Original Research Article

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Influence of Pre-Sowing Seed Treatment and Growing Conditions on Growth Performance of Indian Gooseberry Seedlings (Emblica officinalis Gaertn)

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Abstract

The study was carried out at Fruit Research Station, Imaliya, Department of Horticulture, college of Agriculture, JNKVV, Jabalpur, (M.P.) during January 2018 to May 2018. The experiment consist of three growing conditions viz. (C1) Open condition, (C2) net house, (C3) poly house condition and six treatments of seed i.e. (S1) water soaking, (S2) GA3 200 ppm, (S3) GA3 400ppm, (S4) GA3 600ppm, (S5) Thiourea 0.5%, and (S6) Thiourea 1% having 18 treatment combinations. Among the growing conditions poly house and among the seed treatment, GA3 (600ppm) were proved most promising as compare to others. Among the various treatment combinations, the C3S4 treatment combination (poly house and 600 ppm GA3) was proved most superior over rest of the treatment combinations with respect to growth parameters and Physiological Parameters like height of shoots (35.14 cm), number of leaves per seedling (103.73), girth of stem (1.80 mm) at 120 DAS respectively. However, the fresh weight of shoots (3.00 g), dry weight of shoots (0.69 g), fresh weight of roots (0.59 g), dry weight of roots (0.21) Seedling vigour index I (3178.08 cm), Seedling vigour index II (62.23 g), Leaf Area Index (0.347), Leaf Area Duration (5785.00 cm2.day), Light transmission ratio (30.67) and Energy Interception (0.50), recorded at 120 DAS were found to maximum in C3S4 treatment combination.

Keywords
Indian gooseberry (Emblica officinalis Gaertn), GA3, Thiourea, Growing conditions-Open condition, Net house, Poly house condition

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Introduction

Aonla (Emblica officinalis Gaertn) also known as “Indian goose berry” belongs to family Euphorbiaceae. It is thought to be native of India, Ceylon, Malaysia and China. It thrives well thought out tropical India and is wild or cultivated in the region extending from the base of Himalaya to Ceylon, Malaysia to South China. In India, aonla occupies an area of 88,000 ha. with production of 9,72,000 MT. In M.P., the area under aonla is reported to be 14.85 thousand ha and production 187.07 thousand MT. (Anonymous, 2015-16). Aonla is a branched tree and ranges from 9-12 m in height. Aonla is hardy tree, prolific bearer, highly remunerative even without much care. It can be successfully cultivated in marginal soil and various kinds of wasteland situations such as sodic and saline soil, ravines, dry and semi dry regions including plateau area of central
and southern India. Aonla acclaimed as ‘Amrit phal‘ in ayurveda and has acquired wide popularity all over the world due to its nutritional and medicinal importance. The aonla fruit is highly nutritive and is one of the richest sources of vitamin ‘C. It contains 309.96 to 583.20 mg of ascorbic acid per 100 g of pulp (Supe et al., 1997). The fruit is also rich in pectin and minerals such as iron, calcium and phosphorus. Aonla is acidic, cooling, diuretic and laxative. Hence, it has got great importance in preparation of Ayurvedic medicines. Aonla can be processed into many value added products i.e., murabba, candy, pickles, triphala churna as well as chyavanprash. Aonla can be propagated both by sexual and asexual methods. Sexually, it is propagated by seeds, however, being the cross pollinated crop, the variability does exist in the seedling population. Hence, seeds are only used for raising seedlings which are further used as rootstocks. As the area under aonla is increasing day by day, the demand of budded plants is also increasing but this demand is not fulfilled because of various factors like poor seed germination and poor seedling growth. The presence of impermeable seed coat acts as barrier to seed germination in aonla (Pawshe et al., 1997). Availability of quality planting material is one of the major problems for expansion of area. Therefore, there is an urgent need to standardize the nursery techniques for improving germination and growth of seedlings. Aonla being a minor fruit crop, less work has been taken for enhancing seed germination and seedling growth by using the plant growth regulators and nutrients. Pre-sowing seed treatments with chemicals like GA3, Thiourea, KNO3 and NAA have been reported to influence the duration of germination, per cent seed germination, seedling height, number of branches and roots (Dhankar and Singh, 1996; Pawshe et al., 1997; Gholap et al., 2000; Rajamanickam et al., 2002).

Materials and Methods

The present experiment “Effect of seed treatment and growing conditions on germination, growth and survival of Indian gooseberry seedling (Emblica officinalis Gaertn)” was carried out at Fruit Research Station, Imalia, Department of Horticulture, College of Agriculture, JNKVV, Jabalpur (M.P.) during January 2018 to May 2018. The experiment comprised of three growing conditions viz. (C1) Open condition, (C2) net house, (C3) poly house condition and six treatments of seed i.e. (S1) water soaking, (S2) GA3 200ppm, (S3) GA3 400ppm, (S4) GA3 600ppm, (S5) Thiourea 0.5%, and (S6) Thiourea 1% having 18 treatment combinations. The experiment was laid out in poly bags in factorial completely randomized design with three replications. Observations were recorded using standard procedure and statistically analysed.

