_3$ (4.0 mg $l^{-1}$ IBA) treatment as compared to mean minimum root length (0.52 cm) in control. The effect of higher concentration was at par to the IBA concentration of 4.0 mg $l^{-1}$. The results for longer root with higher concentration of both auxins may probably be explained by the effect that higher concentration of auxins took less time in root induction so the emerged roots get more period for their growth and development as compared to the roots which emerged later in lower concentration of auxins. The present findings are supported by the results obtained by Mausath (1979) who obtained better quality roots with NAA.

***Acclimatization of the plantlets***

*In vitro* propagated plantlets were successfully acclimatized by transferring them into small pots of plastic, containing potting mixture of different medium. The rate of survival of the plantlets in the pots was 91.67% with vermiculite + cocopeat mixture of 3:1 (v/v) which was followed by another mixture i.e. vermiculite + vermicompost (83.33%). The lowest survival of plantlets (58.33%) observed with soil. The higher percentage of survival of plantlets with vermiculite along with either cocopeat or vermicompost may be due to the properties of higher porosity, cation exchange capacity (CEC) and water holding capacity. Cent per cent survival under the same medium has also been reported by (Johnson and Emino, 1979; Vyaskot and Jara, 1984; Ault and Blackmon, 1987).

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**INDIAN JOURNAL OF ARID HORTICULTURE**
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# Effect of sheep manure, vermicompost and biofertilizer on productivity of dill

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**Abstract**

A field experiment was conducted to study the effect of sheep manure, vermicompost and biofertilizers on productivity of dill (*Anethum graveolense* L.) at NRC Seed Spices, Ajmer ( Rajasthan) during *rabi* 2005-06 and 2006-07. The experiment consisted sixteen treatments comprising of control, three levels of sheep manure (5.0, 7.5, and 10.0 t $ha^{-1}$), vermicompost (2.0, 3.0, and 4.0 t $ha^{-1}$) and recommended fertilizer with and without biofertilizer. The results revealed that application of sheep manure, vermicompost and recommended fertilizer with and without bio-fertilizer proved superior over control. Moreover application of biofertilizer alone and with sheep manure, vermicompost and recommended fertilizer resulted in higher growth parameters, yield attributes and yield of dill over control. The increasing levels of sheep manure and vermi compost exhibited higher yield over their respective lower doses. The highest seed yield (15.25 q $ha^{-1}$), stover yield (32.12 q $ha^{-1}$) and biological yield (47.37 q $ha^{-1}$) of dill was obtained with application of sheep manure @ 10 t $ha^{-1}$ with bio-fertilizer.

**Key words:** *Dill, bio-fertilizer, sheep manure, vermi-compost, fertilizer*

## Introduction

Spices are integral part of Indian diet and thats why India is known as home of spices. India is the largest producer, consumer as well as exporter of the seed spices. Dill (*Anethum graveolense* L.) belongs to the family Apiceae and is an important seed spice crop, grown for its seed and leaves which are used for culinary purposes. Fruits are marketed as common condiments for its essential oils (3.0-4.0%) which possesses a peculiar aroma. Oil or its emulsion in water commonly known as "dill water" is considered to be aromatic, carminative, digestive, diuretic and very useful in "colic pain". Seeds are used as whole as well as ground in soup, salad, sauces and pickles. It is mainly grown in Rajasthan, Gujarat, Maharastra, Andhra Pradesh and Madhya Pradesh. Rajasthan contributes about 50% of total production of dill which is grown in an area of 2000 ha. with production of 1000 t having productivity of 500 kg $ha^{-1}$ (Tiwari and Agarwal, 2004).

Traditionally the nutrient requirement of dill is being met out by the application of chemical fertilizers. The experience of many research scientists working in India as well as abroad have shown that excessive and imbalance use of chemical fertilizer and pesticides in the past have resulted in degradation and deterioration of soil's physical, chemical and biological properties To overcome this problem, use of organic sources of nutrition are needed. Such studies are lacking in dill. Moreover, the demand of seed spices all over the world is increasing which is an important source of earning foreign exchange because whole word is looking towards India for supply of quality seed spice free from contamination of toxic residue. In view of the above, the studies were conducted to identify suitable and feasible source of organic nutrition for increasing productivity of dill.

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## Materials and methods

The experiment was carried out at National Research Centere on Seed Spices, Ajmer (Rajasthan) during rabi 2005-06 and 2006-07. The experiment consisted sixteen treatments comprising of three levels of sheep manure (5.0, 7.5, and 10.0 t.$ha^{-1}$), vermicompost (2.0, 3.0, and 4.0 t $ha^{-1}$), recommended fertilizer (50 kg N, 30 kg $P_2O_5$ and 20 kg $K_2O$) with and without biofertilizer *(Azotobacter)* and absolute control in randomized block design with three replications. The organic sources of nutrients were applied before sowing and seeds of dill were treated with bio-fertilizer *(Azotobacter)* immediately before sowing. The soil of the experimental site was sandy loam with a pH of 8.92 and 0.21 per cent organic carbon content having 76.0, 33.4 and 234.1 kg $ha^{-1}$ available N, $P_2O_5$ and $K_2O$, respectively. Observations were recorded on growth parameters, yield attributes and yield of dill.

## Results and discussion

The data revealed that application of increasing levels of sheep manure i.e., 5.0, 7.5 and 10.0 t $ha^{-1}$ and

**Table 1.** Effect of sheep manure, vermi-compost and bio-fertilizer on growth and yield of Dill (Pooled data of two years)

| Treatments | Plant Height (cm) | | Umbels Plant$^{-1}$ | Umbel lets Umbel$^{-1}$ | Seed yield q ha$^{-1}$ | Stover yield q ha$^{-1}$ | Biological yield q ha$^{-1}$ |
|---|---|---|---|---|---|---|---|
| | 80 DAS | Maturity | | | | | |
| Absolute control | 48.25 | 98.35 | 11.40 | 15.90 | 9.40 | 20.24 | 29.64 |
| Recommended Fertilizer dose | 53.25 | 112.25 | 15.00 | 19.20 | 13.80 | 29.40 | 43.20 |
| Bio fertilizer (*Azotobactor*) | 50.40 | 107.25 | 14.00 | 18.68 | 10.50 | 23.45 | 33.95 |
| RF+Biofertilizer | 57.28 | 115.40 | 18.90 | 20.24 | 14.50 | 30.15 | 44.65 |
| Sheep manure @ 5 t ha$^{-1}$ | 51.50 | 109.25 | 16.10 | 19.10 | 12.40 | 26.80 | 39.20 |
| Sheep manure @ 7.5 t ha$^{-1}$ | 53.00 | 113.40 | 17.00 | 19.80 | 13.85 | 29.75 | 46.60 |
| Sheep manure @ 10 t ha$^{-1}$ | 55.20 | 118.20 | 19.60 | 21.30 | 14.50 | 31.40 | 45.90 |
| Sheep manure @ 5 t ha$^{-1}$ + Biofertilizer | 55.25 | 116.25 | 18.00 | 20.24 | 13.50 | 28.15 | 41.65 |
| Sheep manure @ 7.5 t ha$^{-1}$ +Biofertilizer | 59.45 | 122.40 | 19.70 | 22.10 | 14.40 | 29.40 | 43.80 |
| Sheep manure @ 10 t ha$^{-1}$ +Biofertilizer | 63.40 | 125.80 | 20.00 | 23.00 | 15.25 | 32.12 | 47.37 |
| Vermicompost @ 2 t ha$^{-1}$ | 51.00 | 106.40 | 16.00 | 18.70 | 12.15 | 26.10 | 38.25 |
| Vermicompost @ 3 t ha$^{-1}$ | 52.50 | 110.25 | 16.30 | 19.00 | 13.25 | 27.45 | 40.70 |
| Vermicompost @ 4 t ha$^{-1}$ | 54.80 | 115.40 | 16.60 | 19.50 | 14.00 | 29.70 | 43.70 |
| Vermicompost @ 2 t ha$^{-1}$ +Biofertilizer | 54.20 | 114.50 | 17.30 | 20.00 | 14.15 | 29.50 | 43.65 |
| Vermicompost @ 3 t ha$^{-1}$ +Biofertilizer | 58.25 | 119.40 | 19.00 | 20.90 | 14.20 | 30.10 | 44.30 |
| Vermicompost @ 4 t ha$^{-1}$ +Biofertilizer | 62.50 | 121.00 | 19.70 | 22.00 | 14.60 | 31.85 | 46.45 |
| C D at 5% | 0.95 | 1.35 | 0.63 | 0.60 | 1.68 | 0.72 | 0.73 |

vermicompost, 2.0, 3.0 and 4.0 t ha$^{-1}$ exhibited significantly higher plant height, yield attributing character and yield over their respective lower levels (Table 1). Moreover, the application of sheep manure at all three levels showed better performance on yield attributing characters as compared to three levels of vermicompost with and without bio fertilizer. The application of biofertilizer responded positively with all the sources of organic nutrition as well as with recommended fertilizer in respect of growth, yields attributing characters and yield of dill. However, the application of sheep manure @ 10.0 t ha$^{-1}$ with biofertilizer exhibited highest plant height (125.80 cm), umbels/plant (20.20), umbel lets/umbel (23.00), seed (15.25 q ha$^{-1}$) stover (32.12 q ha$^{-1}$) and biological yield (47.37 q ha$^{-1}$) which was followed by the application of vermi-compost @4.0 t ha$^{-1}$ with biofertilizer. This shows the additive effect of organic sources of nutrition and biofertilizer on yield and yield attributing characters of dill.

Application of sheep manure and vermicompost and biofertilizer may be responsible for the improvement of physical, chemical and biological properties of the soil which in turn enhance availability and uptake of macro and micro-nutrients and affect various physical and bio-chemical processes in plants resulting in better yield attributing characters and yield of the crop. Hence, the overall effect of organic source of nutrient in improving yield attributes leads to better seed, stover and biological yield of dill at higher vermi-compost and sheep manure level with biofertilizer. Prabhu *et al.* (2000) reported significantly higher yield of coriander with 25% recommended dose of fertilizer + FYM @ 10 t ha + *Azospirillum* + VAM over other combination of nutrient sources. Similar results were obtained by Mehta *et al.* (2007) in case of ajowain. The results are in close conformity with the findings of Kumar *et al.* (2004) and Kothari *et al.* (1998) in case of coriander.

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# Cost and returns of henna in Pali district of Rajasthan

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**Abstract**

The present investigation was carried out in Sojat tehsil of Pali district in Rajasthan to study the cost of cultivation .A sample of 50 henna cultivators were selected for detailed study. The study relates to the agriculture year 2003-2004. Study of cost of cultivation revealed that the average total coast of cultivation of henna was estimated at Rs. 29978.00 $ha^{-1}$ with Rs. 21922.00 ha-1 as establishment cost and Rs. 8055.00 $ha^{-1}$ as maintenance cost. In establishment cost henna seedlings and transplanting were the single largest cost items of operational cost in all the size groups of farms. Under maintenance cost, cost of rental value of owned land was the prime component of the fixed cost. The per hectare return over maintenance cost from henna cultivation on an average was estimated at Rs. 6155.00 for the life span of one year. The average net return over total cost of henna cultivation was worked out to be negative (Rs.15808.00 $ha^{-1}$). The overall cost of production of henna was Rs. 28.71 $kg^{-1}$.

**Key words:** *Henna, production, economics*

## Introduction

Henna (*Lawsonia inermis* L.) is a white or pink flowered perennial shrub belonging to family lythraceae and popularly known as mehndi. It is grown as a hedge plant through out India, as a commercial dye crop. It is cultivated mainly in arid and semi-arid tract of Rajasthan, Punjab, Gujarat and Madhya Pradesh. Among different states, Rajasthan is the major henna producing state of the country with the production of 19377 tonnes. In Rajasthan, Sojat tehsil of Pali district is the major henna belt covering around 96 per cent of the total area in the state. The cultivation of henna started in a village Saiwat, of Sojat teshil on commercial scale and number of peasants of the tract took to the cultivation of this crop on a commercial scale. However due to higher investment on manpower and cost of cultivation of henna farmers are shifting over other crops. So, an attempt was made to analyze the costs of henna as compare to other arable crops of the area.

## Materials and methods

The present investigation was carried out in Pali district (Sojat tehsil) of Rajasthan during the year 2003-04 to study the cost of cultivation of henna. A sample of 50 henna cultivators were selected for detailed study. Primary data were collected with the help of schedules, which were prepared specially for the purpose, interviewing the respondents, personally collected the data and complete information about size of holding, resource inventory, land utilization, expenditure on variable inputs and crop budget for henna. Cost of marketing, market charges, price received etc., were collected. For analysis of data following analysis procedures were followed.

$$\text{Depreciation} = \frac{\text{Purchase price of asset} - \text{Junk value}}{\text{Number of expected useful years of life}}$$

After calculating total annual depreciation of the farm, the depreciation for a particular crop was worked out. This was done as follows:

$$\text{Depreciation for crop 'X'} = \frac{\text{Total annual depreciation}}{\text{Total cropped area}} \times \text{Area under crop 'X'}$$

Since the structure of cost for the cultivation of henna is quite different to the traditional crop farming, the Establishment Cost and Maintenance (Fixed and Variable) cost concepts are devised.

$$\text{Cost of production} = \frac{\text{cost of cultivation/unit-Value of product/unit area}}{\text{Quantity of main product produced per unit area}}$$

In case of henna crop the value of by-product was considered as zero.

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**Returns**

i) Gross Returns (GR): Gross return was obtained as GR = QP x PP

Where, GR = Gross Return
QP = Quantity of Produce
PP = Price of Produce

ii) Net Return: It is the residue after deducting all cost items i.e. total costs from the gross returns.

iii) Return over maintenance cost = Gross return – Total maintenance cost

For the present analysis, present value of future cash flow has been worked out by discounting the estimated returns and costs at 9 per cent rate of interest, the rate of borrowing money from the financial institution in the study area.

## Results and discussion

Data presented in Table 1 reveal that, on an average, the total cost per hectare for establishing henna crop was Rs. 21922.00. Total establishment cost was estimated to be Rs. 20882.00 $ha^{-1}$ are on small, Rs. 21737.00 $ha^{-1}$ on semi-medium, Rs. 23574.00 $ha^{-1}$, per hectare on medium and Rs. 24626.00 $ha^{-1}$. Thus, the total cost of establishment of henna crop was highest on large farms followed by medium, semi-medium and small farmers. Of the total establishment cost, operational cost accounted for Rs. 12394.00 $ha^{-1}$ (56.54 %). Remaining Rs. 9528.00 $ha^{-1}$ (43.46%) of total establishment cost was the fixed cost. Component wise, the cost of seedling and transplanting was highest (22.43% of the total establishment cost) followed by land preparation (10.13 %), weeding and hoeing (9.53%), interest on working capital (7.14%) manures and fertilizers (3.95%), and plant protection measures (3.36%). Among different group of farmers, the share of seedling and transplanting cost in the total establishment cost was 23.83, 22.25, 20.90 and 19.77 per cent on small, semi-medium, medium and large farmers, respectively indicating decreasing share with the increase in the size of holding. Land preparation cost which stood second in order worked out to be 10.75, 9.96, 9.29 and 9.62 per cent on small, semi-medium, medium and large farmers, respectively, with an overall average of 10.13 per cent. It was highest (Rs. 2370.00 $ha^{-1}$) on large farms and lowest

**Table 1:** Establishment cost* of henna on sample farms in Sojat tehsil of Pali district

(Rs./$ha^{-1}$)

| S. No. | Particulars | Farm size Small | Semi-medium | Medium | Large | Overall |
|---|---|---|---|---|---|---|
| **A.** | **Operational cost** | 2245 | 2165 | 2190 | 2370 | 2221 |
| 1. | Land preparation | (10.75) | (9.96) | (9.29) | (9.62) | (10.13) |
| 2. | Seedlings and transplanting | 4977 (23.83) | 4836 (22.25) | 4925 (20.90) | 4869 (19.77) | 4917 (22.43) |
| 3. | Manures and fertilizers | 667 (3.19) | 975 (4.49) | 1050 (4.55) | 1120 (4.45) | 865 (3.95) |
| 4. | Weeding and hoeing | 2034 (9.74) | 2068 (9.51) | 2185 (9.27) | 2250 (9.14) | 2089 (9.53) |
| 5. | Plant protection measures | 573 (2.74) | 834 (3.84) | 850 (3.61) | 1020 (4.14) | 737 (3.36) |
| 6. | Interest on working capital | 1549 (7.42) | 1524 (7.02) | 1619 (6.87) | 1697 (6.89) | 1565 (7.14) |
| **Total operational cost (A)** | | 12045 (57.68) | 12402 (57.06) | 12819 (54.38) | 13326 (54.11) | 12394 (56.54) |
| **B.** | **Fixed cost** | | | | | |
| 7. | Interest on fixed capital | 833 (3.99) | 1043 (4.80) | 1272 (5.40) | 1352 (5.50) | 1017 (4.64) |
| 8. | Depreciation | 1269 (6.08) | 1719 (7.91) | 1767 (7.50) | 2034 (8.26) | 1553 (7.08) |
| 9. | Land revenue | 15.0 (0.07) | 18.0 (0.08) | 21 (0.09) | 24.0 (0.10) | 18.0 (0.08) |
| 10. | Rental value of owned land | 6720 (32.18) | 6555 (30.15) | 7695 (32.64) | 7890 (32.03) | 6940 (31.66) |
| **Total fixed cost (B)** | | 8837 (42.32) | 9335 (42.94) | 10755 (45.62) | 11300 (45.89) | 9528 (43.46) |
| **Total establishment cost (A + B)** | | 20882 (100.00) | 21737 (100.00) | 23574 (100.00) | 24626 (100.00) | 21922 (100.00) |

Note: Figures in parentheses are the percentage of total establishment cost

* Discounted

(Rs. 2165.00 ha$^{-1}$) on semi-medium farms. Expenditure on weeding and hoeing was another important component, which accounted 9.74, 9.51, 9.27 and 9.14 per cent on small, semi-medium, medium and large farms. Manures and fertilizers contributed 3.19, 4.49, 4.45, and 4.55 per cent to the total cost on small, semi-medium, medium and large farms, respectively. Expenditure on plant protection measures was worked out to be 2.74, 3.84, 3.61 and 4.14 per cent on small, semi-medium, medium and large farms, respectively of the total establishment cost. Interest on working capital accounted 7.42, 7.02, 6.87 and 6.89 per cent on small, semi-medium, medium and large farms, respectively of the total establishment cost. Rental value of owned land contributed maximum (31.66 %) share in the total fixed cost of establishing the henna crop followed by depreciation (7.08%), interest on fixed capital (4.64%) and land revenue (0.08%). Similar costs pattern were reported by Chand *et al.*, 2002 for henna cultivation.