Growth parameter

The following observations were recorded at 120 days after sowing. Randomly selected five plants were tagged for following observations.

Height of seedling (cm) – Height was measured from ground level to the tip of opened leaf.

Girth of stem (mm) – The girth of stem was measured with the help of digital vernier calipers just above the ground surface and the average was calculated.

No. of branches per plant - The total number of branches per plant was counted and the average was calculated.

Number of leaves per seedling – The total number of leaves per seedling was counted and the average was calculated. Matured leaves were taken into account.
Fresh weight (g) of shoot - The plants were carefully washed to remove the soil adhering to their roots and shoots. The weight was taken with the help of electronic balance and average value was computed.

Dry weight (g) of shoot - For dry weight plant was chopped and oven dried at 60 ± 2 °C temperature till a constant weight. The weight was taken with the help of electronic balance and average value was computed.

Fresh weight (g) of root - The plants were carefully washed to remove the soil adhering to their roots and shoots and cut the roots from plant. The weight was taken with the help of electronic balance and average value was computed.

Dry weight (g) of root - For dry weight roots were chopped and oven dried at 60 ± 2 °C temperature till a constant weight. The weight was taken with the help of electronic balance and average value was computed.

Total dry matter production - For determining the dry matter production three plants were removed from polybags and roots were washed. After recording the fresh weight, the samples were at 600 c for 36 hrs (till constant weight). The dry weight of total plant was recorded accordingly.

Seedling vigour index - I It was calculated by adding the values of root length and shoot length which was randomly selected and multiplying with their corresponding germination percentage and the values were recorded (Abdulbaki and Anderson, 1973).

Seedling vigour index I =

\[
\text{Germination percentage } \times [\text{root length (cm)} + \text{shoot length (cm)}]
\]

Seedling vigour index - II - It was calculated by multiplying dry weight of seedlings with their corresponding germination percentage.

Seedling vigour index II = dry weight of seedlings (g) x germination percentage.

Physiological parameters

Leaf area index (LAI)

LAI expressed the ratio of leaf surface considerably to the ground area occupied by the plant or a crop stand worked out as per specification of Gardner et al. (1985),

\[
\text{LAI} = \frac{(\text{LA}_2 + \text{LA}_1)}{2P} \times 100
\]

Where,

\[
\text{A}_2 + \text{A}_1 = \text{Leaf area of two consecutive intervals}
\]

\[
P = \text{Ground area}
\]

Leaf area duration (LAD)

Leaf area duration expresses the magnitude and persistence of leaf area of leafiness during the period of crop growth. It reflects the extent of period of crop growth. It reflects the extent of seasonal integral of light interception and correlated with yield. LAD was computed as follows (Watson, 1952).

\[
\text{LAD} = \frac{\text{LA}_1 + \text{LA}_2}{2} \times t_{2-t_1} \text{cm}^2.\text{days}
\]

Light transmission ratio (LTR)

It is the ratio of light intensities reaching at the base of crop canopy to the total incoming solar radiation and was worked out as per specifications of Golumguai and Mabbayad (1969).

\[
\text{LTR} = \frac{\text{I}}{\text{I}_0} \times 100
\]
Where

\[ I = \text{Light intensity at the base of crop canopy and} \]

\[ I_0 = \text{Total incoming radiation the light intensities were recorded by using Lux Meter Model LX-105} \]

**Energy interception (EI)**

The total incident light at the canopy crown and transmitted light within the crop were converted into average incident and transmitted energy on the basis of value reported by Gaastra (1963)

\[ 71 \text{ k.lux} = 1 \text{ cal. Cm}^{-2} \text{ min}^{-1} \]

The efficiency of the crop canopy for solar energy interception (EI) was calculated as per the formula given by Hayashi (1966)

\[ EI = \text{Total incident energy} - \text{Transmitted energy} \]

**Chlorophyll content index**

The chlorophyll content index was recorded by using chlorophyll meter Model CCM 200. The observations were recorded at different canopy depths.

**Results and Discussion**

**Growth parameter**

**Height of plants (cm), Girth of stem (mm), No. of branches / plant, Number of leaves at 120 DAS**

The data showed that almost all the growing conditions and treatments showed significant effect on height of plant, Girth of stem (mm), No. of branches / plant, Number of leaves. The maximum plant height (33.43 cm), stem girth (1.73 mm), no. of branches / plant (13.58), number of leaves (100.71) were noted under C3 (poly house condition). The minimum plant height (13.19 cm), stem girth (1.71 mm), no. of branches / plant (9.44), no. of leaves (68.03) were recorded under C1 (open condition). The maximum plant height (27.39 cm), stem girth (1.76 mm), no. of branches / plant (13.01), number of leaves (92.97) were noted with S4 (GA3 600 ppm) and the minimum plant height (25.08 cm), stem girth (1.61 mm), no. of branches / plant (11.30), no. of leaves of (87.39) were recorded in S1 (control). The maximum plant height (35.14 cm), stem girth (1.42 mm), no. of branches / plant (13.97), no. of leaves (103.73) were noted under C3S4 (poly house condition and GA3 600 ppm), whereas, the minimum height (12.03 cm), stem girth (1.52 mm), no. of branches / plant (8.73), no. of leaves (64.73) were recorded under in C1S1 (open condition and control). Our results are also in the line of Ngullie and Biswas (2017) in the case of height in poly house. Basically, plant height is a genetically controlled character but several studies have indicated that plant height can be increased by application of synthetic plant growth regulators. However, in the present investigation, a significant difference in plant height was noticed by the application of different concentration of GA3. It might be due to GA3 effect on elongation of internodes, as GA3 is known to enhance cell elongation. Our results are also in the line of Chandra and Govind (1990) and Singh et al. (2002), Pampanna et al. (1995) in the case of height in GA3. Our results are also in the line of Singh et al. (2004) and Meena and jain (2005) in the case of girth of stem. The production of more number of leaves in GA3 treatments may be due to the vigorous growth and more number of branches induced by GA3 which facilitates better harvest of sunshine by the plants to produce more number of leaves. Similar findings were also reported by
Chandore et al (2016), Thamer and Falahy (2014) in the case of no. of leaves (Table 1).

**Fresh and dry weight of shoot (g)**

The data pertaining to fresh and dry weight of shoot were recorded at 120 days after seed sowing the conditions significantly influenced the fresh and dry weight of shoots and the maximum fresh weight (2.92 g), dry weight (0.64 g) were recorded under C3 (poly house condition) and minimum fresh weight (2.89 g), dry weight (0.62 g) were noted in C1 (open condition). The treatments significantly influenced the fresh and dry weight of shoot at 120 days after sowing. Among the treatments, S4 (GA3 600 ppm) recorded maximum (2.97 g) fresh weight and dry weight (0.67 g) of shoot followed by treatment. The treatment S1 (control) gave minimum fresh weight (2.85 g), dry weight (0.61 g) shoot. The maximum (3.00) fresh weight, dry weight (0.69 g) were recorded under the treatment combination of C3S4 (poly house and GA3 600 ppm). The minimum fresh weight (2.80 g) under treatment combination C1S1 (open condition and control). The minimum dry weight (0.59 g) was recorded under treatment combination C1S5 (open condition and thiourea 1%).

Increase in the dry weight of different plant parts due to improved mobilization of nutrients due to the application of GA3, which promotes plant growth and development. Our results are also in line of Ratan and Reddy (2004), Gurung et al. (2014).

**Fresh and dry weight of root**

The data about fresh and dry weight of root were recorded at 120 days after sowing of seed the growing conditions were found to have significant influence on the fresh and dry weight of roots and the maximum (0.56 g) fresh weight and (0.16 g) dry weight were recorded under treatment C3 (poly house) and the minimum fresh weight (0.55 g) dry weight (0.15 g) were noted in C1 (open condition). The seed treatments also influenced the fresh and dry weight of root at 120 days after sowing. Among to increase the fresh and dry weight of root the various treatments, S4 (GA3 600 ppm) were found significant and it was maximum fresh weight (0.57 g) and dry weight (0.19 g). The treatment S1 (control) gave minimum fresh weight (0.53 g) and dry weight of root (0.14 g).

The maximum (0.59 g) fresh weight and dry weight (0.21 g) were recorded under the treatment combination of C3S4 (poly house condition and GA3 600 ppm) and the minimum fresh weight (0.52 g) and dry weight (0.12 g) under treatment combination C1S1 (open condition and control).

Increase in fresh weight of roots is due to the influence of GA3 on different plant parts, which could be due to its effect in stimulating cell division, cell elongation, auxin metabolism, cell wall plasticity and permeability of cell membrane leading to enhanced growth. Increase in the dry weight of different plant parts due to improved mobilization of nutrients due to the application of GA3, which promotes plant growth and development. Our results are also in line of Ratan and Reddy (2004), Gurung et al. (2014).