It is revealed from the Table 2 that, on an average the total cost per hectare for maintenance of henna crop was estimated to be Rs. 8055.00. Under maintenance cost, total operational and fixed costs were worked out to be Rs.4899.00 (60.82% of total maintenance cost) and Rs. 3156.00 ha$^{-1}$ (39.18% of maintenance cost), respectively. Total maintenance cost was estimated to be Rs. 7374.00 ha$^{-1}$ on small, Rs. 8250.00 ha$^{-1}$ on semi-medium, Rs. 8849.00 on medium and Rs. 9285.00 ha$^{-1}$ on large farms. Thus the total cost of maintenance was highest on large farms followed by medium, semi-medium and small.

Component wise, the cost of rental value of owned land was the highest (30.19% of the maintenance cost) followed by harvesting (27.79%), weeding and hoeing (18.62%). Among different groups of farms the share of harvesting cost in the total maintenance cost was 28.50, 27.86, 26.88 and 26.51 per cent on small, semi-medium, medium and large farms, respectively, indicating increasing share in the decreasing size of holding. Weeding and hoeing cost worked out to be 19.03, 18.59, 18.26 and 17.78 per cent of the total maintenance cost on small, semi-medium, medium and large farms, respectively with an overall average of 18.62 per cent. It was highest (Rs. 1651.00 ha$^{-1}$) on large farms and lowest (Rs. 1403.00 ha$^{-1}$) on small farms.

Expenditure on manures and fertilizers was accounted to be 3.68, 4.52, 5.37 and 5.72 per cent of the total maintenance cost on the small, semi-medium, medium and large farms with an overall average of 4.46 per cent. Cost of

**Table 2.** Maintenance cost* of henna on sample farms in Sojat tehsil of Pali district

(Rs./ha$^{-1}$)

| S. No. | Particulars | Farm size | | | | |
|---|---|---|---|---|---|---|
| | | Small | Semi-medium | Medium | Large | Overall |
| A. | **Operational cost** | | | | | |
| 1. | Weeding and hoeing | 1403 | 1534 | 1616 | 1615 | 1500 |
| | | (19.03) | (18.59) | (18.26) | (17.78) | (18.62) |
| 2. | Manures and | 271 | 373 | 475 | 531 | 359 |
| | fertilizers | (3.68) | (4.52) | (5.37) | (5.72) | (4.46) |
| 3. | Plant protection | 175 | 209 | 212 | 248 | 198 |
| | measures | (2.37) | (2.53) | (2.40) | (2.67) | (2.46) |
| 4. | Harvesting | 2102 | 2298 | 2379 | 2461 | 2239 |
| | | (28.50) | (27.86) | (26.88) | (26.51) | (27.79) |
| 5. | Transportation | 192 | 202 | 198 | 210 | 198 |
| | | (2.60) | (2.45) | (2.24) | (2.26) | (2.46) |
| 6. | Interest on | 373 | 416 | 439 | 459 | 405 |
| | working capital | (5.06) | (5.04) | (4.96) | (4.94) | (5.03) |
| **Total operational cost (A)** | | 4516 | 5032 | 5319 | 5560 | 4899 |
| | | (61.24) | (60.99) | (60.11) | (59.88) | (60.82) |
| B. | **Fixed cost** | | | | | |
| 7. | Interest on | 216 | 270 | 330 | 351 | 262 |
| | fixed capital | (2.93) | (3.27) | (3.73) | (3.78) | (3.25) |
| 8. | Depreciation | 367 | 497 | 553 | 588 | 457 |
| | | (4.98) | (6.03) | (6.25) | (6.33) | (5.68) |
| 9. | Land revenue | 4.0 | 5.0 | 5.0 | 6.0 | 5.0 |
| | | (0.05) | (0.06) | (0.05) | (0.07) | (0.06) |
| 10. | Rental value of | 2271 | 2446 | 2642 | 2780 | 2432 |
| | owned land | (30.80) | (29.65) | (29.86) | (29.94) | (30.19) |
| **Total fixed cost (B)** | | 2858 | 3218 | 3530 | 3725 | 3156 |
| | | (38.76) | (39.01) | (39.89) | (40.12) | (39.18) |
| **Total maintenance cost** | | 7374 | 8250 | 8849 | 9285 | 8055 |
| **(A + B)** | | (100.00) | (100.00) | (100.00) | (100.00) | (100.00) |

Note: Figures in parentheses are the percentage of total maintenance cost

* Discounted

transportation accounted to be 2.60, 2.45, 2.24 and 2.26 per cent of the total maintenance cost on small, semi-medium, medium and large farms with an overall average of 2.46 per cent. The expenditure on plant protection measures and interest on working capital is worked out to be 2.37, 2.53, 2.40 and 2.67 per cent of the total maintenance cost, on small, semi-medium, medium and large farms and interest on working capital was 5.06, 5.04, 4.96 and 4.94 per cent of the total maintenance cost on small, semi-medium, medium and large farms with an overall average of 5.03, per cent. Rental value of owned land contributed maximum (30.19% ) share in the total fixed cost of maintenance of henna crop followed by depreciation (5.68% ), interest on fixed capital (3.25%) and land revenue (0.06%). Maintenance cost was reported by Rao *et al.*, 1993 for jasmine cultivation.

The total cost was calculated to be Rs. 29978.00 ha$^{-1}$ of which operational cost accounted for Rs. 17293.00 ha$^{-1}$ (57.69 per cent of total cost) and fixed cost accounted for Rs. 12685.00 ha$^{-1}$ (42.31% of total cost).On the basis of farm size the total cost worked out to be Rs. 28256.00, 29987.00, 32423.00 and 33911.00 ha$^{-1}$ on small, semi-medium, medium and large farms, respectively which is given inTable3.

The costs and returns from henna crop on sample farms have been given in Table 4. The total cost of cultivation of henna was Rs. 29978.00 ha$^{-1}$, of which establishment cost accounted of Rs. 21922.00 ha$^{-1}$. The share of maintenance cost in the total cost of cultivation was Rs 8055.00 ha$^{-1}$. The share of establishment cost was highest on large farm i.e. Rs 24626.00 ha$^{-1}$ followed by medium Rs. 23574.00 ha$^{-1}$ ,

**Table 3.** Total cost* of henna on sample farms in Sojat tehsil of Pali district

(Rs./ha$^{-1}$)

| S. No. | Particulars | Farm size | | | | |
|---|---|---|---|---|---|---|
| | | Small | Semi-medium | Medium | Large | Overall |
| **A.** | **Operational cost** | | | | | |
| 1. | Land preparation | 2245 | 2165 | 2190 | 2370 | 2221 |
| | | (7.95) | (7.22) | (6.75) | (6.99) | (7.41) |
| 2. | Seedlings and transplanting | 4977 | 4836 | 4925 | 4869 | 4917 |
| | | (17.61) | (16.13) | (15.19) | (14.36) | (16.40) |
| 3. | Manures and fertilizers | 938 | 1348 | 1525 | 1651 | 1224 |
| | | (3.32) | (4.50) | (4.70) | (4.87) | (4.88) |
| 4. | Weeding and hoeing | 3437 | 3602 | 3801 | 3901 | 3589 |
| | | (12.16) | (12.01) | (11.72) | (11.50) | (11.97) |
| 5. | Plant protection measures | 748 | 1043 | 1062 | 1268 | 935 |
| | | (2.65) | (3.48) | (3.28) | (3.74) | (3.13) |
| 6. | Harvesting | 2102 | 2298 | 2379 | 2461 | 2239 |
| | | (7.44) | (7.66) | (7.34) | (7.26) | (7.47) |
| 7. | Transportation | 192 | 202 | 198 | 210 | 198 |
| | | (0.68) | (0.67) | (0.61) | (0.62) | (0.66) |
| 8. | Interest on working capital | 1922 | 1940 | 2058 | 2156 | 1971 |
| | | (6.80) | (6.47) | (6.35) | (6.36) | (6.57) |
| **Total operational cost (A)** | | 16561 | 17434 | 18138 | 18886 | 17293 |
| | | (58.61) | (58.14) | (55.94) | (55.70) | (57.69) |
| **B.** | **Fixed cost** | | | | | |
| 9. | Interest on fixed capital | 1049 | 1313 | 1602 | 1703 | 1280 |
| | | (3.71) | (4.38) | (4.94) | (5.02) | (4.27) |
| 10. | Depreciation | 1636 | 2216 | 2320 | 2622 | 2012 |
| | | (5.79) | (7.39) | (7.16) | (7.73) | (6.71) |
| 11. | Land revenue | 19.0 | 23.0 | 26.0 | 30.0 | 22.0 |
| | | (0.07) | (0.08) | (0.08) | (0.09) | (0.07) |
| 12. | Rental value of owned land | 8991 | 9001 | 10337 | 10670 | 9371 |
| | | (31.82) | (30.01) | (31.88) | (31.46) | (31.26) |
| **Total fixed cost (B)** | | 11695 | 12553 | 14285 | 15025 | 12685 |
| | | (41.39) | (41.86) | (44.06) | (44.30) | (42.31) |
| **Total cost (A + B)** | | 28256 | 29987 | 32423 | 33911 | 29978 |
| | | (100.00) | (100.00) | (100.00) | (100.00) | (100.00) |

Note: Figures in parentheses are the percentage of total of each column* Discounted

**Table4.** Costs and returns* of henna on sample farms in Sojat tehsil of Pali district

(Rs./ha$^{-1}$)

| S. No. | Particulars | Farm size | | | | Overall |
|---|---|---|---|---|---|---|
| | | Small | Semi-medium | Medium | Large | |
| 1. | Cost of cultivation | 28256 | 29987 | 32423 | 33911 | 29978 |
| a. | Establishment cost | 20882 | 21737 | 23574 | 24626 | 21922 |
| b. | Maintenance cost | 7374 | 8250 | 8849 | 9285 | 8055 |
| 2. | Yield (kg/ha) | 1150 | 1030 | 970 | 860 | 1058 |
| 3. | Gross Return | 15155 | 13773 | 13347 | 12094 | 14170 |
| 4. | Return over maintenance cost | 7781 | 5523 | 4498 | 2809 | 6115 |
| 5. | Net return over total cost | -13101 | -16214 | -19076 | -21817 | -15808 |
| 6. | Cost of production (Rs./kg$^{-1}$) | 24.57 | 29.11 | 33.42 | 39.43 | 28.71 |

* Discounted

semi-medium Rs. 2137.00 ha$^{-1}$ and Rs. 20882.00 ha$^{-1}$ on small farms. The share of maintenance cost was highest on large farms i.e. Rs. 9285.00 ha$^{-1}$ followed by medium Rs. 8849.00 ha$^{-1}$, semi-medium Rs. 8250.00 ha$^{-1}$ and Rs. 7374.00 ha$^{-1}$ on small farms. The average yield per hectare was estimated to be 1058 kg ha$^{-1}$. It was highest on small farms i.e. 1150 kg ha$^{-1}$ followed by semi-medium (1030 kg ha$^{-1}$), medium (970 kg ha$^{-1}$) and large farms (860 kg ha$^{-1}$). The aggregate gross return was estimated to be Rs. 14170.00 ha$^{-1}$. Its magnitude was highest on small farms (Rs. 15155.00 ha$^{-1}$) followed by semi-medium (Rs. 13773.00 ha$^{-1}$), medium (Rs. 13347.00 ha$^{-1}$) and Rs 12094.00 ha$^{-1}$ on large farms. The estimated average returns over maintenance cost were Rs. 6115.00 ha$^{-1}$ of which highest share of small farms (Rs. 7781.00 ha$^{-1}$) followed by semi-medium (Rs. 5523.00 ha$^{-1}$), medium (Rs. 4498.00 ha$^{-1}$) and Rs. 2809.00 ha$^{-1}$on large farms. The total net return over total cost of cultivation was negative (i.e. Rs. –15808.00 ha$^{-1}$). Out of which highest on small farms (Rs. –13101.00 ha$^{-1}$) followed by semi-medium (Rs. -16214.00 ha$^{-1}$), medium (Rs. –19076.00 ha$^{-1}$) and large (Rs. –21817.00 ha$^{-1}$) farms.

The average cost of production was Rs. 28.71 kg$^{-1}$, which is highest on large farms (Rs. 39.43/kg) followed by medium (Rs. 33.42/ kg), semi-medium (Rs. 29.11/ kg) and Rs. 24.57 kg$^{-1}$ on small farms. The total cost of establishing a henna crop was estimated to be Rs 21922.00 ha$^{-1}$ as regards the various component of the cost. The cost of rental value of owned land formed the single largest cost item with 31.66% share in the total establishment cost. The overall maintenance cost ha$^{-1}$ for henna crop was estimated to be Rs 8055.00. Component wise, rental value of owned land and cost of harvesting was having the highest share (30.19 and 27.79%), respectively in total maintenance cost. The average total cost (establishment plus maintenance) of cultivation of henna crop was estimated at Rs 29978.00 ha$^{-1}$. The total cost of cultivation was found to be highest (Rs 33911.00 ha$^{-1}$) on large farms and lowest (Rs 28256.00 ha$^{-1}$) on small farms. The return over maintenance cost from henna on an average was found to be Rs 6155.00 ha$^{-1}$. The net return over total cost of cultivation was estimated as negative (Rs –15808.00 ha$^{-1}$). The average cost of production in study area was estimated to be Rs 28.71 kg$^{-1}$. Such type of costs and returns were also reported by Raju and Rao, 1995 for Agricultural Commodities.

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# Ascorbic acid loss, microbial spoilage and sensory changes in aonla juice during storage

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**Abstract**

Being acidic and astringent in taste and perishable in nature the potential of aonla for preparation of vitamin C rich beverages has been explored on. In present endeavor attempt was made to study the effect of pasteurization, sulphitation in combination with different storage conditions so as to draw inference as to how long the quality of aonla juice stands intact. Sulphitation (350 ppm $SO_2$) of aonla juice coupled with storage at low temperature minimized the loss of vitamin 'C' and produce best sensory quality even after six months of storage. Pasteurization and sulphitation both inhibited the yeast growth throughout the storage period and thus helped extend the storability of aonla juice.

**Key words:** *Ascorbic acid, aonla, juice, pasteurization, storage, sulphitation*

## Introduction

The aonla (*Emblica officinalis* Gaertn.) also known as Indian Gooseberry is one of the oldest minor fruits of India. It is well known for its nutritional quality being rich in vitamins, minerals and tannins. It is the richest source of vitamin 'C' among the fruits except Barbados cherry. Its vitamin 'C' content varies from 200-900 mg 100 $g^{-1}$, depending upon variety and size of the fruit (Barthakur and Arnold, 1991).