**Total dry matter production, seedling vigour index I (cm) and Seedling vigour index II (g)**

The results showed that growing conditions significantly influenced the total dry matter production, Seedling vigour index I (cm) and Seedling vigour index II (g) and the maximum (0.25 g) dry matter, seedling vigour index I (2630.34 cm) and seedling vigour index II (56.88 g) were recorded under C3 (poly house), the minimum dry matter (0.21
g), seedling vigour index I (1825.04 cm) and seedling vigour index II (51.92 g) in C₁ (open condition). The maximum dry matter production (0.32 g), seedling vigour index I (2641.62 cm) and seedling vigour index II (60.20 g) were recorded with S₄ (GA₃ 600 ppm) and minimum dry matter production (0.15 g), seedling vigour index I (1841.14 cm) and seedling vigour index II (50.67 g) recorded in S₁ (control). The maximum (0.36 g) dry matter, seedling vigour index I (3178.08 cm) and seedling vigour index II (62.23 g) value were recorded under the treatment combination of C₃S₄ (poly house and GA₃ 600 ppm). However, the minimum dry matter (0.13 g) was recorded under treatment combination C₂S₁ (net house and control). Seedling vigour significantly differed due to invigoration of seeds. The highest seedling vigour in GA₃ was attributed to enlarged embryos, higher rate of metabolic activity and respiration, better utilization and mobilization of metabolites to growth points and higher activity of enzymes. Enzymatic and hormonal mechanism stimulates metabolic process such as sugar mobilization, protein hydrolysis, oxidation etc. Our results are also in the line of Dhoran and Gudadhe (2012), Gurung et al. (2014) in the case seedling vigour index I. The seedling vigor significantly differed due to invigoration of seeds. The highest seedling vigour in GA₃ was attributed to enlarged embryos, higher rate of metabolic activity and respiration, better utilization and mobilization of metabolites to growth points and higher activity of enzymes. Enzymatic and hormonal mechanism stimulates metabolic process such as sugar mobilization, protein hydrolysis, oxidation etc. Our results are also in the line of Dhoran and Gudadhe (2012), Chiranjeevi et al (2017) in the case of seedling vigour index II (Table 3).

Physiological parameters

Leaf Area Index (LAI) and Leaf Area Duration (LAD)

The Growing conditions indicated significant variation on Leaf Area Index (LAI) and Leaf Area Duration (LAD) at 120 days after sowing and maximum Leaf Area Index (LAI) (0.31) and Leaf Area Duration (LAD) (5125.37 cm².day) were recorded under C₃ (poly house). The minimum Leaf Area Index (LAI) (0.29) and Leaf Area Duration (LAD) (5008.69 cm².day) were recorded under C₁ (open condition). The seed treatments significantly influenced the Leaf Area Index (LAI) and Leaf Area Duration (LAD) at 120 days after sowing. Maximum Leaf Area Index (0.33) and Leaf Area Duration (LAD) (5624.74 cm².day) were recorded at 120 days after sowing with S₄ (GA₃ 600 ppm). Whereas, minimum Leaf Area Index (0.27) and Leaf Area Duration (LAD) (4758.87 cm².day) were recorded in S₁ (control). The interaction of growing conditions and seed treatments also showed significant effect on Leaf Area Index (LAI) and Leaf Area Duration (LAD).

The maximum Leaf Area Index (LAI) (0.34) and Leaf Area Duration (LAD) (5785.00 cm².day) were noted under treatment combination C₃S₄ (poly house and GA₃ 600 ppm) while minimum Leaf Area Index (LAI) (0.26) and Leaf Area Duration (LAD) (4663.77 cm².day) were noted under C₁S₁ (open condition and control). The increase of Leaf Area Index due to rich source of nutrient and presence of 600 ppm GA₃. This was higher ascribed to higher magnitude increases in parameter associated with the LA. The finding was supported by Munde and Gajbhiye (2010), Roy and shrivastava (2011) in the case of LAI. It may be due to synergistic effect of both factors (Table 4).

Light Transmission Ratio (LTR)

The data revealed that minimum Light Transmission Ratio (LTR) 44.04 % was recorded under C₃ (poly house) whereas, maximum Light Transmission Ratio (LTR) 46.97 % was recorded under C₁ (open condition). As regards the seed treatment, the minimum LTR 42.75 % was noted under S₄ (GA₃ 600 ppm).
Table 1(A) Effect of growing conditions and seed treatment on height, girth of stem, no. of branches /plant, no. of leaves /seedling of aonla seedlings