Owing to high acidity and astringency, aonla fruit is not popular as a desert or table fruit. Value addition seems viable option to avert this constraint. Being amenable to help extend the period of availability and offering variety, the technique is effective in ensuring economic utilization of fruit also. It is the value addition which ensures its utilization as processed products viz. preserve (murabba), candies, jam etc.; dehydrated products viz. aonla shreds, supari, tit-bits, salt (churan) and various kinds of pickles. Besides aonla fruit have its uses across ayurvedic preparations such as *Chyavanprasha, Triphala, Ashoka-Arishtha, Arogya- Vardhini,* etc. There has been a considerable increase in the consumption of processed products especially fruits and vegetables beverages in the world during last few years (Anon., 1998). Various workers (Singh and Kumar, 1995; Nath, 1999; Jain and Khurdiya, 2004; Jain, *et al.*, 2006) have reported utility of aonla fruits in preparation of vitamin 'C' rich beverages. Since, aonla is seasonal in nature it is important to store the juice all round the year for use as raw material for processing into various types of beverages. But during processing and subsequent storage, the aonla juice suffers from loss of vitamin 'C', microbial spoilage and changes in sensory quality. In line to this problem, the present investigation was conducted to study the effect of sulphitation, pasteurization and storage conditions on the vitamin 'C' content, microbial load and sensory quality of the aonla juice during storage.

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## Materials and methods

### *Sample preparation and treatments*

For the study, aonla fruits of Chakaiya variety were procured from Azadpur Fruit Mandi, New Delhi. Juice was extracted by crushing and pressing the blanched fruits (after seed removal) and water in 1:1 ratio (Jain and Khurdiya, 2002). The whole juice was divided into four lots and following treatments were given before filling and sealing in 200 ml glass bottles.–

1. Untreated (Control)
2. Pasteurization at $90^0$C for 1 minute and filling hot in the pre-sterilized, hot glass bottles (Jain and Khurdiya, 2003).
3. Treatment with 350 ppm sulphur dioxide.
4. Pasteurization at $90^0$C for 1 minute; cooled to $60^0$C and added with 350 ppm sulphur dioxide before sealing in glass bottles.

For each treatment, total number of bottles were divided into three lots and stored under following storage conditions for a period of six months: -

1. Room temperature ($25\pm1^0$C) in ambient light
2. Room temperature($25\pm1^0$C) in dark condition
3. Cool storage ($4\pm1^0$C)

***Vitamin 'C' analysis***

The vitamin 'C' (ascorbic acid) content of the samples was determined by 2, 6-dichlorophenol indophenol visual titration method. The interference due to $SO_2$ was eliminated by adding 40 per cent formaldehyde and HCl before titration (Ranganna, 1997).

***Microbial spoilage***

The stored aonla juice was evaluated qualitatively and quantitatively for microbial load to determine the effect of various treatments and storage conditions. Five media viz. Potato Dextrose Agar (PDA), Plate Count Agar (PCA), Nutrient Agar (NA), Malt Extract Agar (MEA) and Dextrose Trypton Agar (DTA) were prepared. The media were sterilized in autoclave at 1.1 kg $cm^{-2}$ pressure (121°C) for 20 minutes and poured into pre-sterilized petri- dishes. Each sample bottle was thoroughly shaken before opening under aseptic condition (laminar-air-flow cabinet). A loop full of sample was streaked on the medium in a Petri dish. Streaked plates were inverted and incubated in a BOD incubator at 25 ± 1°C and observations were recorded after every 24 hours for 7 days.

For the determination of microbial population of the juice, initially as well as after fermentation, spotting method was used. Serial dilutions from $10^{-1}$ to $10^{-6}$ were prepared from the original juice samples, using sterilized distilled water. A drop of known volume was spotted on the solid Plate Count Agar (PCA) medium with the help of a Pasteur pipette. The plates were left undisturbed for 1 hr for the spot to be absorbed in the medium. The plates were then inverted and incubated in a BOD at 25±1$^0$C. The colonies were counted on a colony counter after 72 hr of incubation. The results were expressed in cfu/ml of juice.

***Sensory quality evaluation***

The juice from various treatments and storage conditions were used for preparation of RTS beverage containing 10 per cent juice, 10° Brix TSS and 0.225 per cent acidity and evaluated for colour, flavour and taste on a 9 point hedonic scale rating (Amerine *et al.*, 1965) by a panel of seven expert judges. A score of 5.5 and above was considered as acceptable.

***Statistical analysis***

The entire experiment was laid out in complete randomized block design with three replications. Data collected for the experiment during storage of aonla juice was subjected to statistical analysis by the analysis of variance technique as suggested by Panse and Sukhatme (1989). Wherever variance value (f value) was found significant, the critical difference value at 5 % level of probability was compared for making the comparison between the different treatments.

## Results and discussion

The stored juice was analyzed for ascorbic acid and sensory attributes at monthly interval up to a period of six months. Microbial load was enumerated in fresh juice and after fermentation which was evident by gas formation, development of fermented smell, bulging of crown cap of bottle and formation of white film on the surface of the juice.

***Ascorbic acid***

Irrespective of the treatments and storage conditions a continuous decrease in ascorbic acid content of the aonla juice was observed as the storage period progressed. After six months of storage, maximum vitamin 'C' content (232.7 mg/ 100 ml) was observed in $SO_2$ treated juice stored at low temperature, followed by 195.5 mg/ 100 ml in pasteurized + $SO_2$ treated and 189.3 mg/ 100 ml in pasteurized aonla juice stored at low temperature. Similar findings have also been reported in lemon juice (Bansal and Dhawan, 1993). The higher loss of ascorbic acid at room temperature than cool store might be due to higher rate of degradation of ascorbic acid at higher storage temperature (Mehta and Rathore, 1976 and Deka, 2000). Exclusion of light by keeping the aonla juice in dark condition retained more ascorbic acid as compared to light condition at ambient temperature. This might be due to light sensitivity of vitamin 'C'. These findings are in conformity with the findings of Deka (2000).

***Microbial quality of aonla juice***

In fresh aonla juice, there were no evidences of mould or bacterial contamination but growth of yeasts was noticed (Table 1). However, treatments viz., pasteurization, $SO_2$

**Table 1.** Occurrence of microorganisms in aonla juice as affected by different preservation methods on different media

| Treatment | Media | | | | |
|---|---|---|---|---|---|
| | PDA | PCA | NA | MEA | DTA |
| Untreated | + (yeast) | + (yeast) | + (yeast) | + (yeast) | + (yeast) |
| Pasteurization | – | – | – | – | – |
| $SO_2$ (350 ppm) | – | – | – | – | – |
| Pasteurization + $SO_2$ | – | – | – | – | – |

PDA - Potato Dextrose Agar
PCA - Plate Count Agar
NA - Nutrient Agar
MEA - Malt Extract Agar
DTA - Dextrose Trypton Agar
(+): Presence of viable microorganisms
(–): Absence of viable microorganisms

treatment and pasteurization + $SO_2$ treatment completely inhibited the growth and did not show any evidence of fermentation of juice by yeast throughout the storage period, irrespective of storage conditions. Similarly, complete inhibition of yeasts by pasteurization and $SO_2$ treatment has been reported by Kalra and Revathi (1981) in guava pulp.

With the advancement of storage period there was a gradual increase in the population of yeasts in untreated aonla juice (Table 2). But the rate of yeast growth was slower in cool stored aonla juice as compared to room temperature. Initially, the yeast population was $3.57x10^2$ cfu/ml which got increased to $20.5x10^3$ and $21.5x10^3$ cfu/ml at second month in light and dark condition of room temperature, respectively. This coincided with the fermentation of the sample. At this stage, the yeast population in cool stored juice was $1.5x10^3$ cfu/ml, which was still acceptable. But yeast count got increased to $16.7x10^3$ cfu/ml at third month and caused fermentation of juice. Fermentation was also evident by bulging of crown cap of the bottles, gas formation and frothing. These findings are in consonance with the findings of Kalra and Revathi (1981) who reported higher yeast count in guava pulp stored at ambient temperature as compared to low temperature, after 45 days of storage.

**Table 2.** Yeast population (colony forming units/ml) in untreated aonla juice stored under different storage conditions

| Storage condition | Storage period (months) | | |
|---|---|---|---|
| | 0 | 2 | 3 |
| Room temperature (light) | $3.57x10^2$ | $20.5x10^3$ | * |
| Room temperature(dark) | $3.57x10^2$ | $21.5x10^3$ | * |
| Cool store | $3.57x10^2$ | $1.5x10^3$ | $16.7x10^3$ |

(*) = Observation not recorded since sample discarded due to complete spoilage at 2nd month

The yeasts which caused fermentation in untreated juice, stored at both the light and dark conditions of room temperature and cool store were identified as *Saccharomyces cereviceae* and *Candida tropicalis*, respectively.

***Sensory quality of RTS beverage***

The data presented in Table 3 indicate that initially, the RTS beverage prepared from untreated and pasteurized aonla juice had higher sensory quality as compared to that from $SO_2$ treated and pasteurized + $SO_2$ treated aonla juice. This may be due to smell of sulphur dioxide in the KMS treated aonla juice. The sensory quality of RTS prepared from $SO_2$ treated aonla juice increased during first month of storage, thereafter it decreased. This increase in sensory quality during first month of storage may be due to reduction in the residual $SO_2$ content in the juice. However, in case of untreated and pasteurized juice, the sensory quality of RTS beverage showed continuous decline right from the start of storage study and throughout the storage period. Similar decline in sensory quality of aonla juice was

**Table 3.** Sensory score (out of 9) of RTS beverage prepared from aonla juice as affected by preservation methods and storage conditions

| Storage condition | Treatment | Storage period (months) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| RT (light) | Untreated | 7.50 | 6.53 | 6.11[a] | * | * | * | * |
| | Pasteurization | 7.37 | 7.08 | 6.65 | 6.26 | 5.78 | 5.18 | 4.42 |
| | Sulphitation ($SO_2$) | 6.87 | 7.04 | 6.75 | 6.48 | 6.14 | 5.51 | 4.93 |
| | Past. + $SO_2$ | 6.87 | 7.04 | 6.77 | 6.46 | 6.13 | 5.53 | 4.98 |
| RT (dark) | Untreated | 7.50 | 6.14 | 5.57[a] | * | * | * | * |
| | Pasteurization | 7.37 | 6.73 | 6.37 | 6.12 | 5.85 | 5.36 | 4.75 |
| | Sulphitation ($SO_2$) | 6.87 | 6.89 | 6.5 | 6.27 | 6.11 | 5.38 | 5.08 |
| | Past. + $SO_2$ | 6.87 | 6.80 | 6.35 | 6.18 | 5.97 | 5.60 | 5.12 |
| Cool store | Untreated | 7.50 | 6.97 | 6.46 | * | * | * | * |
| | Pasteurization | 7.37 | 7.17 | 6.86 | 6.68 | 6.38 | 5.97 | 5.47 |
| | Sulphitation ($SO_2$) | 6.87 | 7.39 | 7.31 | 7.15 | 6.95 | 6.77 | 6.56 |
| | Past. + $SO_2$ | 6.87 | 7.30 | 7.04 | 6.89 | 6.58 | 6.37 | 6.18 |
| Mean | | 7.15 | 6.92 | 6.56 | 6.50 | 6.21 | 5.74 | 5.28 |
| C. D. at 5% | | | | | | | | |
| Storage condition × treatment | | NS | 0.13 | 0.07 | 0.14 | 0.13 | 0.18 | 0.14 |

RT = Room temperature (25±1°C)

(a) Juice spoiled due to fermentation

(*) Observations not recorded due to fermentation

reported by Tripathi *et al.* (1988).

After six months of storage, only the RTS beverage prepared from aonla juice preserved by $SO_2$ alone and Pasteurization + $SO_2$, stored in cool store was acceptable whereas, others were acceptable only up to five months. This may be due to better retention of colour due to lower NEB and better flavour retention due to $SO_2$ treatment, as also reported by Ranote and Bains (1982) in Kinnow mandarin juice. Similarly, better retention of sensory quality of beverages under low temperature has also been reported by Khurdiya *et al.* (1995) in ameliorated juice of teinturier grape hybrids.

There was no significant difference in sensory quality of aonla juice, stored in light and dark conditions at room temperature at fifth month of storage. These findings are in consonance with the findings of Granzer (1983) in orange juice.

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# Prolonging shelf life of ber under semi-arid environment

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**Abstract**

An experiment was conducted during the year 2005 and 2006 to study the effect of $CaCl_2$, Til oil 2.0% emulsion, potassium permanganate coated silica gel @ 10 g per bag, potassium sulphate 2.0% and mustard oil 2.0% emulsion on shelf life and fruit quality attributes of ber (*Zizyphus mauritiana* Lam.) cv. Gola during storage at ambient temperature under semi-arid environment of western India. Different post harvest treatments were imposed to the fruits after harvest. Increase in physiological loss in weight (PLW), spoilage percentage, total soluble solids, total sugar and reducing sugar and decrease in acidity, ascorbic acid with advancement of storage period were general phenomena in all the treatments. Fruits treated with calcium chloride 1.5% recorded the least physiological loss in weight (17.45%) and spoilage loss (25.20 %) and exhibited 5 days of shelf life, while untreated control had 3 days shelf life under ambient conditions. The same treatment also showed lowest respiratory activity (0.22 mg $CO_2$ $kg^{-1}hr^{-1}$), however, it was recorded highest in the control (0.43 mg $CO_2$ $kg^{-1}hr^{-1}$) on the last day of storage (day 9). It was closely followed by calcium chloride 2.0%. It may be concluded that the fruits treated with calcium chloride (1.5%) was found most efficient to retain the fruit quality attributes till the last day of storage under ambient conditions of western India.

**Key words:** *Shelf life, physiological loss in weight, spoilage loss, respiration rate*

## Introduction

Ber (*Zizyphus mauritiana* Lam.) is one of the important commercial fruits owing to its hardy nature and commercial yield potential without much care on marginal lands and is being grown in semi-arid and arid regions of western India. The fruit is richer than apple in protein, phosphorus, calcium, carotene and vitamin C (Ghosh and Mitra, 2004). Gola is one of the leading early cultivars of ber but it suffers due to very poor shelf life at room temperature. Though the fruits of ber are firm and can easily be transported to the distant market, but the potentiality of its storage stability needs to be explored particularly under semi-arid environment of western India. The fruit respires and transpires continuously resulting into high weight loss and then becomes susceptible to various diseases, which ultimately reduce the saleable tonnage. Due to prevalence of high temperature ($12 \pm 2$ °C-$28 \pm 2^0$ C) during the time of harvesting, fruits start spoilage rapidly. To regulate the marketing for consumers' acceptability and greater remuneration, it is necessary to prolong shelf life of ber fruits during storage. Calcium regulates respiration and other metabolic processes in the mature fruits and may preserve the cellular organization not only by preserving the cell membranes but also by maintaining the nucleic acid and protein synthesis (Jayachandran *et al.*, 2005 and Singh *et al.*, 2005). Calcium is also known to stabilize cell membranes of fruits during storage (Saure, 2005). Fruits treated with potassium sulphate, potassium permanganate coated silica gel and oil emulsion also enhanced shelf-life of fruits (Damodaran *et al.*, 2001; Singh *et al.*, 2002; Hiwale and Singh 2003; Gautam *et al.* 2003 and Singh *et al.* 2006). Since storage studies under ambient condition for ber cv. Gola are lacking, particularly under harsh semi-arid ecosystem of Gujarat, an experiment was conducted to evaluate the efficacy of different post harvest treatments on storability and fruit quality attributes during storage at room temperature.

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## Materials and methods

An Experiment was conducted during the year 2005 and 2006 to study the effect of different post harvest treatments on shelf-life and fruit quality attributes of ber cv. Gola during storage at ambient temperature under semi-arid environment of Gujarat. Different post harvest treatments were imposed to the fruits after harvest. The treatments were ($T_1$) calcium chloride 1.0%, ($T_2$) calcium chloride 1.5%, ($T_3$) calcium chloride 2.0%, ($T_4$) Til oil 2.0% emulsion, ($T_5$) potassium permanganate coated silica gel @ 10 g per bag, ($T_6$) potassium sulphate 2.0%, ($T_7$) Mustard oil 2.0% emulsion, ($T_8$) control. The experiment was laid out in factorial completely randomized design with three replications. The fruits were separated in to lots of 2.5 kg each treatment and stored at ambient temperature ranging

between 12 ± 2°C (minimum) and 28 ± 2°C (maximum) with a relative humidity 65 ± 3% at 8 a.m. The physiological loss in weight, spoilage loss, total soluble solids and acidity were determined by standard methods. Economic shelf-life (in days) of fruits was determined by counting the number of days, on the date after which cumulative spoilage percentage of fruits in particular treatment exceeded 12%, from the date of harvest of the fruits (Singh *et al.*, 2003 ). Ascorbic acid and total sugar content were determined by the methods advocated by AOAC (1980). The respiration rate was measured as suggested by Loomis and Shull (1973).

## Results and discussion

The physiological loss in weight (PLW) gradually increased in all the treatments with the advancement of storage period (Table 1). Calcium chloride 1.5% was the most effective treatment in retaining the PLW in all the days of observations and showed only 17.45% PLW on day 9 of storage followed by calcium chloride 2.0% (18.34 %) and calcium chloride 1.0% (18.50%). Fruits treated with potassium permanganate coated silica gel @ 10 g per bag proved to be superior to Til oil 2.0 % emulsion and mustard oil 2.0% emulsion. The highest PLW (23.10%) was recorded in control on the day 9th of storage. The increased weight loss in untreated fruits might be due to increased storage break down associated with higher transpiration and respiration rate as compared to calcium treated fruits. Singh *et al.* (2005) and Sarkale *et al.* (2003) and Ramkrishna *et al.* (2001) also recorded similar trends during storage of fruits. Spoilage of ber fruits started on the day 3 of storage in all the treatments (Table 1). The minimum spoilage loss (25.20 %) was recorded in calcium chloride 1.50%, which was closely followed by calcium chloride 2.00% (26.10%), and calcium chloride 1.0% (27.00 %), while it was noted maximum (42.00%) control on day 9th of storage. Singh *et al.* (2005) opined that calcium controlled the disintegration of mitochondria, endoplasmic reticulum and cytoplasmic membranes and thus helped in restraining respiration rate and ultimately reduced the spoilage loss. This is in close agreement with findings of Singh *et al.* (2002), Hiwale and Singh (2003) and Singh *et al.* (2006) in ber, guava and custard apple respectively.

On the basis of spoilage within 12%, the maximum economic shelf life (5 days) was exhibited by calcium chloride (1.5% and 2.0%). Fruits treated with potassium permanganate coated silica gel @ 10 g per bag showed 4 days economic shelf life, however the untreated control recorded 3 days only. Total soluble solids (TSS) content increased linearly up to 7th day and declined thereafter during storage (Table 2). Increment in the TSS was found to be minimum in the fruits treated with calcium chloride 1.50% during storage, closely followed by calcium chloride 2.0%, while it was noted highest in control. Increase in TSS during storage might be associated with the transformation of pectic substances, starch, hemi cellulose or other polysacharides in soluble sugar and also with the dehydration of fruits (Singh *et al.*, 2003; Singh *et al.*, 2004 and Singh *et al.*, 2005). Slow increase in TSS during storage in the treated fruits was due to slow weight loss that caused less dehydration of the fruits (Rajkumar *et al.*, 2005). The minimum acidity (0.10%) was recorded in the control on the last day of storage, while the maximum (0.17 %) was observed in calcium chloride (1.50%) treated fruits closely followed by calcium chloride 2.00% and calcium chloride 1.00%. The reduction in acidity during storage might be associated with the conversion of organic acids into sugars and their derivatives or their utilization in respiration. (Singh et *al.*, 2003 and Singh *et al.*, 2005). The treated fruits could maintain higher level of acidity up to last day of storage. It might be due to reduced respiration rate in the later stage of storage as affected by calcium treatments. Similar findings have been reported by Singh, *et al.* (2005) and Gautam *et al.* (2003) in aonla and mango.

The ascorbic acid content of fruits decreased progressively during storage in all the treatments (Table 3). Maximum ascorbic acid content (76.20 mg/100 g) was

**Table1.** Physiological loss in weight, spoilage loss and economic life of ber fruits during storage.

| Treatments | Physiological loss in weight (%) Days after harvest | | | | Spoilage loss (%) Days after harvest | | | | Economic shelf life (Days) |
|---|---|---|---|---|---|---|---|---|---|
| | 3 | 5 | 7 | 9 | 3 | 5 | 7 | 9 | |
| Control | 5.70 | 13.50 | 19.38 | 23.10 | 10.50 | 18.10 | 30.00 | 42.00 | 3 |
| Calcium chloride 1.0 % | 4.40 | 9.30 | 15.00 | 18.50 | 5.60 | 13.00 | 17.10 | 27.00 | 4 |
| Calcium chloride 1.5 % | 4.30 | 8.61 | 14.80 | 17.45 | 5.50 | 8.10 | 16.50 | 25.20 | 5 |
| Calcium chloride 2.0 % | 4.34 | 8.80 | 15.00 | 18.34 | 5.60 | 8.20 | 16.80 | 26.10 | 5 |
| Til oil 2.0 % emulsion | 5.30 | 10.90 | 16.12 | 20.10 | 6.40 | 15.00 | 18.00 | 28.90 | 3 |
| Potassium permanganate coated silica gel @ 10 g/ bag | 5.00 | 10.00 | 16.00 | 19.90 | 6.10 | 13.60 | 19.52 | 28.00 | 4 |
| Potassium sulphate 2.0 % | 5.10 | 10.60 | 17.10 | 20.30 | 7.10 | 15.12 | 20.00 | 30.00 | 3 |
| Mustard oil 2.0 % emulsion | 5.40 | 11.10 | 17.40 | 20.90 | 7.20 | 15.90 | 20.50 | 30.90 | 3 |
| C D at 5% | Treatments (T)= 0.12, Days (D)= 0.15. | | | | Treatments (T)= 0.05, Days (D)= 0.09. | | | | |
| | Dx T= 0.21 | | | | D x T= 0.20 | | | | |

**Table 2.** Changes in TSS and titratable acidity during storage of ber fruits.

| Treatments | T S S (%) | | | | | Titratable acidity (%) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Days after harvest | | | | | Days after harvest | | | | |
| | 1 | 3 | 5 | 7 | 9 | 1 | 3 | 5 | 7 | 9 |
| Control | 19.30 | 20.90 | 21.60 | 21.90 | 21.60 | 0.32 | 0.24 | 0.19 | 0.16 | 0.10 |
| Calcium chloride 1.0 % | 19.10 | 19.70 | 20.90 | 21.30 | 20.80 | 0.32 | 0.26 | 0.24 | 0.21 | 0.14 |
| Calcium chloride 1.5 % | 19.10 | 19.60 | 20.80 | 21.00 | 20.70 | 0.32 | 0.29 | 0.26 | 0.23 | 0.17 |
| Calcium chloride 2.0 % | 19.20 | 19.70 | 20.85 | 21.10 | 20.80 | 0.33 | 0.28 | 0.25 | 0.22 | 0.15 |
| Til oil 2.0 % emulsion | 19.40 | 20.00 | 21.10 | 21.60 | 21.10 | 0.33 | 0.26 | 0.23 | 0.20 | 0.13 |
| Potassium permanganate coated silica gel @ 10 g/ bag | 19.20 | 19.90 | 21.00 | 21.50 | 21.00 | 0.33 | 0.25 | 0.23 | 0.20 | 0.14 |
| Potassium sulphate 2.0 % | 19.30 | 20.00 | 21.10 | 21.70 | 21.10 | 0.34 | 0.25 | 0.22 | 0.19 | 0.13 |
| Mustard oil 2.0 % emulsion | 19.20 | 20.00 | 21.20 | 21.70 | 21.20 | 0.34 | 0.25 | 0.22 | 0.19 | 0.13 |
| C D at 5% | Treatments (T)= 0.06, Days (D)= 0.13, D x T= 0.21 | | | | | Treatments (T)= 0.02, Days (D)= 0.01 D x T= 0.02 | | | | |

retained by the fruits treated with calcium chloride 1.50% followed by calcium chloride 2.00% (74.50 mg/100g) and calcium chloride 1.0% (71.00 mg/100 g) on last day of storage, while it was found least in the control (50.00 mg/ 100g). Fruits treated with potassium permanganate coated silica gel @ 10 g per bag proved to be superior to Til oil 2.0% emulsion and mustard oil 2.0% emulsion in respect of retention of vitamin C content during storage. Variation in decreasing trend of ascorbic acid might be due to different levels of oxidation in different treatments. During storage, oxidizing enzymes like ascorbic acid oxidase, peroxidase, catalase and polyphenol oxidase might have caused decrease in ascorbic acid of the fruits (Singh *et al.*, 2003 and Singh *et al.*, 2005). Activities of oxidizing enzymes might be reduced in the treated fruits that resulted in higher level of ascorbic acid content up to last day of storage. This finding is in agreement with those of Mahajan *et al.*, 2005; Kumar *et al.*, 2005 and Singh *et al.*, 2006 in kinnow, aonla and custard apple respectively. There was continuous decrease in respiratory activity till the last day of storage (day 9). The lowest respiratory activity (0.22 mg $CO_2$ kg-1 $hr^{-1}$) was noted in calcium chloride 1.50% followed by calcium chloride 2.00%, calcium chloride 1.00%, while it was found to be highest in the control (0.43 mg $CO_2$ $kg^{-1}$ $hr^{-1}$) on the last day of storage. Singh *et al.*, 2005 stated that calcium could have reduced the endogenous substrate catabolism during respiration by limiting the diffusion of substrate from the vacuole to the cytoplasm and favoured the uptake of sorbital, thus dissolving its involvement in reactions related to internal breakdown. The results are in consonance with the findings of Tsantili *et al.* 2002. Total sugar and reducing sugar contents increased up to 7th day and declined thereafter during storage (Table 4). The increment in sugars during storage was least in the fruits treated with calcium nitrate 1.50 %, closely followed by calcium chloride 2.0 %, while it was noted to be maximum in control. Slow increment in sugar content of the treated fruits of ber during storage was due to least physiological loss in weight. These findings are in close agreement with the findings of Singh *et al.* 2005 in aonla. An increase in sugars during storage was due to conversion of starch and polysaccharides in to soluble sugars and dehydration of fruits (Kumar *et al.*, 2005 and Rajkumar *et al.* 2005).

**Table3.** Changes in ascorbic acid and respiration rate during storage of ber fruits.

| Treatments | Ascorbic acid (mg/ 100g) | | | | | Respiration rate (mg $CO_2$/kg/h) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Days after harvest | | | | | Days after harvest | | | | |
| | 1 | 3 | 5 | 7 | 9 | 1 | 3 | 5 | 7 | 9 |
| Control | 96.30 | 85.10 | 67.12 | 60.12 | 50.00 | 0.17 | 0.24 | 0.72 | 0.63 | 0.43 |
| Calcium chloride 1.0 % | 95.10 | 89.00 | 81.00 | 75.00 | 71.00 | 0.17 | 0.20 | 0.37 | 0.46 | 0.29 |
| Calcium chloride 1.5 % | 94.10 | 92.10 | 86.12 | 81.00 | 76.20 | 0.16 | 0.18 | 0.24 | 0.36 | 0.22 |
| Calcium chloride 2.0 % | 96.00 | 91.00 | 85.00 | 80.00 | 74.50 | 0.17 | 0.19 | 0.25 | 0.37 | 0.24 |
| Til oil 2.0 % emulsion | 95.00 | 89.00 | 76.12 | 74.50 | 69.00 | 0.17 | 0.22 | 0.44 | 0.49 | 0.31 |
| Potassium permanganate coated silica gel @ 10 g/ bag | 95.00 | 90.00 | 79.00 | 74.90 | 70.00 | 0.17 | 0.21 | 0.41 | 0.48 | 0.29 |
| Potassium sulphate 2.0 % | 96.00 | 89.20 | 76.20 | 72.10 | 66.90 | 0.17 | 0.22 | 0.45 | 0.48 | 0.30 |
| Mustard oil 2.0 % emulsion | 96.12 | 89.00 | 76.10 | 72.00 | 66.00 | 0.17 | 0.22 | 0.46 | 0.49 | 0.31 |
| C D at 5% | Treatments (T)= 2.19, Days (D)= 3.10, D x T=3.00 | | | | | Treatments (T)= 0.02, Days (D)= 0.09, D x T= 0.07 | | | | |

**Table 4.** Changes in total sugar and reducing sugar during storage of ber fruits.

| Treatments | Total sugar ( %) | | | | | Reducing sugar (%) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Days after harvest | | | | | Days after harvest | | | | |
| | 1 | 3 | 5 | 7 | 9 | 1 | 3 | 5 | 7 | 9 |
| Control | 13.10 | 13.97 | 14.33 | 14.83 | 14.60 | 4.90 | 5.16 | 5.42 | 5.48 | 5.23 |
| Calcium chloride 1.0 % | 13.00 | 18.80 | 14.06 | 14.40 | 14.30 | 4.90 | 5.04 | 5.30 | 5.37 | 5.30 |
| Calcium chloride 1.5 % | 13.00 | 13.67 | 13.83 | 14.12 | 14.00 | 4.92 | 4.94 | 5.20 | 5.30 | 5.26 |
| Calcium chloride 2.0 % | 13.11 | 13.68 | 13.85 | 14.15 | 14.10 | 4.91 | 4.96 | 5.23 | 5.32 | 5.28 |
| Til oil 2.0 % emulsion | 13.00 | 13.92 | 14.10 | 14.53 | .14.43 | 4.92 | 5.10 | 5.25 | 5.39 | 5.36 |
| Potassium permanganate coated silica gel @ 10 g/ bag | 13.00 | 13.90 | 14.13 | 14.60 | 14.50 | 4.92 | 5.09 | 5.30 | 5.38 | 5.34 |
| Potassium sulphate 2.0 % | 13.00 | 13.90 | 14.18 | 14.70 | 14.58 | 4.93 | 5.09 | 5.31 | 5.39 | 5.34 |
| Mustard oil 2.0 % emulsion | 13.10 | 13.96 | 14.19 | 14.72 | 14.62 | 4.90 | 5.10 | 5.32 | 5.40 | 5.35 |
| C D at 5% | Treatments (T)= 0.80, Days (D)= 0.13, DxT = 0.21 | | | | | Treatments (T)= 0.05, Days (D)=0.08, D x T= 0.11 | | | | |

On the basis of spoilage loss and fruit quality a with calcium chloride (1.5 %) and calcium chloride (2.0 %) were found most efficient to retain the fruit quality attributes till the last day of storage under ambient conditions.

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# Emerging vistas in post harvest paradigm of guava

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**Abstract**

Guava (*Psidium guajava* L.), a common man's fruit commonly called the "apple of the tropics" is cultivated or grown wild throughout the tropical and subtropical regions of the world. India's output of guava increased from 10.15 lakh tonnes in 1989-90 to 16.85 lakh tonnes in 2004–05. The area rose from 1.03 lakh ha. to 1.62 lakh ha. with a yield of 11.10 t $ha^{-1}$. Guava is one of the richest sources of vitamin C (200 to 400 mg per 100g fresh weight) and some cultivars are also rich in vitamin A. Guava fruit consists of about 20% peel, 50% fleshy portion, and 30% seed core. It contains 74-87 % moisture, 13-26% dry matter, 0.8-1.5% proteins, 0.4-0.7% fat, and 0.5-1.0 % ash. It is one of favourite fruit, which can be utilized for processing however selection of guava•varieties for processing depends on several factors such as content of pulp, seeds, sugars, acids, pectin, and tannins in the fruit. The guava fruit can be consumed fresh; processed into a semiproduct in the form of puree, clarified juice, or concentrate and frozen or aseptically stored; or processed continuously to the final products, which include nectar, syrup, jam, jelly, fruit bar, cheese, chutney, ketchup, wine, dried fruit and powder, as well as canned guavas. Among them, guava nectar is more important than the others in the quantity of production and the popularity among consumers. The fruits of *Sardar* variety yield high-grade pectin with higher jelly units than the fruits from other varieties. Juice obtained from fresh fruits or from pulp can be used in the manufacture of clear guava nectar, clear guava juice blend, clear guava jelly, or guava powder.

**Key words:** *Guava, processing, juice, nectar, vitamin A*

## Introduction

Guava (*Psidium guajava* L.), an important member of the Myrtaceae family, is believed to have originated in Central America and the southern part of Mexico. The Spanish explorers took the guava to the Philippines, and the Portuguese disseminated it from the Philippines to India (Nakasone and Paull, 1998). It now grows throughout the tropics and sub-tropics in the world in almost all habitats as one of the most widely utilized fruits. It is considered as common man's fruit and is rightly called the "apple of the tropics". Guava is particularly rich in vitamin C and pectin (Menzel, 1985). India produces 1.68 million tonnes of guava from an area of about 1.62 lakh hectares with a productivity of 11.1 metric tonnes per ha. in a year 2004-5 (Indian Horticultural Database-2005).