| Treatments | Height of seedlings (cm) | Girth of stem (mm) | No. of branches /plant | No. of leaves /seedling |
|------------|-------------------------|-------------------|-----------------------|------------------------|
| **Growing condition** |                         |                   |                       |                        |
| C1         | Open condition          | 13.19             | 1.71                  | 9.44                   | 68.03                  |
| C2         | Net house condition     | 31.59             | 1.63                  | 13.43                  | 100.44                 |
| C3         | Poly house condition    | 33.43             | 1.73                  | 13.58                  | 100.71                 |
| S. Em±     |                         | 0.09              | 0.001                 | 0.04                   | 0.02                   |
| C.D. 5% level |                       | 0.26              | 0.003                 | 0.12                   | 0.06                   |
| **Seed treatment** |                        |                   |                       |                        |
| S1         | Water soaking           | 25.08             | 1.61                  | 11.30                  | 87.39                  |
| S2         | GA3 200ppm              | 26.45             | 1.68                  | 12.41                  | 90.12                  |
| S3         | GA3 400ppm              | 26.30             | 1.71                  | 11.89                  | 89.97                  |
| S4         | GA3 600ppm              | 27.39             | 1.76                  | 13.01                  | 92.97                  |
| S5         | Thiourea 0.5%           | 25.76             | 1.71                  | 12.09                  | 89.12                  |
| S6         | Thiourea 1.0%           | 25.44             | 1.68                  | 12.21                  | 88.60                  |
| S. Em±     |                         | 0.12              | 0.001                 | 0.06                   | 0.03                   |
| C.D. 5% level |                       | 0.36              | 0.004                 | 0.18                   | 0.09                   |
| **(B) Interaction effect of growing conditions and seed treatment on aonla seedlings** | | | | |
| C1S1       | Open condition+ Water soaking | 12.03           | 1.52                  | 8.73                   | 64.73                  |
| C1S2       | Open condition+ GA3 200ppm  | 12.84           | 1.72                  | 10.00                  | 69.30                  |
| C1S3       | Open condition+ GA3 400ppm  | 13.84           | 1.74                  | 8.93                   | 68.33                  |
| C1S4       | Open condition+ GA3 600ppm  | 14.58           | 1.77                  | 11.20                  | 72.40                  |
| C1S5       | Open condition+ Thiourea 0.5% | 13.34           | 1.68                  | 9.00                   | 66.57                  |
| C1S6       | Open condition+ Thiourea 1.0% | 12.51           | 1.70                  | 8.77                   | 66.83                  |
| C2S1       | Net house+ Water soaking | 31.04           | 1.65                  | 12.93                  | 99.20                  |
| C2S2       | Net house+ GA3 200ppm    | 31.70           | 1.58                  | 13.33                  | 100.60                 |
| C2S3       | Net house+ GA3 400ppm    | 31.67           | 1.67                  | 13.27                  | 100.53                 |
| C2S4       | Net house+ GA3 600ppm    | 32.45           | 1.71                  | 13.87                  | 103.07                 |
| C2S5       | Net house+ Thiourea 0.5%  | 31.48           | 1.70                  | 13.53                  | 100.67                 |
| C2S6       | Net house+ Thiourea 1.0%  | 31.16           | 1.61                  | 13.67                  | 100.20                 |
| C3S1       | Poly house+ Water soaking | 32.18           | 1.65                  | 12.23                  | 98.23                  |
| C3S2       | Poly house+ GA3 200ppm   | 34.81           | 1.73                  | 13.90                  | 100.47                 |
| C3S3       | Poly house+ GA3 400ppm   | 33.38           | 1.71                  | 13.47                  | 101.03                 |
| C3S4       | Poly house+ GA3 600ppm   | 35.14           | 1.80                  | 13.97                  | 100.73                 |
| C3S5       | Poly house+ Thiourea 0.5% | 32.44           | 1.75                  | 13.73                  | 100.43                 |
| C3S6       | Poly house+ Thiourea 1.0% | 32.65           | 1.72                  | 13.20                  | 98.77                  |
| S. Em±     |                         | 0.22             | 0.002                 | 0.11                   | 0.05                   |
| C.D. 5% level |                       | 0.64              | 0.007                 | 0.32                   | 0.16                   |
Table 2(A) Effect of growing conditions and seed treatment on aonla seedlings

| Treatments | Fresh weight of shoot (g) | Dry weight of shoot (g) | Fresh weight of root (g) | Dry weight of root (g) |
|------------|---------------------------|------------------------|--------------------------|------------------------|
| Growing condition | | | | |
| C₁ | Open condition | 2.89 | 0.62 | 0.55 | 0.15 |
| C₂ | Net house condition | 2.92 | 0.63 | 0.55 | 0.15 |
| C₃ | Poly house condition | 2.92 | 0.64 | 0.56 | 0.16 |
| S.Em± | | 0.008 | 0.002 | 0.001 | 0.002 |
| C.D.5% level | | 0.022 | 0.005 | 0.003 | 0.007 |
| Seed treatment | | | | |
| S₁ | Water soaking | 2.85 | 0.61 | 0.53 | 0.14 |
| S₂ | GA₃ 200ppm | 2.93 | 0.63 | 0.56 | 0.15 |
| S₃ | GA₃ 400ppm | 2.89 | 0.63 | 0.55 | 0.14 |
| S₄ | GA₃ 600ppm | 2.97 | 0.67 | 0.57 | 0.19 |
| S₅ | Thiourea 0.5% | 2.87 | 0.62 | 0.55 | 0.16 |
| S₆ | Thiourea 1.0% | 2.93 | 0.62 | 0.56 | 0.15 |
| S.Em± | | 0.01 | 0.002 | 0.002 | 0.003 |
| C.D.5% level | | 0.03 | 0.007 | 0.004 | 0.009 |

(B) Interaction effect of growing conditions and seed treatment on aonla seedlings

| C₁S₁ | Open condition+ Water soaking | 2.80 | 0.61 | 0.52 | 0.12 |
| C₁S₂ | Open condition+ GA₃ 200ppm | 2.92 | 0.62 | 0.55 | 0.15 |
| C₁S₃ | Open condition+ GA₃ 400ppm | 2.85 | 0.62 | 0.56 | 0.16 |
| C₁S₄ | Open condition+ GA₃ 600ppm | 2.94 | 0.63 | 0.57 | 0.19 |
| C₁S₅ | Open condition+ Thiourea 0.5% | 2.86 | 0.59 | 0.56 | 0.17 |
| C₁S₆ | Open condition+ Thiourea 1.0% | 2.92 | 0.62 | 0.56 | 0.16 |
| C₂S₁ | Net house+ Water soaking | 2.84 | 0.59 | 0.54 | 0.14 |
| C₂S₂ | Net house+ GA₃ 200ppm | 2.94 | 0.62 | 0.56 | 0.16 |
| C₂S₃ | Net house+ GA₃ 400ppm | 2.84 | 0.64 | 0.55 | 0.13 |
| C₂S₄ | Net house+ GA₃ 600ppm | 2.98 | 0.68 | 0.57 | 0.18 |
| C₂S₅ | Net house+ Thiourea 0.5% | 2.97 | 0.63 | 0.55 | 0.17 |
| C₂S₆ | Net house+ Thiourea 1.0% | 2.97 | 0.63 | 0.56 | 0.13 |
| C₃S₁ | Poly house+ Water soaking | 2.91 | 0.61 | 0.53 | 0.13 |
| C₃S₂ | Poly house+ GA₃ 200ppm | 2.92 | 0.65 | 0.55 | 0.14 |
| C₃S₃ | Poly house+ GA₃ 400ppm | 2.98 | 0.62 | 0.55 | 0.13 |
| C₃S₄ | Poly house+ GA₃ 600ppm | 3.00 | 0.69 | 0.59 | 0.21 |
| C₃S₅ | Poly house+ Thiourea 0.5% | 2.79 | 0.64 | 0.54 | 0.14 |
| C₃S₆ | Poly house+ Thiourea 1.0% | 2.91 | 0.62 | 0.55 | 0.16 |
| S.Em± | | 0.02 | 0.004 | 0.003 | 0.006 |
| C.D.5% level | | 0.06 | 0.012 | 0.007 | 0.016 |
Table 3(A) Effect of growing conditions and seed treatment on aonla seedlings

| Treatments | Total dry matter production (g) | Seedling Vigour Index –I | Seedling Vigour Index –II |
|------------|--------------------------------|--------------------------|---------------------------|
| **Growing condition** | | | |
| C₁ | Open condition | 0.21 | 1825.04 | 51.92 |
| C₂ | Net house condition | 0.24 | 2608.51 | 56.01 |
| C₃ | Poly house condition | 0.25 | 2630.34 | 56.88 |
| S.Em± | | | |
| C.D.5% level | 0.012 | 247.66 | 0.004 |
| **Seed treatment** | | | |
| S₁ | Water soaking | 0.15 | 1841.14 | 50.67 |
| S₂ | GA₃ 200ppm | 0.19 | 2350.09 | 55.11 |
| S₃ | GA₃ 400ppm | 0.24 | 2485.51 | 55.49 |
| S₄ | GA₃ 600ppm | 0.32 | 2641.62 | 60.20 |
| S₅ | Thiourea 0.5% | 0.26 | 2402.35 | 54.83 |
| S₆ | Thiourea 1.0% | 0.23 | 2407.07 | 53.31 |
| S.Em± | | | |
| C.D.5% level | 0.006 | 121.62 | 0.002 |
| **(B) Interaction Effect of growing conditions and seed treatment on aonla seedlings** | | | |
| C₁S₁ | Open condition+ Water soaking | 0.173 | 1308.08 | 48.27 |
| C₁S₂ | Open condition+ GA₃ 200ppm | 0.220 | 1691.39 | 57.77 |
| C₁S₃ | Open condition+ GA₃ 400ppm | 0.183 | 1893.77 | 57.67 |
| C₁S₄ | Open condition+ GA₃ 600ppm | 0.248 | 2033.53 | 58.20 |
| C₁S₅ | Open condition+ Thiourea 0.5% | 0.218 | 1993.91 | 53.13 |
| C₁S₆ | Open condition+ Thiourea 1.0% | 0.219 | 2029.59 | 57.93 |
| C₂S₁ | Net house+ Water soaking | 0.132 | 2225.24 | 52.40 |
| C₂S₂ | Net house+ GA₃ 200ppm | 0.188 | 2454.05 | 58.10 |
| C₂S₃ | Net house+ GA₃ 400ppm | 0.251 | 2576.77 | 59.30 |
| C₂S₄ | Net house+ GA₃ 600ppm | 0.339 | 2893.43 | 60.17 |
| C₂S₅ | Net house+ Thiourea 0.5% | 0.333 | 2454.47 | 58.02 |
| C₂S₆ | Net house+ Thiourea 1.0% | 0.227 | 2997.90 | 53.26 |
| C₃S₁ | Poly house+ Water soaking | 0.151 | 1990.09 | 48.73 |
| C₃S₂ | Poly house+ GA₃ 200ppm | 0.171 | 2904.84 | 49.47 |
| C₃S₃ | Poly house+ GA₃ 400ppm | 0.292 | 2986.00 | 49.50 |
| C₃S₄ | Poly house+ GA₃ 600ppm | 0.362 | 3178.08 | 62.23 |
| C₃S₅ | Poly house+ Thiourea 0.5% | 0.215 | 2758.67 | 53.33 |
| C₃S₆ | Poly house+ Thiourea 1.0% | 0.251 | 2013.55 | 51.33 |
| S.Em± | | | |
| C.D.5% level | 0.01 | 210.65 | 0.003 |
| C.D.5% level | 0.03 | 606.65 | 0.009 |
Table 4(A) Effect of growing conditions and seed treatment on LAI, LAD (cm\(^2\).day) and LTR (%) of aonla seedlings