***Harvesting and postharvest handling***

Guava fruits are borne on current growth and can be produced throughout the year by adjusting the bahar treatment in different parts of the same orchard. However, three flowering seasons in guava are June-July, October-November and January-February. Of these, June-July flowering is commonly followed.

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***Maturity and quality indices***

Colour is a good indicator of ripeness stage in guava; size and shape may also be important in some markets. Guava fruits are picked at mature-green stage (colour change from dark- to light-green). The fruits are picked at the firm yellow to half-ripe (softer) stage for long-distance transport or at the fully ripe (yellow and soft) stage for local markets. Guava fruit takes about 110-150 days from the date of flowering to reach maturity. Several physico-chemical changes take place during development of guava fruit. The fruit weight and volume increases moderately up to the first 50 days, rapidly up to 100 days, and very slowly thereafter. The colour of the fruit remains green up to maturity. Chlorophyll degradation starts just before it reaches maturity. The softening of guava fruit progresses after about 115 days from anthesis. The fruit detachment force and fruit deformation force decline during maturation (Paul and Goo, 1983). Sugar content of guava fruit increases during development. Among the sugars, fructose increases rapidly, while glucose content increases slowly. Pectin content of guava increases during ripening and declines rapidly in overripe fruit (Luh, 1967). Acidity decreases while ascorbic acid content increases during development of guava fruit (El-Zorkani, 1968). Firm, yellow to half-yellow,

mature fruits should be harvested manually by hand. Fruits for export are harvested mature green (Brown and Wills, 1992). The use of shallow wooden boxes (crates) or corrugated cartons protects the fruits from external hazards. For long-distance transport, it is better to harvest firm, slightly under-ripe fruits.

***Chemical Composition***

Guava fruit consists of about 20% peel, 50% fleshy portion, and 30% seed core. The physicochemical characteristics of guava fruit change significantly with maturity. Guavas contain 74-87% moisture, 13-26% dry matter, 0.8-1.5% proteins, 0.4-0.7% fat, and 0.5-1.0 % ash (Wilson, 1980). The composition of guava varies significantly with variety, stage of maturity, and season (Singh, 1988). Carbohydrates are the principal constituents of guava. Sugars constitute about 6-11% of the fresh weight of guava (Singh *et al.*, 1990). Chan and Kwok (1975) reported that fructose, glucose, and sucrose are present in proportions of 59%, 36%, and 5%, respectively. The fruits are an excellent source of vitamin C (Dhillon *et al.*, 1987). They also contain appreciable quantities of niacin, thiamin, riboflavin, carotene, calcium, iron, phosphorus and dietary fiber. In general, guava fruit contains more citric acid than ascorbic acid. Malic acid and glycolic acid are the other two major organic acids (Wilson *et al.*, 1982). A wide variation in ascorbic acid content of guava fruits has been reported depending on the variety, season, location, maturity, and horticultural practices (Singh, 1988). Red-fleshed guavas contained more ascorbic acid than white-fleshed ones (Kumar and Hoda, 1974). Guava fruits ripened during the winter season contained more ascorbic acid (325 mg/100 g) than those ripened during the rainy season (140 mg/100 g) (Singh, 1988; Mitra *et al.*, 1984). Ahire (1989) reported 286 and 122 mg of ascorbic acid per 100 g in flesh and seed core, respectively. Dried guava fruits and guava powder are rich in ascorbic acid (about 4%). Guava fruits are a rich source of pectin. The total pectin content of guava fruit is in the range 0.5-1.8% and its concentration is influenced by a number of factors such as variety, maturity and cropping season. The quality of pectin is measured by its ability to form a gel and is measured in terms of jelly units. Dingra *et al.* (1983) observed that winter-season guava fruits contained higher amounts of pectin with more jelly units than rainy-season guava fruits. Half-ripe fruits yield more jelly units than unripe ones.

Among the varieties studied by Dhingra *et al.* (1983), the fruits of Sardar variety yielded high-grade pectin with higher jelly units than the fruits from other varieties. The methoxyl content of purified guava pectin is relatively low (55%). Hydrolyzed guava pectin contained 72% D-galacturonic acid, 12% D-galactose, and 4% L-arabinose .The fruits contain citric, malic, glycolic, tartaric, and lactic acids. Of these, the first two are the predominant ones.

The flavor is the most distinguishing characteristic of guava fruits. The flavour of guava has been attributed to the presence of several volatile constituents, which include hydrocarbons, alcohols, and carbonyls. Steven *et al.*, (1970) identified 22 compounds, of which methyl benzoate, hexanol, p-phenyl ethyl acetate, methyl cinnamate, and cinnamyl acetate play predominant roles in the flavour and odour of guava fruit. Wilson and Shaw (1978) noted that cinnamyl acetate has the most guava like aroma. Guava fruits contain significant amount of polyphenols which decreases with the maturity of guava fruit. The decrease in astringency with ripening of guava is associated with increased polymerization of leucoanthocyanidins. The pigments in guava fruit include chlorophyll, carotene, xanthophyll, and lycopene. The pink flesh color found in some varieties of guava has been attributed to the presence of lycopene. Nakasone *et al.*,(1967) reported 4.8-6.9 mg/100g lycopene in guava fruits. The chlorophyll content of guava fruit is in the range of 0.2-1.6 mg/100 g, while carotene and xanthophyll contents vary from 0.1 to 0.9 and from 0.01-to 0.17 mg/100g, respectively (Jagtiani *et al.*, 1988).

***Storage***

Guava is a climacteric fruit (Akamine and Goo, 1979). Its shelf-life at room temperature is few days (Tandon *et al.*, 1989). The peak in $CO_2$ and ethylene production occurs about 5-6 days after harvest. Storage at 0°C causes chilling injury to the pulp. A temperature of 8-10°C is considered to be the optimum storage temperature for mature-green and partially-ripe guavas for 2-3 weeks at Optimum Relative Humidity of 90-95 % ( Vazquez-ochoa and Cotinas-Leon, 1990).

***Rates of Ethylene Production and Response***

Rates of respiration and ethylene production depend upon cultivar and maturity/ripeness stage. Ethylene production at 20°C ranges from 1 to 20 $\mu l\ kg^{-1}\ hr^{-1}$. Ethylene at 100 ppm for 1-2 days can accelerate ripening of mature-green guavas to full-yellow stage at 15-20°C and 90-95% relative humidity. This treatment results in more uniform ripening, which is more important for guavas destined for processing.

***Responses to Modified and Controlled Atmospheric storage***

Scanty research on guava indicates that 2-5% oxygen levels may delay ripening of mature-green and partially ripe guavas kept at 10°C. Tolerance to elevated carbon dioxide levels has not been determined. Guava fruits packed in 300-gauge poly packs can be stored at room temperature for 10 days (Khedkar *et al.*, 1982). Singh, *et al.* (1984) reported that prepackaging of guava in 200-gauge polyethylene bags with 0.25-0.50% ventilation proved better than wax coating. Varietal differences in shelf life of guava fruits have been reported (Singh *et al.*, 1990). The shelf-life of guava fruits stored at 18 ± 2°C and 80-85% relative humidity ranged from 6 days in Allahabad Safeda to 9 days in Chittidar and Sardar cultivars. Adsule and Tandon (1983) reported that guava fruits stored in 600-gauge low density polyethylene (LOPE) bags at ambient temperature (18-23°C)

exhibited better organoleptic score and marketability up to 10 days than those stored in open atmosphere. Dhoot *et al.* (1984) reported that the shelf life of Sardar guava was prolonged up to 12 days when treated with 150 ppm naphthalene acetic acid (NAA) and stored in polyethylene bags having 0.05% vents.

***Pretreatments***

Preharvest spray of 1 % Ca $(NO_3)_2$ + 100 ppm NAA was found to maintain guava fruits in marketable conditions for 6 days, as opposed to 3 days for untreated fruits (Singh, 1988). Amen (1987) observed that guava fruits of cultivar Baladi dipped in 2% Ca $Cl_2$ solution with or without 2.5% corn flour could be stored in polyethylene bags at ambient temperature for up to 12 days. Preharvest application of 2.5 ppm or postharvest application of 2.5-5.0 ppm morphactin (a chlorflurenol methyl ester) reduced the postharvest weight loss, retained chlorophyll, increased soluble sugars, and extended the shelf life of guava fruits (Gupta and Mukherjee, 1980). Mudahar and Bhatia (1987) blanched guava fruits in boiling water for 4 min and filled into glass jars. The fruits were covered with steeping syrup containing 30% sugar, 0.4% acidity, and 400 ppm $SO_2$ in 1:1 proportion. The fruits were found to be acceptable after 4 months of storage at room temperature.

***Storage Diseases***

Anthracnose, canker, and rots are the most common postharvest diseases of guava (Wills *et al.*, 1983; Ramaswamy *et al.*, 1984; Snowdon, 1990). The rots of stored guava include those caused by *Phomopsis destructum*, *Guignardia psidi*, *Phytophthora citricola, P. nicotianae* var. *parasitica, Rhizopus stolonifer, Botryodiplodia theobromae, Curvularia tuberculata, Cylindrocladium scoparium* Morgan, *Fusarium solani, Macrophoma allahabadensis* and *Carticium rolfsii* (Adisa,1985; Kapoor, 1983; Ullasa and Rawal,1985; Lim and Razau, 1986).

***Processing***

Guava fruits are mainly consumed fresh. They are also into a semi product in the form of puree, clarified juice, or concentrate and frozen or aseptically stored; or processed continuously all the way to the final products, which include guava nectar, guava syrup, guava jam, guava jelly, guava bar, guava cheese, guava chutney, and guava powder, as well as canned guavas. Among them, guava nectar is far more important than the others in the quantity of production and the popularity among consumers.

***Fresh-cut Guava Wedges***

The shelf life of fresh-cut guava fruit is limited by the occurrence of softening, discoloration, and microbial growth. However, fresh-cut guava wedges can be washed with ozone-injected water to reduce the microbial load and stored at 5°C for 5 days with acceptable quality (Hsieh, 2000, Mattiuz *et al.*, 2003, Chan, 2004).

***Osmotic dehydration***

Osmotic dehydration of guava under different pulse vacuum conditions was reported by Panades *et al.*, (2003). Guava slices were osmotically dehydrated in different sweeteners and subsequently cabinet dehydrated to a final moisture content of 25%. Guava slices treated with sucrose: glucose (7:3) mixture with added potassium metabisulphite and ascorbic acid showed best results in terms of total fungal count during storage period. The guava slices prepared with sucrose :glucose (7:3) solutions showed highest overall acceptability with regard to its organoleptic quality.

***Guava Puree***

Guava fruits are usually macerated into puree first and then further processed to nectars, nectar blends, clarified juice, concentrates, powder, juice bar, beverages, syrup, ice cream topping, jams, jellies and more. For preparation of guava puree, fully mature, washed fruits are cut or sliced and fed into a pulper. The pulper removes seeds and fibrous material and forces the remainder of the product through a perforated stainless steel screen (CFTRI, 1990).Guava puree is preserved by (a) freezing to -29°C and storing at -18°C (frozen guava puree); (b) canning (canned guava puree); (c) aseptic packaging; or (d) dehydration. The deaeration of aseptically packaged guava puree helped in retention of ascorbic acid during storage up to 6 months (Chan, Jr. and Cavaletto, 1986).

Slightly over-ripened guava fruit, are macerated and finished by a rotor crusher, a paddle pulper, and a paddle finisher, all lined up in sequence. The screen on the pulper removes the seeds and the fibrous fragments of skin tissue. The residual stone cells may be ground by passing the finished pulp through a mill as it improves the mouthfeel (Jagtiani *et al.*, 1988). The type of centrifuge and the operation condition being used vary among factories. After flash heating and cooling in a scraped surface heat exchanger system, the puree can be filled into a presterilized, low-oxygen-permeability, laminated bag under aseptic conditions (Chan and Cavaletto, 1982). Brat-P *et al.*,(2002) prepared guava purees by flash vacuum-expansion.

***Clarified Guava Juice***

Guava juice is obtained either from fresh fruits or from pulp. Clarified guava juice can be used in the manufacture of clear guava nectar, clear guava juice blend, clear guava jelly, or guava powder. It is basically transparent and slightly colored pink, yellow, or white, depending on the cultivar. For extraction of juice, fruits are cut into small pieces, cooked by adding 250 ml of water and 0.2 g of citric acid per kilogram of fruit pieces, and stirred constantly. The cooked mass is strained through muslin cloth and the juice is collected. The recovery of juice may be increased to 70% by treatment with pectic enzyme (CFTRI, 1990). The fruit are macerated and treated with a commercial pectic enzyme preparation. The pulp is then passed through a hydraulic-plate-pack press to obtain the cloudy juice, normally over 80% in the yield. The cloudy juice is quickly heated in a plate heat exchanger for enzyme inactivation and then clarified by flowing through a plate or membrane

microfilter. Finally, the clarified juice is packed and stored, following procedures similar to those for guava puree, or concentrated.. Guava juice is further processed and utilized in the form of concentrate, beverage, jelly, powder, and other products. Gagrani *et al* (1987) prepared a whey beverage using 25% guava fruit juice. The beverage had good flavor and contained 0.5% acidity and 20% TSS. Storage stability of guava juice has been studied by several workers (Gagrani, *et al*., 1987; Shah *et al*., 1975). There is significant loss of vitamin C during storage of guava juice.

***Guava Concentrate***

Guava juice can be concentrated to four to five times its original TSS content at 50-55°C under vacuum (Aurora *et al*., 1990). During juice concentration, there is increase in TSS, acidity, sugars, pectin, and ascorbic acid, due to loss of water. The colour of the juice changes to brown due to browning reaction (Sandhu and Bhatia, 1985). Guava juice concentrate has been found to be suitable for drying into guava juice powder and ready-to-serve beverage. It may be advantageous to concentrate guava puree or clarified guava juice for long-term storage or for overseas shipments. Guava puree is usually subjected to an enzyme-depectinization pretreatment to reduce the viscosity before a concentration process starts. A depectinized puree can be concentrated to 34° Brix and remains flowable in an evaporator (Brekke and Myers, 1978). Clarified guava juice can even be concentrated up to 66° Brix (Muralikrishna *et al*., 1968). For preserving good flavor and color quality, guava concentrates should be packed in low oxygen permeability packages and stored in frozen form.

***Guava RTS***

Pandey and Singh (1999) standardized recipes for commercial preparation of guava RTS beverage. The varietal suitability and storage stability were examined. The recipe containing 10% pulp and 11% TSS (total soluble solids) with 0.25% acidity was found most ideal. The RTS beverage prepared from cv. Sardar (L-49) was better than that from cv. Allahabad Safeda, Apple Colour and Sangam. Storage stability of the product was found 4 months at ambient temperature.

***Guava Squash***

Squash prepared from four guava cultivars were evaluated upto six month under ambient condition by Pandey and Singh (1998). Studies indicated that recipe containing 25 per cent pulp and 45 per cent total soluble solids with 1.0 per cent acidity was found most ideal. The squash prepared from Sardar (L-49) had a significantly higher organoleptic score than that from the cultivars (Allahabad Safeda, Apple Colour and Sangam). Storage stability of product was 6 months at ambient temperature.

***Guava Nectar***

Guava nectar is prepared by blending guava pulp or puree and 14-15° Brix syrup and is preserved by freezing at -18°C or by canning. Kalra and Tandon (1984) prepared guava nectar containing 15% pulp, 14% soluble solids, and 0.25% acidity. The nectar was fortified with 100mg/100 g vitamin C and stored in glass bottles. Guava nectar may be diluted to prepare ready-to-serve beverage. Jain and Borkar (1966) prepared good-quality ready-to-serve bottled beverages by dilution of guava nectar with four times its volume of water. The beverage can also be prepared from fresh or preserved pulp using 1 kg of sugar, 6 liters of water and 20 g of citric acid per kilogram of pulp. Guava puree, clarified guava juice, or guava concentrate can be blended with water, sucrose, citric acid, and other flavor additives to formulate cloudy nectar or clear nectar. The former type of nectar is more popular than the latter in most countries. A small amount of carboxymethyl cellulose, approximately 0.05% wt, may be added to improve the cloud stability. For example, typical guava nectar on the market in Taiwan is of the cloudy type, about 25% juice content, at pH 3.8, and contains about 11°Brix of sugar and 0.2 g/100 ml of titratable acids (Chen *et al*., 1994).