| Treatments | LAI | LAD     | LTR    |
|------------|-----|---------|--------|
| **Growing conditions** |     |         |        |
| C\(_1\)     | 0.29| 5008.69 | 46.97  |
| C\(_2\)     | 0.30| 5041.79 | 45.21  |
| C\(_3\)     | 0.31| 5125.37 | 44.04  |
| S.Em±       | 0.002| 9.52 | 0.12   |
| C.D.5% level| 0.005| 27.41 | 0.34   |
| **Seed treatment** |     |         |        |
| S\(_1\)     | 0.27| 4758.87 | 49.93  |
| S\(_2\)     | 0.32| 5033.96 | 43.23  |
| S\(_3\)     | 0.29| 5033.62 | 47.58  |
| S\(_4\)     | 0.33| 5624.74 | 42.75  |
| S\(_5\)     | 0.31| 5040.02 | 44.41  |
| S\(_6\)     | 0.30| 4860.48 | 44.55  |
| S.Em±       | 0.002| 13.46 | 0.16   |
| C.D.5% level| 0.006| 38.77 | 0.48   |

(B) Interaction effect of growing conditions and seed treatment on LAI, LAD (cm\(^2\).day) and LTR (%) of aonla seedlings

| Treatments | LAI     | LAD     | LTR    |
|------------|---------|---------|--------|
| C\(_1\)S\(_1\) | 0.263| 4663.77 | 50.00  |
| C\(_1\)S\(_2\) | 0.320| 4772.60 | 40.92  |
| C\(_1\)S\(_3\) | 0.277| 5308.12 | 45.25  |
| C\(_1\)S\(_4\) | 0.313| 5417.10 | 46.47  |
| C\(_1\)S\(_5\) | 0.300| 5219.39 | 42.09  |
| C\(_1\)S\(_6\) | 0.320| 4869.75 | 45.51  |
| C\(_2\)S\(_1\) | 0.267| 4903.61 | 42.98  |
| C\(_2\)S\(_2\) | 0.323| 5198.15 | 44.63  |
| C\(_2\)S\(_3\) | 0.297| 4962.15 | 49.37  |
| C\(_2\)S\(_4\) | 0.330| 5672.13 | 44.00  |
| C\(_2\)S\(_5\) | 0.323| 5220.27 | 47.83  |
| C\(_2\)S\(_6\) | 0.297| 4795.89 | 46.21  |
| C\(_3\)S\(_1\) | 0.270| 4709.23 | 42.70  |
| C\(_3\)S\(_2\) | 0.303| 5131.12 | 42.71  |
| C\(_3\)S\(_3\) | 0.287| 4830.58 | 48.12  |
| C\(_3\)S\(_4\) | 0.347| 5785.00 | 30.67  |
| C\(_3\)S\(_5\) | 0.300| 4680.39 | 43.31  |
| C\(_3\)S\(_6\) | 0.297| 4915.81 | 41.91  |
| S.Em±       | 0.004| 23.32 | 0.28   |
| C.D.5% level| 0.011| 67.16 | 0.83   |
Table 5(A) Effect of growing conditions and seed treatment on energy interception (cal. cm\(^{-2}\) min\(^{-1}\)) and chlorophyll content index of aonla seedlings

| Treatments          | Energy Interception | Chlorophyll content index |
|---------------------|---------------------|---------------------------|
| **Growing condition** |                     |                           |
| C\(_1\) Open condition | 0.36               | 7.76                      |
| C\(_2\) Net house condition | 0.38           | 7.77                      |
| C\(_3\) Poly house condition | 0.41           | 8.18                      |
| S.Em±               | 0.01               | 0.04                      |
| C.D.5% level        | 0.03               | 0.12                      |
| **Seed treatment**  |                     |                           |
| S\(_1\) Water soaking | 0.32               | 7.49                      |
| S\(_2\) GA\(_3\) 200ppm | 0.38             | 7.87                      |
| S\(_3\) GA\(_3\) 400ppm | 0.39             | 7.98                      |
| S\(_4\) GA\(_3\) 600ppm | 0.47             | 8.23                      |
| S\(_5\) Thiourea 0.5% | 0.38              | 8.02                      |
| S\(_6\) Thiourea 1.0% | 0.35              | 7.88                      |
| S.Em±               | 0.01               | 0.06                      |
| C.D.5% level        | 0.04               | 0.17                      |