The pectinesterase in guava is more heat-resistant than peroxidase, and, therefore, should be taken to be the target instead (Garces, 1969). *D* and *z* values for pectinesterase in different cultivars vary in a wide range though. the *D* 96°C and *z* values in pink-fleshed 'Allahabad' cultivar grown in India are 0.592 min and 16.6°C (Nath and Ranganna, 1983), whereas the *D* 90°C and *z* values in white-fleshed 'Pear' cultivar grown in Taiwan are 0.054 min and 8.9°C (Chen and Wu, 1991). The minimum shelf life for canned guava nectar in common storage conditions is 6 months. During the ambient storage of processed white-fleshed cloudy guava nectar, nonenzymatic browning plays an important role in the deterioration in quality. Ascorbic acid and tannins are involved in the discoloration (Chen *et al*., 1994). The reduction in pH by the addition of citric acid in the formulation of nectar may reduce the browning rate effectively (Chen and Wu, 1993). Aradhita-*et al*, 1995 found that guava hybrids, are more suitable for the preparation of "nectar", in comparison to commercially established cultivars, Allahabad Safeda, Banarsi Surkha and L-49.

***Guava Juice Blends and Nectar Blends***

Guava puree or clarified guava juice can be blended with deflavored apple or grape juice to make guava juice blends and sold in the category of 100% juice. Guava puree may also be blended with sugar, water, and orange juice, grapefruit juice, or passion fruit juice to make nectar blends with different compositions that suit the tastes of different consumers. The processing procedures are similar to that for guava nectar. Shukla *et al*.(2003) developed beverages using fruit juice/pulp, separated milk and reconstituted skim milk. Shukla *et al*. (2004) prepared fruit beverages using whey and buttermilk by blending guava, juice/pulp (10.0, 20.0, 30.0, and 40.0%) Organoleptic evaluation of the beverages showed that guava pulp of up to 10.0%, respectively, could be used with both whey and buttermilk

***Carbonated Beverages***

The clarified guava juice can be converted to a sugar syrup base containing 40% guava juice at 40° Brix and 1% acidity. After dosing 50 ml of this syrup into a glass bottle (200 ml capacity) filled with chilled, 4–6 °C, carbonated water at 80 psi (5.6 kg/cm 2) pressure of carbon dioxide gas, the bottle is sealed and pasteurized at 60 °C. The carbonated guava beverage can be stored for 3 months at room temperature maintaining acceptable color, flavor, and overall quality (Khurdiya *et al.*, 1996).

***Canned Guava***

Canned guavas may frequently be seen on the market in some countries including India, Pakistan and Indonesia. They are usually packed in syrup in the form of wholes, halves, shells, or slices. The firm, ripe guava fruit are lye-peeled by immersing in 2.5% boiling sodium hydroxide solution for 15 sec, rinsing with water, and then dipping in 0.5% citric acid solution to neutralize the residual alkalinity. The fruit is cut into quarters and cored to obtain the shells. The shells are dipped in 2% calcium chloride solution for 1 h to firm the texture, rinsed, and then placed into cans. The 45% sugar syrup that contains 0.25% citric acid as the acidifying agent is then hot-filled at 88°C to cover the shells and to reduce the headspace to less than 1 cm. The filled cans are heated in a steam exhauster, sealed soon after their center temperatures reach 79°C, processed in boiling water for 25 min, cooled in a water bath to 40 °C, and then air-dried. Guava can be preserved by canning as halves or quarters, with or without seed core (shells) by another procedure also. Fully ripe fruits are peeled with a knife and cut into halves or quarters. For canning of shells, the seed core is scooped with a spoon-shaped knife. The halves, quarters, or shells are immersed in 1-2% brine solution for about 5 min. They are then removed, drained, and canned in syrup of 40° Brix containing 0.25% citric acid. The cans are exhausted at 82-100°C for 7-10 min or until the temperature in the center of the can reaches at least 74°C. The cans are then sealed, sterilized in boiling water for 20-25 min, and then cooled to room temperature (Lal *et al.*, 1986). Siddappa (1982) reported that Allahabad seedless white guavas were more suitable for canning as halves.

***Dehydrated Guava***

Guava pieces or slices (halves or quarters) are dehydrated by air-drying, osmotic dehydration, or osmovac dehydration (Campbell and Campbell, 1983). In air-drying methods, guava slices are blanched in boiling water for 4 min, sulfured in a sulfur box for 20 min, and dried at 71°C for about 15 h or until the final moisture content is reduced to 6-7%. Air-drying may be done in a flow dehydrator, in a solar hut, or in the sun. Chemical blanching with 0.1% KMS + 2.0% $CaCl_2$ at 100°C for 3 min or sulfiting with 1% KMS for 5 min or fumigation with sulfur at 2 g/kg fruit pieces for 4 h avoids browning of slices. Khurdiya and Roy (1974) dried guava quarters in a cabinet drier at 60 ± 5°C for 18 h or until the final moisture content was less than 3%. Osmotic dehydration is used to prepare glazed guava slices. The guava slices are heated in an equal weight of 70° Brix syrup containing 0.1% KMS at 90°C for 3 min. After cooling, they are allowed to soak overnight. The slices are drained, spread out on glycerine-coated drying trays, and dried at 80°C for 1 h and then at 65-70°C for 7-8 h . In osmovac dehydration, the guava slices are submerged in 70° Brix syrup for 5-6 h. They are then dried under vacuum until a final moisture content of 2% is attained.

***Powder***

Dehydrated guava slices are pulverized to obtain guava fruit powder. Guavas are quartered and seed core is removed. The shells are blanched for 2 min and air-dried at 54°C for 10-12 h. The dried guavas are then powdered and packed (CFTRI, 1990). Khurdiya and Roy (1974) reported preparation of guava powder by drying guava slices at 60+-5° C in a cross-flow cabinet drier. The storage of guava powder for 6 months resulted in significant decrease in ascorbic acid and $SO_2$ levels, with a slight increase in moisture content. Guava fruit powder can be used for preparation of guava juice, ready-to-serve guava beverage, milk shake or *shrikhand.* A milk shake was prepared by mixing 1.5 g of guava powder and 16 g of sugar with 100 ml of milk (Ahire, 1989). The product was found to have good color, aroma, and taste. Guava powder was mixed with *shrikhand* at a 10% level to obtain guava *shrikhand (Perukhand).* The produce was found to have good acceptability (Ahire, 1989).

***Intermediate-Moisture Fruit***

Guava can be preserved as an intermediate-moisture fruit (IMF). Pretreatments such as blanching in plain water improved the acceptability of IMF (Ahire, 1989). Addition of 1.5% citric acid in steeping water was found to give proper sugar-acid taste to the final product. The storage of IMF in 200-gauge polyethylene bags did not produce any deteriorative changes in flavor or acceptability up to 3 months. Jayaraman *et al.*(1974) prepared an intermediate-moisture guava by an immersion equilibration procedure using a soak solution containing glycerol, sucrose, water, and potassium sorbate. The product was acceptable up to 4 months at 0° C and up to 3 months at room temperature.

***Pulp***

The pulp can be stored in good condition under refrigeration up to 2-3 months in glass or PVC containers with added $SO_2$ (500-1000 ppm) (Tandon and Kalra, 1984). Lower concentrations of $SO_2$ (500 ppm) are required for storage of guava pulp at room temperature for short periods (up to 60 days) (Tandon *et al.*, 1983). During storage of guava pulp in PVC containers at room temperature there was increase in sugars, and decrease in vitamin e, tannins, and free S02 levels . Nila *et al.* (1987) prepared fruit yoghurt by blending plain yoghurt with guava pulp. Guava syrup can be diluted to make ready- to-serve guava beverage (Ambadan, 1973). The guava beverage can be preserved for 2- 7 months using 50-ppm sorbic acid as a preservative

(Kalra *et al.*, 1987).Bons and Dhawan( 2003) preserved Guava pulp in food grade plastic jars by addition of potassium metabisulphite (KMS) and potassium sorbate (PS) at 0.07 and 0.1% either alone or in combination with heating. Results showed that guava RTS beverage prepared from pulp treated with KMS 0.07% and stored at freezing temperature obtained maximum sensory scores, followed by pulp with KMS 0.1% stored at low temperature.

***Jam***

Guava Jam is made by combining 45 parts of guava puree or pulp with 55 parts sugar. Dry pectin or pectin solution may be added to the pulp if needed and the mixture is thoroughly mixed while heating. Sugar is added while stirring. The mixture is heated until the Brix reaches 65°. The jam is filled, capped, and cooled as in the case of jelly.

***Cheese***

Firm ripe guava fruits are washed, cut into thin slices, and boiled with an equal quantity of water. The softened pulp is screened through net cloth and to every kilogram of pulp are added 1.25-1.50 kg of sugar, 2.2-3.3 g of citric acid, and 56 g of butter. The mixture is cooked to a thick paste. Small quantities of permitted red color and common salt may be added toward the end to improve the appearance of the final product. The hot cheese is allowed to set by spreading on a greasy tray. After cooling, it is cut into small pieces of suitable size. The pieces are wrapped *in* moisture-proof paper or polyethylene sheets (Lal *et al.*, 1986). The cheese can be stored at 4°C up to 120 days without loss of organoleptic properties (Singh *et al.*, 1983). Guava cheese prepared from Allahabad Safeda, Banarasi Surkha, and Lucknow-49 contained 1.241.55% pectin and 14.6-41.5 mg/100 g ascorbic acid (Singh *et al.*, 1983). The contents of pectin and ascorbic acid decreased during storage. This decrease was less during storage at low temperature .

Guava bar with highly acceptable texture can be made by hot air drying of clarified guava juice added with maltodextrin, sucrose, soluble starch, wheat flour, pectin, and antibrowning agent such as potassium metabisulfite (Vijayanand and Narasimham, 1998; Vijayanand *et al.*, 2000).

***Toffee***

Guava toffee is prepared by concentrating the pulp to about one-third of its original volume and mixing with sugar, fat, and acid. To every kilogram of guava pulp, 1.5 kg of sugar and 125 g of butter or ghee are added and the mixture is heated to obtain a thick mass. To this, 2 g of citric acid, a teaspoonful salt, and edible color are added. The product is spread in fat-smeared trays to about 0.6 cm thickness. After cooling, it is cut into small pieces of attractive shapes and sizes. The pieces are wrapped in butter paper and stored in clean, dry glass containers (Parpia, 1967). Guava toffee has good organoleptic properties and is comparable to chocolate. Chauhan and Sharma (1997) prepared fruit toffees by pulping and blending Fresh guava with soya slurry in different proportions. Sensory evaluation showed that the maximum soya slurry which could be added without compromising acceptability was 20-30% (depending on the fruit used).

***Jelly***

Fresh, slightly under ripe guavas with plenty of pulp and fewer seeds are used for preparation of jelly. The juice is extracted and allowed to settle overnight in a tall vessel. The clear juice is siphoned off and tested for pectin content. The juice is mixed with sugar (0.75 kg/kg of pectin-rich juice or 0.5 kg/kg of low-pectin juice) and boiled in a shallow vessel. Boiling is continued until the temperature reaches 105°C or until it gives a "sheet test." The hot jelly is poured into sterilized bottles or glass jars. These bottles are sealed and stored in a cool dry place (Lal *et al.*, 1986). Guava jelly has an attractive purplish-red color, pleasant taste, and aroma. It can be prepared from guava pulp by dilution with water or whey in 1:1.5 proportion (l00). The peel and seed core, discarded during canning of guava, can also be used for preparation of guava jelly. The pink-fleshed variety Beaumont gave jelly of better quality than white-fleshed or other red-fleshed varieties (Ramanjaneya, 1983).

***Wine***

Two types of wines can be prepared from guava fruit: guava juice wine (GJW) and guava pulp wine (GPW). The treatment of pulp with pectinase increases the final yield of wine (Bardiya *et al.*, 1974). Guava pulp wine is prepared in the same way as guava juice wine. When the Brix reading reaches 10°, the pomace is removed and more sugar is added (10%) to the fermenting materials and the mixture is allowed to ferment further (Bardiya *et al.*, 1974).The cultivars Apple Colour, Allahabad Safeda, Banarsi Surkha, Lucknow-49 and Seedless were assessed for chemical composition of juice, wine and brandy and for recovery of brandy from wine. Highest wine alcohol content (5.81%) was obtained from Allahabad Safeda. The recovery of alcohol (74.2%) in brandy from wine was highest with Lucknow-49 ( Dhawan *et al.*, 1983). Ananta and Shukla (2004) prepared Low-alcoholic beverage from ripened guava using *Saccharomyces cerevisiae* strain having titrable acidity range from 1.11 to 1.95%. The residual sugar in fermented fruit juice varied from 5.87 to 13.86%.

***Pectin***

Guava fruits are an important source of food-grade or natural pectin. Pectin is used in food products as an inexpensive source of natural food thickener and gelling agent. Pectin is extracted from guava fruits by boiling and concentrated by vacuum evaporation. The use of sodium hexametaphosphate at 0.25-0.75% concentration or 1:1 mixture of ammonium oxalate and oxalic acid at 0.25-0.75% concentration during extraction gave higher yields of pectin with high jelly grade and higher number of jelly units from winter guava (Dhingra and Gupta, 1984).

***Seed Oil***

Guava seeds are usually discarded during processing of juice and pulp. The seeds contain about 5-13% oil, but

guava seed oil (Table 1) is rich in essential fatty acids. Oleic (54%) and linoleic (29%) are the major fatty acids found in guava seed oil. The oil can be readily used in salad dressing.

Guava seeds are a waste product of guava fruits used for processing. Chemical analysis of the shells after elimination of fermentable substances and being ground into a powder revealed a high lignocellulose content and low mineral content. The ground seed powder can be suitable for use as an abrasive material for use in cosmetics. Oil from the kernels had a high (88%) unsaturated fatty acid content with (80%) linoleic acid predominating (Bourgeois- *et al.*, 1998)

***Vinegar***

Guava fruits (Psidium guajava cv. Banarasi Surkha)

**Table 1.** Characteristics of Guava Seed Oil (Landgraph, 1960).

| Characteristic | Value |
|---|---|
| Specific gravity (25°C) | 0.8902-0.9135 |
| Refractive index (25°C) | 1.4712 |
| Saponification value | 154-198 |
| Acid value | 3.4-7.0 |
| R-M number | 0.08-0.35 |
| Iodine number | 96-141 |
| Polenske number | 0.08-0.10 |
| Acetyl number | 74 |
| Unsaponifiable matter (%) | 0.5-3.5 |
| Total saturated fatty acids (%) | 10.1-16.0 |
| Total unsaturated fatty acids (%) | 84.0-89.9 |

are converted into vinegar using *Saccharomyces cerevisiae* yeast culture and ber vinegar (inoculum) for acetic acid fermentation (Simmon *et al.*, 2004). Results revealed that the vinegar prepared from fresh guava had the highest total acid (3.84 and 4.20%) and ascorbic acid (6.40 and 2.40 mg/100 ml) contents in both pulp: water dilutions (1:1 and 1:2); the vinegar prepared from guava pomace had the least total acid (3.22 and 3.10%) and ascorbic acid (1.05 and 0.65 mg/100 ml) contents. Sensory evaluation showed that the vinegar prepared from fresh guava had the highest overall acceptability for colour, appearance and taste with minimum astringency in 1:2 dilution. The vinegar prepared from 1:2 diluted pulp gave good colour and appearance.

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Short communication

# Influence of position of fruit in relation to maturity in guava

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Guava, the "apple of tropics" or "poor man's apple" is a popular and common fruit which belongs to the family Myrtaceae. It is grown practically in most of the states of India and excels in productivity, hardiness, adaptability and nutritive value. The fruit is a rich source of vitamin-C i.e. 234.3 mg/100g. Physical characters such as fruit weight, volume, specific gravity and dry matter content are influenced positively by their position on the tree in different directions i.e. east, west, north and south. These directions are mainly concerned with exposure of tree canopies to the light periods. The fruits from winter season crop develop more uniform colour with good quality and store better than rainy season crop, Tiwari *et al.* (2005). The disappearance of the green pigment is considered as a criteria in judging the harvest maturity.

There are visible physical appearance or bio-chemical indices of fruits that consistently reflect the appropriate stage of fruit maturity for harvest. Fruit harvesting should be carried out when the fruit is fully developed, mature end begin to turn light green. This communiqué deals with variation in physical and biochemical characters of the fruit vis-à-vis their position on the tree with reference to the direction.