(B) Interaction effect of growing conditions and seed treatment on Energy Interception (cal. cm\(^{-2}\) min\(^{-1}\)) and chlorophyll content index of aonla seedlings

| C\(_1\)S\(_1\) Open condition+ Water soaking | 0.30 | 7.33 |
| C\(_1\)S\(_2\) Open condition+ GA\(_3\) 200ppm | 0.44 | 7.87 |
| C\(_1\)S\(_3\) Open condition+ GA\(_3\) 400ppm | 0.38 | 7.97 |
| C\(_1\)S\(_4\) Open condition+ GA\(_3\) 600ppm | 0.44 | 8.11 |
| C\(_1\)S\(_5\) Open condition+ Thiourea 0.5% | 0.38 | 7.49 |
| C\(_1\)S\(_6\) Open condition+ Thiourea 1.0% | 0.34 | 7.94 |
| C\(_2\)S\(_1\) Net house+ Water soaking | 0.33 | 7.42 |
| C\(_2\)S\(_2\) Net house+ GA\(_3\) 200ppm | 0.40 | 7.53 |
| C\(_2\)S\(_3\) Net house+ GA\(_3\) 400ppm | 0.44 | 7.79 |
| C\(_2\)S\(_4\) Net house+ GA\(_3\) 600ppm | 0.46 | 8.13 |
| C\(_2\)S\(_5\) Net house+ Thiourea 0.5% | 0.43 | 8.12 |
| C\(_2\)S\(_6\) Net house+ Thiourea 1.0% | 0.38 | 7.61 |
| C\(_3\)S\(_1\) Poly house+ Water soaking | 0.32 | 7.73 |
| C\(_3\)S\(_2\) Poly house+ GA\(_3\) 200ppm | 0.28 | 8.21 |
| C\(_3\)S\(_3\) Poly house+ GA\(_3\) 400ppm | 0.35 | 8.18 |
| C\(_3\)S\(_4\) Poly house+ GA\(_3\) 600ppm | 0.50 | 8.46 |
| C\(_3\)S\(_5\) Poly house+ Thiourea 0.5% | 0.33 | 8.44 |
| C\(_3\)S\(_6\) Poly house+ Thiourea 1.0% | 0.35 | 8.08 |
| S.Em±            | 0.02               | 0.10                      |
| C.D.5% level      | 0.07               | 0.30                      |
The findings are supported by Munde and Gajbhiye (2010), while maximum Light Transmission Ratio (LTR) 49.93 % was recorded in S1 (control). The minimum LTR 30.67 % was recorded under C3S4 (poly house and GA3 600 ppm) while, the maximum Light Transmission Ratio (LTR) 50.00 % was recorded under C1S1 (open condition and control).

**Energy Interception (EI)**

The data revealed that growing conditions and seed treatments significantly increased the Energy Interception (EI). As regards the growing conditions, maximum Energy Interception 0.41 cal. cm⁻² min⁻¹ was recorded under C3 (poly house) (Table 5).

While it was minimum 0.36 cal. cm⁻² min⁻¹ under C1 (open condition). Maximum Energy Interception 0.47 cal. cm⁻² min⁻¹ was recorded in S4 (GA3 600 ppm) treated seedling and minimum Energy Interception 0.32 cal. cm⁻² min⁻¹ was recorded under S1 (control).

The interaction of growing conditions and seed treatments showed significant effect on Energy Interception. The maximum Energy Interception 0.50 cal. cm⁻² min⁻¹ was recorded under C3S4 (poly house and GA3 400 ppm) which was found statistically at par with C2S4 (0.46 cal. cm⁻² min⁻¹), C2S3 (0.43 cal. cm⁻² min⁻¹), C2S1 (0.44 cal. cm⁻² min⁻¹), C1S4 (0.44 cal. cm⁻² min⁻¹), C1S2 (0.44 cal. cm⁻² min⁻¹) and minimum Energy Interception 0.30 cal. cm⁻² min⁻¹ was recorded under C1S1 (open condition and control). The probable reason may be that interception of light by a crop canopy is strongly related to total leaf area. A crop will thus intercept more PAR and hence grow faster if it develops leaf area rapidly. Our results are also in line of Maddonni and Otegui (1996).

**Chlorophyll content index**

The results revealed that among different growing conditions, maximum chlorophyll content index (8.18) was associated with C3 (poly house) while C1 registered minimum (7.76) CCI. Among different treatments, S4 (GA3 600 ppm) was found to have maximum (8.23) CCI. The S1 (control) exhibited the minimum (7.49) CCI. Among interactions, significantly maximum (8.46) CCI was noted in C3S4. The C1S1 registered minimum CCI (7.33).

On the basis of present investigation, it is concluded that among the various treatment combinations, C3S4 treatment combination (poly house and 600 ppm GA3) proved superior to rest of the treatment combinations with respect to growth parameters and Physiological Parameters like height of shoots, number of leaves per seedling, girth of stem, the fresh weight of shoots, dry weight of shoots, fresh weight of roots, dry weight of roots, Seedling vigour index I, Seedling vigour index II., Leaf Area Index, Leaf Area Duration, Light transmission ratio, Energy Interception and chlorophyll content index. However, among the growing conditions poly house and among the seed treatment GA3 (600ppm) were proved most promising as compare to others.

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