The investigation was conducted in the orchard of Central Institute for Subtropical Horticulture, Rehmankhera, Lucknow during 2004-2005. Individual fruits in different directions of the tree i.e., east, west, north and south were tagged on 1st October, 2004. The fruits were harvested periodically at 10 days interval from 20th October to 20th January, 2005 and were divided into three lots having ten fruits per replication. The observation were recorded for physico-chemical attributes i.e., weight, volume, specific gravity, chromacity values, dry matter content, acidity and ascorbic acid.

Dry matter content, fruit colour, TSS, acidity and ascorbic acid content were determined by following standard procedures as described by Rangana (1986). The data was subjected to statistical analysis using MSTATC software.

Maximum fruit weight (162.9 g) was recorded from the fruits positioned in the east direction of the tree followed by south (160.68 g), north (158.43 g) and minimum was in fruits positioned in west 155.41g (Table 1). Conclusively it has been observed that fresh weight and volume of fruits increases at faster rate in the east followed by south, north and was least in the west directions. The findings are in line with the results obtained by Duecan *et al.* (1973) and Rajan and Lal (1999).

The data presented in Table 1 reveal that the maximum specific gravity was recorded in west position (1.028), while minimum (1.014) in the east direction at harvest maturity. Our findings are in consonance with Sites and Reitz, 1950b who reported that as the fruits approach maturity the specific gravity decreases thus indicating that the fruits obtained from east direction matured and ripened earlier than those positioned in other directions.

**Table 1.** Physical characteristics of guava fruits in cv. Sardar positioned in different directions at final harvesting stage.

| Directions | Parameters | | | |
|---|---|---|---|---|
| | Fruit wt. (g) | Volume (ml) | Specific gravity | Dry matter (%) |
| East | 162.861 | 160.617 | 1.014 | 13.403 |
| West | 155.414 | 151.237 | 1.028 | 14.483 |
| North | 158.425 | 154.970 | 1.023 | 13.883 |
| South | 160.679 | 158.367 | 1.017 | 13.583 |
| Mean | 159.345 | 156.298 | 1.020 | 13.838 |
| C D at 5 % | 0.578 | 1.231 | 0.001 | 0.357 |

It was observed that the lowest dry matter (13.40) content was noted in the fruits from east direction where as the highest (13.58) in fruits harvested from west direction (Table-1).This is because of utilization of photosynthates at a faster rate with growth and development of fruits, (Robinson and Lakso,1989). Total soluble solids and

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**Table 2.** Chemical characteristics of guava fruits cv. Sardar positioned in different directions at final harvest.

| Directions | Parameters | | |
|---|---|---|---|
| | TSS (%) | Acidity (%) | Ascorbic acid (mg/100 g) |
| East | 10.267 | 0.429 | 202.107 |
| West | 9.93 | 0.436 | 195.203 |
| North | 10.00 | 0.432 | 198.980 |
| South | 10.13 | 0.430 | 197.417 |
| Mean | 10.08 | 0.432 | 198.427 |
| C D at 5 % | 0.088 | 0.002 | 1.289 |

ascorbic acid content also differed significantly due to stage of harvest and direction (Table-2). Among different directions, the maximumTSS value and ascorbic acid (10.27% and 202.11mg, respectively) was recorded in the fruits from east and minimum (9.93 and 195.20 g, respectively) from west direction (Table 2).

In general acidity in terms of citric acid also varied significantly in fruits borne in different directions (Table 2). Out of different directions, lowest (0.429 %) acidity was recorded in fruits positioned in east directions and highest acid contents (0.436 %) were observed from those in west direction. This could be explained well in the light of well established fact that the fruit which matures earlier exhibits less greeness and specific gravity with higher 'YI' values (Sites and Ritz, 1950a).

Based on 'L' 'a' and 'b' chromacity values, yellowness index (YI) differed significantly due to different directions.

**Table 3.** Chromacity value of guava fruits cv Sardar positioned in different directions at final harvest.

| Directions | Parameters | | | |
|---|---|---|---|---|
| | 'L' value | 'a' value | 'b' value | Yellowness Index |
| East | 44.577 | 0.537 | 17.277 | 75.237 |
| West | 53.090 | -2.807 | 19.870 | 63.757 |
| North | 50.178 | -1.700 | 19.447 | 68.240 |
| South | 50.343 | -1.633 | 19.467 | 69.317 |
| Mean | 49.549 | -1.401 | 19.015 | 69.137 |
| C D at 5 % | 2.202 | 0.378 | 0.868 | 1.447 |

Chromacity value in terms of 'L' value increased gradually with advancement of fruit growth of every direction which was observed maximum (53.09) in west direction and minimum (44.58) in east direction at final harvest stage. Greenness of the fruit 'a' value was found maximum (-1.63) in west and minimum (0.54) from east direction (Table 3). Chromacity in terms of 'b' value was affected in relation to direction, which was recorded maximum (19.87) in west and minimum (17.28) in east at final harvest stage. Data revealed that out of different direction maximum YI (75.24) was from east followed by south, north and minimum from west (63.76) direction (Table 3). This is in further confirmation that fruits harvested from east direction mature earlier than those in other directions. The earliness in maturity may be due to the exposure of fruits to sun light for longer period than the fruits of other directions.

In conclusion, fruit maturity was affected by the position of the fruits in different directions. The fruits of Sardar guava positioned in east direction matured earlier followed by those in south and north directions, respectively.

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Short communication

# Macro and micronutrient removal pattern of different parts of perlette grapes

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Perlette is an important grape cultivar, which is extensively grown in Punjab, Haryana and adjoining areas of Rajasthan. One of the major factor for profitable grape production is the judicious application of fertilizes. However, farmers are not judiciously applying manures and fertilizers as per the recommendations. The information regarding nutrient removal pattern helps in assessing the nutrient requirement of a plant. This further helps in standardization of fertilizer requirement of plants. Very little information is available regarding nutrients removal by grape vines. Hence a field experiment was conducted on uniform eight years old perlette grape vines, to find out the nutrient removal through different parts of the plant. The grape vines were yielding 31kg/ vine. The soil of the experimental field was sandy loam and calcareous alkaline in reaction (pH 8.4), EC 0.23 dS $m^{-1}$ , low in organic carbon (0.33%), medium in available P (17.60 kg/ha) and was high in available K (374 kg/ha). The vines were pruned to 3-4 buds per cane with a total number of 45 canes/ vine at the time of annual pruning during January, 2005. Cultural practices were followed as per PAU, recommendation (Anonymous 2005). To study the nutrients removal by leaves, all the fallen leaves under the vines were collected between March and October and their weight was recorded in the month of October and sample drawn for the analysis of nutrients. Nutrient removal through berries was studied by collecting all the berries from five bunches of the experimental vines at the time of berry ripening. The berries were washed and were used for analysis. During annual pruning in 2006, pruned wood was collected for analysis after washing it properly with 0.1 N HCL and double distilled water. Nitrogen was estimated by Nesseler's reagent method, P by vandomolybdate phosphate yellow colour method, K by flame photometry and calcium and, mangnesium, were estimated by versanate methods ( Chang and Bray 1951; Jackson 1967 and Piper, 1966)). To determine the micronutrients, plant material was digested in diacid and micronutrients were determined by using atomic absorption spectrophotometer. Total nutrient removal through wood, leaves and berries was calculated by computing the nutrient concentration and total dry weight.

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The data present in Table 1 indicate that among the macronutrients the highest total uptake was observed in case of Potassium (259.00 g/vine) and it was minimum (47.3 g/vine) for Mg content. In total 210.26 g N, 148.61 g Ca and 52.12 P were removed by vines. Magnesium content did not differ significantly among the different plant parts. Nitrogen, Phosphorus and potassium content were removed maximum through berries followed by wood and leaves. The leaves removed higher amount of Ca than berries and pruned wood. This might be due to poor mobility of Ca towards other parts of the plant. The data further revealed that the least amount of N, P and K were removed through leaves. The available literature on nutrient removal pattern is rather confusing and vast differences exist in the reported amount of nutrients removed in different localities. In the present investigation, vines removed maximum potassium from the soil. This might be due to higher amount of availability of potassium in the soil solution. The results are in confirmity with the findings of Arora *et al.* (1991)

Among the micronutrient Fe removal was maximum (2405 mg/vine), whereas minimum (204.13 mg/vine) removal was observed in case of Cu (Table2). The uptake of zinc (215.15 mg/vine) and Fe (972.00mg/vine) was maximum in case of wood followed by leaves and berries). Copper uptake

**Table 1.** Uptake of macronutrients by grapevines CV, perlette (g/vine)

| | N | P | K | Ca | Mg |
|---|---|---|---|---|---|
| Berries | 136.31 | 33.32 | 208.92 | 26.33 | 16.65 |
| Wood | 42.95 | 11.55 | 26.33 | 39.13 | 15.05 |
| Leaves | 31.01 | 7.25 | 23.75 | 83.25 | 15.68 |
| Total | 210.37 | 52.12 | 259.00 | 148.61 | 47.38 |
| C D at 5% | 13.11 | 3.44 | 26.69 | 12.07 | NS |

**Table 2.** Uptake of micronutrients by grapevines CV. perlette (mg/vine)

| | Zn | Cu | Mn | Fe |
|---|---|---|---|---|
| Berries | 73.63 | 128.45 | 476.01 | 563 |
| Wood | 215.15 | 42.87 | 546.00 | 972 |
| Leaves | 154.56 | 32.81 | 795.77 | 870 |
| Total | 443.34 | 204.13 | 1817.00 | 2405 |
| CD 5% | 29.64 | 23.62 | 102.69 | 67.80 |

was highest in berries (128.45 mg/vine). Manganese uptake by various parts amounted 1817 mg/vine and leaves removed higher amount of Mn than berries and wood. The results are in conformity to the findings of Dehen *et al.* (1988).

It can be concluded from the results that perlette grapevines is heavy feeder of the various nutrients and there is need to supply sufficient amount of nutrients to the soil to obtain the proper yield from the grapevines.

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Short communication

# Effect of biofertilizers on growth and yield of garlic

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Garlic is an important commercial spice crop of India. It is the second most important widely used and cultivated bulb crops after onion. Garlic bulb are rich source of carbohydrates, protein, phosphorus, vitamin C and also have several medicinal values. The productivity of garlic in India is low (4.07 t $ha^{-1}$) in comparison to other countries. Thus, there is an ample scope for increasing productivity and production thorough fertilizers in particular to biofertilizers in light textured soils. The present experiment was conducted to study the effect of biofertilizers on growth and yield of garlic.

The experiment was carried out during 2003-04 at SKN College of Agriculture, Rajasthan Agricultural University, Bikaner. The treatment comprising five levels of biofertilizers i.e. $I_0$ (Control), $I_1$ (*Azotobacter* seed treatment), $I_2$ (*Azotobacter* soil application), $I_3$ (*Azospirillum* seed treatment) and $I_4$ (*Azospirillum* soil application) in randomized block design with three replications. The garlic variety "G-1" was planted in 1 x 1 $m^2$ sized plots at 10 x 20 cm spacing. Garlic seeds (cloves) were treated with biofertilizers (*Azotobacter* and *Azospirillium*) by mixing the seeds in biofertilizers @ 2 kg *Azotobacter* and 2 kg *azospirillium* with jaggery solution per hectare seed quantity. For soil application 2 kg $ha^{-1}$ of biofertilizers (*Azotobacter* and Azospirillium) each was mixed in 20 kg FYM. Keeping it moist and shady place for bacteria multiplication, than apply in experimental plots. Ten plants were tagged at random in each treatments for recording observations.

Data presented in table-1 clearly revealed that the maximum plant height and number of leaves per plant was recorded in *Azotobacter* seed treatment method. This treatment enhance plant height and number of leaves significantly as compared to remaining treatments i.e. soil application and control but it was at par with *Azospirillium* seed treatment. Efficient and healthy strain of *Azotobacter* in rhizosphere, which turn have resulted in greater fixation of atmospheric nitrogen and consequently for use by the plant resulting in vigorous growth of plant. Similar result have also been reported by Dibut *et al.* (1993) in onion. Likewise, *Azospirillum* have ability to fix nitrogen-produce plant growth promoting antifungal and antibacterial substances which influences plant growth. The bacterial effect of *Azospirillum* was also observed by Sankarnarayana *et al.* (1995). Application of biofertilizer by seed treatment significantly improved yield attributes *viz.* bulb diameter, fresh weight of bulb, number of cloves per bulb, bulb yield and harvest index as compared to soil application and control. Seed treatment method of biofertilizers proved most efficient inoculant to increase yield attributes and yield. These results are in close conformity with findings of Warade *et al.* (1996), Joi and Shende (1976) and Bhonde *et al.* (1997).

Application of biofertilizer (*Azotobacter* and *Azospirillum*) recorded maximum values on growth characteristics and yield attributes and yield. The highest bulb yield (112.79 q $ha^{-1}$) was recorded from the *Azotobacter* seed treatment as

**Table 1.** Effect of biofertilizers on growth, yield attributes and yield of garlic cv. "G-1"

| Treatment | Height of plants (cm) | Number of leaves/ plant | Bulb diameter (cm) | Number of clove per bulb | Fruit weight (g) | Bulb yield (q $ha^{-1}$) | Harvest index (%) |
|---|---|---|---|---|---|---|---|
| $I_0$ | 36.84 | 7.72 | 2.46 | 27.75 | 18.51 | 89.60 | 56.35 |
| $I_1$ | 45.27 | 8.25 | 3.09 | 31.51 | 23.53 | 112.79 | 61.20 |
| $I_2$ | 38.68 | 7.97 | 2.79 | 28.91 | 21.28 | 101.72 | 57.54 |
| $I_3$ | 44.65 | 8.17 | 3.01 | 32.11 | 23.51 | 110.22 | 60.56 |
| $I_4$ | 38.19 | 7.90 | 2.74 | 28.75 | 21.27 | 99.14 | 57.34 |
| C D at 5% | 2.59 | 0.41 | 0.13 | 1.80 | 1.17 | 4.78 | 3.06 |

$I_0$ (control); $I_1$ (*Azotobacter* seed treatment ); $I_2$ (*Azotobacter* soil application); $I_3$ (*Azospirillum* seed treatment ); $I_4$ (*Azospirillum* soil application);

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compare to other treatment such as soil application (101.72 q $ha^{-1}$) and control (89.60 q $ha^{-1}$), but it was at par with *Azospirillum* seed treatment (110.22 q $ha^{-1}$).

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Short communication

# Vase life of anthurium cut flowers as influenced by holding solutions

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Anthurium are tropical plants grown for their showy cut flowers and attractive foliage. These tropical cut flowers received a boost with the emergence of anthurium in the world scenario, dominated largely by sub-tropical and temperate cut flowers. Because of its long shelf life, anthurium is an excellent export product. The flowers are perishable and therefore need to be treated with suitable chemicals to enhance their life in vase and to improve the quality. One important factor causing senescence is the increase in loss of water from flower parts coupled with the reduced rate of water uptake during storage. Various holding solutions preservatives are used for the long term storage of anthurium cut flowers.

The present investigation was carried out during June-July 2005 at the Department of Horticulture, IGAU, Raipur. The cut flowers were harvested after the unfolding of the spathe is complete. Immediately after harvest, cut end of harvested flowers were dipped in freshly collected tap water and brought to laboratory. Thereafter, fresh cut stems was taken and kept in equal sized large test tubes containing 100 ml of each holding solution viz., Benzyl adenine (25 ppm); Benzoic acid (500 ppm) and Sucrose (5% solution). The experiment was laid out in completely randomized design. Each treatment was replicated thrice keeping six cut stems in each replication. The termination of vase life was marked by the wilting of Spathe and colour fading.

Data presented in Table 1 indicates that the complete flower opening and vase life varied significantly while kept in different holding solutions, namely Benzyl adenine (25 ppm) benzoic acid (500 ppm) and Sucrose (5% solution) under different cultivars viz., Titicala, Grace, Esmeralda, Flame andAkapana. Titicala, the maximum vase life (21.33 days) was recorded in Benzyl adenine (25 ppm) followed by 15.33 days vase life in Benzoic acid (500 ppm) while minimum vase life (14.33 days) was recorded in Sucrose (5% solution). In grace the maximum vase life (15.66 days) was recorded in benzyl adenine (25 ppm) followed by 15.33 days vase life in Benzoic acid (500 ppm) while minimum vase life (11.00 days) was recorded in Sucrose (5% solution). In Esmeralda the maximum vase life (20.00 days) was recorded in Benzyl adenine (25 ppm) followed by 14.66 days vase life in Benzoic acid and minimum vase life (14.00 days) was recorded in Sucrose (5% solution) in Flame the maximum vase life (17.33 days) was recorded in Benzyl adenine (25 ppm) followed by 13.33 days vase life in benzoic acid (500 ppm) and minimum vase life (11.66 days) was recorded in sucrose (5% solution). In Akapana the maximum vase life (14.00 days) was recorded in Benzyl adenine (25 ppm) followed by 11.00 days vase life in Benzoic acid (500 ppm) and minimum vase life (10.66 days) was recorded in sucrose (5% solution). Difference in vase life between cultivars under holding solution may be due to their genetical character. Kushal *et al.* (2001) reported that the pre harvest, harvest and post harvest factor affecting the post harvest life and quality of cut flowers, including genetic or inherent factors.

The maximum vase life was recorded with Benzyl adenine (25 ppm) treatment followed by Benzoic acid (500 ppm) because of its bactericidal properties. The use of bactericides with their resulting reduction of bacterial population, improves water balance, inhibit senescence and prolong the vase life of flowers. Similar results for Benzyl adenine were reported by Salvi *et al.* (1997). Paull and Chantrachit (2001) reported that the anthurium cvs. that responded positively to Benzyl adenine. Shrirakawa *et al.* (1964) reported that treatments with Benzyl adenine reduced respiration rate of anthurium flowers.

**Table 1.** Effect of holding solution on vase life of Anthurium

| Cultivars | Benzyl adenine (25 ppm) | Benzoic acid (500 ppm) | Sucrose (5% solution) |
|---|---|---|---|
| Titicala | 21.33 | 15.33 | 14.33 |
| Grace | 15.66 | 11.33 | 11.00 |
| Esmeralda | 20.00 | 14.66 | 14.00 |
| Flame | 17.33 | 13.33 | 11.66 |
| Akapana | 14.00 | 11.00 | 10.66 |
| C D at 5% | 1.3 | 1.69 | 2.30 |

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Short communication

# Variability in pomegranate fruit spot pathogen

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Pomegranate (*Punica granatum* L) is the most important fruit crop of the tropical and subtropical regions. It is also grown in arid and semi-arid regions of India in a total area of 79,157 ha with a production of 5,09,480 million tonnes. Fruit and leaf spots are important diseases affecting the yield and quality of fruits. Fruit spot caused by *A. alternata* (Fr.) Keissler occurs in pre-harvest and post harvest stages of pomegranate in some areas particularly in western parts of the country. Our surveys in western Rajasthan also revealed that it was major constraints resulting in uprooting of the pomegranate plants of local variety i.e. Jalore seedless in the Jalore District of Rajasthan. Survey revealed that mostly the plants of more than 10-15 years old have been adversely affected and the fruits are not fetching remunerative price even in domestic markets. The test pathogen has also been also reported to cause leaf spots and blights on susceptible cultivars. It is well known that *A. alternata* has different isolates or strains as reported from different crop plants. In pomegranate also, diversified symptoms on different cultivars could be seen. Successful management of this disease depends on the identification of virulent isolates or strains and for that characterization of basic features of pathogen is essentially required. Among different parameters, proteins and amino acid compositions are important biochemical components, which are useful for the chemotaxonomic characterizations of pathogenic isolates. Perhaps, due to genetic factors of the hosts or the diversity among pathogenic populations itself, different characteristic symptoms may be expressed in host plants and therefore, it is imperative to study the basic aspects of the pathogens for the better management of the disease. Therefore, presently, morphological characters and some of the biochemical parameters have been investigated and diversity of different isolates of *A. alternata* of pomegranate is presented.

Pathogenic isolates of *A. alternata* causing fruit spots in pomegranate from Anantapur (Andhra Pradesh), Bikaner (Rajasthan) and Rahuri (Maharashtra) locations were collected and pure culture was made on potato dextrose agar medium. Pathogenic isolates were tested for pathogenicity and maintained for different studies. Cultures were grown over thin layer of medium on sterile microscopic slides and 48 hr. old colonies were stained with cotton blue-lactophenol (HiMedia, Mumbai) and examined under 400x magnifications of light microscope (Olympus, Japan). The mycological attributes such as colour, size and shape of mycelia and conidia of pathogenic isolates were measured using the Software (Dewinter) and digital photographs were also taken using DP-12 Camera of Olympus microscope. Biochemical constituents like total and soluble proteins and amino acids were estimated as per standard procedures (Sadasivam and Manickam, 1992). Isolates were grown in liquid medium of PDA and 15 days old cultured were taken for the proteins estimation. Mycelia mat was collected and ground with phosphate butter (pH 7.0). Constitutive amino acids constituents were estimated from culture filtrates. The results on proteins were expressed in terms of micro gram per 100 mg. of mycelia and total amino acids content was expressed as percentage as per standard procedures.

The results given in Table 1 reveal the existence of morphological variation of three *A. alternata* isolates. Mycelial growth and conidiogenesis were fast in Anantapur and Bikaner isolates as compared to isolate from Rahuri (Maharashtra). Initially olive green and later brown mycelia colonies were noticed in Bikaner isolate while brown colonies from rest of the isolates chains of conidia were observed irrespective of isolates. However, size and shape were dissimilar. Chain of conidia measuring 24.12-33.43 x 7.6-11.53 µm with more number was seen in Anantapur isolate. Roberts *etal.* (2000) reported that accurate identification of small spore *Alternaria* spp. is challenging because of morphological plasticity under non-standard conditions and the common misapplication of the name *A. alternata* to a variety of morphologically distinct taxa. 11.53. Cellular proteins and total amino acids of mycelia of pathogen were also estimated in different isolates. Isolate from Anantapur showed high (1.386 µg/100 mg) total protein followed by isolate of Rahuri (1.295 µg 100 mg) whereas, soluble protein was more (0.824 µg100 mg) in Bikaner isolate followed by 0.64/100 mg in Rahuri isolate. Isolate from Anantapur recorded maximum of 0.16% total amino acids followed by 0.11% in Rahuri and 0.096% in Bikaner isolate. Similarly, variation on percentage of synthesized amino

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**Table 1.** Diversity on morphologenesis of *A. alternata* isolates of pomegranate.

| Isolates | Mycelia (µm) | Conidia (µm) | |
|---|---|---|---|
| | | length | width |
| Rahuri | 2.43-2.72 | 19.20-23.45 | 10.0-11.77 |
| Bikaner | 2.35-2.61 | 12.25-20.43 | 4.2-6.19 |
| Anantapur | 2.75-2.96 | 24.12-33.43 | 7.6-11.53 |

acids in liquid medium showed that maximum of 0.032% from Anantapur isolate followed by 0.024% in Rahuri and 0.02% in Bikaner isolate. Present results are in agreement with those of Lal *et al.* (1976) that variation in amino acids in the growing culture of *Alternaria alternata*. Earlier study on the composition of proteins from mycelial mass of *Alternaria alternata, Aspergillus carbonarius, Penicillium verruculosum, Tyromyces lacteus* and *Coriolus hirsutus* grown in submerged or solid-state conditions showed that albumins and globulins were predominant out of 70% of total proteins (Babitskaya *et al.*, 1989). Portnoy *et al.* (1993) identified representative strains of *A. alternara*. Each strains was grown on two types of solid media and characterized with descriptions of pigmentation and morphology. The biochemical composition of three isolates of *A. brassicae* designated as isolated A, C and D, which produces three distinct spots on leaves of *Brassica carinata* cv. ppcs-1, was investigated. On the basis of host response, isolate A was rated highly virulent, isolate C as moderately virulent and D as avirulent. Isolate A had the highest composition of carbohydrates and the least virulent D isolate had the lowest total carbohydrate content. It was also suggested that higher levels of carbohydrate may be correlated with isolate virulence. Isolate C had significantly higher levels of lipids, proteins, and DNA in comparison with isolates A and D (Vishwanath and Klte, 1997). Very few qualitative differences were found between the amino acids, organic acids and sugars in the mycelium of *A. triticina* and *A. tenuis* (*A. alternata*) providing biochemical support for the suggestion that *A. triticina* may be an ecotype of *A. alternata*. On the basis of amino acid composition it could not be confirmed that *A., solani* which is closely related to either *A. triticina* or *A. alternata* (Vijaya kumar and Rao, 1976 and 1977).

It is concluded that the fruit rot pathogens of pomegranate is variable particularly with respect to amino acid and protein concentrations and further investigations to correlate with their pathogenic virulence and biochemical factors is required.

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Short communication

# Dormancy and seed germination in *Solanum nigrum* Linn: A wild medicinal plant

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*Solanum nigrum* L. commonly known as black nightshade is a wild medicinal plant. In general, wild species are sources of desirable genes in any crop improvement programme. However, the precise use of such species in future breeding cannot be determined until they are collected, grown and their compatibility with cultivated strains assessed. The demand for this leafy vegetable was increased from 2077.9 (2001-02) to 2192.2 tonnes (2004-05), indicating the commercial value and the farmers are moving into its production. Recognizing the importance as a leafy vegetable plant in urban and rural areas in addition to ethnic and medicinal value, conservation of the species needs attention. Most of the relevant germplasm is undoubtedly being conserved by the users in *in-situ*, especially where the plants are used for culinary purpose. However, there is a need to conserve the seeds of this species in Seed Gene Bank (SGB). Under National Agricultural Technology Project (NATP-PB), *Solanum nigrum* genotypes were collected from different geographical regions for conservation in National Genebank, NBPGR, New Delhi. While testing the viability of seeds for long term conservation it was observed that seeds of some species exhibited dormancy/ hardiness ranging from 92-98%. The variation in hardiness of seed is possibly due to different environmental conditions of their place of origin, degree of maturation, time of collection and length of storage period. Induction of germination after breaking long term dormancy is required for rapid multiplication of this hardy vegetable crop. Therefore, an experiment was carried out to standardize the best treatment to overcome the dormancy and to attain high germination. The overall results of various treatments on the seeds collected from different sources are presented in this paper.

Seeds of various genotypes of the tested crop were collected from seven different locations viz., Rajasthan, Andhra Pradesh, Andaman & Nicobar Island, Punjab, Tamil Nadu, Kerala, and Orissa in India under National Agricultural Technology Project. A total of five physico-chemical treatments were imposed to break the dormancy/ hardseededness. The treatments viz., i) Pre-Chilling at 10°C for 7 days, ii) Pre-Chilling at 10°C for 7 days followed by soaking in 0.2% $KNO_3$ for 48h, iii) Pre-Chilling at 10°C for 7 days followed by soaking in $GA_3$ 500 ppm for 48h, iv) treatment with $GA_3$ 500 ppm, and v) treatment with 0.2% $KNO_3$ at the time of planting were given. Before subjecting to various treatments seeds were surface sterilized using 2.5% sodium hypochlorite with several rinses of distilled water. The germination test was conducted in 9 cm Petri dishes containing two layer of Whatman No 1 filter paper. The Plates were maintained at temperature of 30 ± 1°C in a seed germinator along with the untreated seed used as control. The seeds were observed regularly after seven days for germination and continued till the seedling developed all essential structures such as shoot and root. Final observation carried out on 28th day to record normal, abnormal, hard and dead seeds as per the International Rules for Seed Testing (ISTA 1999).

The data generated from the laboratory experiments were analyzed statistically by adopting CRD as described by Panse and Sukhatme (1985). The data on germination percentage were transformed to the respective angular (arc sine) values before subjecting them to statistical analysis using MSTAT software.

*Solanum nigrum* genotypes tested for seed viability under ambient conditions showed very low germination ranging from 2-6% and rest of the seeds remained fresh hard or dormant even after 30 days of planting. It is clear that there is dormancy in the tested genotypes. Salisbury *et al.* (1961) reported that the buried seeds of *Solanum nigrum* remained dormant for at least 39 years in Britain and resulting in 83% germination when moved into a suitable environment. Dormancy is a condition where seeds will not germinate even when the optimum/congenial environmental conditions including water, temperature and aeration are provided for germination (Hartmann *et al.*, 2002). It not only prevents immediate germination but also regulates the time, conditions and place that germination will occur.

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**Table 1.** Effect of Seed dormancy breaking treatments on germination percentage in different genotypes of *Solanum nigrum*.

| Treatments | IC 370439 (Rajasthan) | IC 382115 (A.P) | IC 539854 (A&N Isls) | IC 258522 (Punjab) | IC 260041 (T.N) | IC 333525 (Kerala) | IC259895 (Orissa) | Mean |
|---|---|---|---|---|---|---|---|---|
| Pre-chilling at 10°C for 7 days | 48.0 (44.1) | 52.0 (46.4) | 54.0 (47.5) | 33.0 (35.4) | 46.0 (42.9) | 50.0 (45.3) | 13.0 (21.4) | 42.2 (40.4) |
| Pre-chilling at 10°C for 7 days followed by soaking of seeds in 0.2% $KNO_3$ for 48 h | 79.0 (63.1) | 84.0 (66.9) | 89.0 (71.1) | 74.0 (59.7) | 87.0 (69.3) | 89.0 (71.1) | 43.0 (41.3) | 77.8 (63.2) |
| Pre-chilling at 10°C for 7 days followed by soaking of seeds in $GA_3$ 500 ppm for 48 h | 74.0 (59.7) | 80.0 (63.8) | 71.0 (57.7) | 68.0 (55.9) | 82.3 (65.30) | 83.0 (66.0) | 49.0 (44.7) | 72.4 (59.1) |
| Treatment with 0.2% $KNO_3$ at the time of plating | 69.0 (56.4) | 66.5 (54.9) | 70.0 (57.1) | 56.0 (48.7) | 68.0 (55.8) | 70.0 (57.1) | 21.0 (27.6) | 60.0 (51.1) |
| Treatment with $GA_3$ 500 ppm at the time of plating | 61.0 (51.6) | 49.0 (44.7) | 61.0 (51.6) | 44.0 (41.8) | 67.0 (55.2) | 66.0 (54.6) | 27.0 (31.6) | 53.5 (47.3) |
| Control | 5.0 (13.5) | 3.0 (10.6) | 6.0 ( 14.6) | 2.0 (9.1) | 5.0 (13.5) | 5.0 (13.5) | 2.0 (9.1) | 4.0 (12.0) |
| Mean | 56.00 | 55.75 | 58.50 | 46.17 | 59.12 | 60.50 | 25.83 | |

C D at 5% Treatments (A): 1.90 (1.33), Genotypes (B): 2.05 (1.45), (AXB): 5.02 (3.54)

Figures in parenthesis are transformed arc sin values

Among the various physico-chemical treatments tested to break dormancy, pre-chilling at 10°C for 7 days followed by soaking of seeds in 0.2% $KNO_3$ for 48 h was effective in improving germination percentage of all genotypes and reduced the hard seed per cent (Table 1). Pre-chilling and soaking in $GA_3$ 500 ppm also showed significant effect in all genotypes, except seeds collected from Orissa where only 49 per cent germination was obtained as compared to rest of the genotypes. Gao and Yamata (1991) observed the persistence of seed dormancy in eggplant for more than 2 months and reported that $GA_3$ 100 ppm was the most effective treatment in breaking seed dormancy. Similarly, Krishnasamy and Palaniappan (1990) reported high degree of seed dormancy in eggplant that persisted up to 5 months and was overcome by $GA_3$ 200 ppm.

In general, stratification treatments have been reported to break dormancy of viable seeds and enhance germination in many species (Baskin *et al.*, 2001). In the present study pre-chilling at 10°C for 7 days could also improve germination from 3 to 54 per cent in three genotypes viz., 52, 54 and 50 collected from Kerala, Andhra Pradesh and Andaman & Nicobar Island, respectively over untreated control (Table1). Similarly, Bond and Turner (2002) reported that *S. nigrum* seeds stored for more than 7 months exhibited seed dormancy and was overcome by subjecting the seeds to stratification for 2 days at 5°C, whereas, at very low temperatures seeds showed low viability. However, exposure of seeds to different duration of stratification has also been used by various workers to improve seed germination and seedling vigour. The physiological role behind these phenomena is usually associated with the breakdown of germination inhibitors (Tucker and Gray, 1986). Treatment with 0.2% $KNO_3$ showed significant increase in seed germination up to 70% and $GA_3$ 500 ppm up to 67%, it also showed comparable performances in breaking seed dormancy irrespective of the genotypes collected from different places. These results were supported by Gupta and Singh (1996) who observed that application with $GA_3$ and $KNO_3$ improved germination in *Solanum viarum* seeds. In the present study significant difference were observed between the genotypes, treatments and genotypes over treatments as per the statistical analysis. However, it can be concluded that for the purpose of commercial cultivation, development of seedlings through seeds is the best and cheaper method and the results of our study indicated that pre-chilling at 10°C for 7 days followed by soaking for 48 h in 0.2% $KNO_3$ is a suitable dormancy breaking treatments for obtaining maximum germination of *Solanum nigrum*.

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