Int.J.Curr.Microbiol.App.Sci (2019) *8*(3): 1936-1948

International Journal of Current Microbiology and Applied Sciences
***ISSN: 2319-7706* Volume 8 Number 03 (2019)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2019.803.230

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

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Keywords

Indian gooseberry (*Emblica officinalis Gaertn*), GA_3 , Thiourea, Growing conditions-Open condition, Net house, Poly house condition

Article Info

Accepted:
15 January 2019
Available Online:
10 February 2019

A B S T R A C T

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. (C_1) Open condition, (C_2) net house, (C_3) poly house condition and six treatments of seed i.e. (S_1) water soaking, (S_2) GA_3 200 ppm, (S_3) GA_3 400ppm, (S_4) GA_3 600ppm, (S_5) Thiourea 0.5%, and (S_6) Thiourea 1% having 18 treatment combinations. Among the growing conditions poly house and among the seed treatment, GA_3 (600ppm) were proved most promising as compare to others. Among the various treatment combinations, the C_3S_4 treatment combination (poly house and 600 ppm GA_3) 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 cm^2.day), Light transmission ratio (30.67) and Energy Interception (0.50), recorded at 120 DAS were found to maximum in C_3S_4 treatment combination.

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 GA_3, Thiourea, KNO_3 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. (C_1) Open condition, (C_2) net house, (C_3) poly house condition and six treatments of seed i.e. (S_1) water soaking, (S_2) GA_3 200ppm, (S_3) GA_3 400ppm, (S_4) GA_3 600ppm, (S_5) Thiourea 0.5%, and (S_6) 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 fallowing 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 verneer 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 was 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 ^{0}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 ^{0}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 =

Germination percentage x [root length (cm) + 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),

$$\mathbf{LAI} = \frac{(LA_2 + LA_1) / 2}{P} \times 100$$

Where,

A_2+ A_1= Leaf area of two consecutive intervals

P= 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).

$$\mathbf{LAD} = \frac{LA_1 + LA_2}{2} \times t_2\text{-}t_1 \text{ cm}^2\text{.days}$$

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 Golinguai and Mabbayad (1969).

$$LTR = \frac{I}{I_0} \times 100$$

Where

I = Light intensity at the base of crop canopy and

I_0 = 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 in to average incident and transmitted energy on the basis of value reported by Gaastra (1963)

71 k.lux = 1 cal. Cm^{-2} min^{-1}

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

EI = Total incident energy – 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 C_3 (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 C_1 (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 S_4 (GA_3 600 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 S_1 (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 C_3S_4 (poly house condition and GA_3 600 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 C_1S_1 (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 GA_3. It might be due to GA_3 effect on elongation of internodes, as GA_3 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 GA_3. 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 GA_3 treatments may be due to the vigorous growth and more number of branches induced by GA_3 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 C_3 (poly house condition) and minimum fresh weight (2.89 g), dry weight (0.62 g) were noted in C_1 (open condition).The treatments significantly influenced the fresh and dry weight of shoot at 120 days after sowing. Among the treatments, S_4 (GA_3 600 ppm) recorded maximum (2.97 g) fresh weight and dry weight (0.67 g) of shoot followed by treatment. The treatment S_1 (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 C_3S_4 (poly house and GA_3 600 ppm). The minimum fresh weight (2.80 g) under treatment combination C_1S_1 (open condition and control). The minimum dry weight (0.59 g) was recorded under treatment combination C_1S_5 (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 GA_3, which promotes plant growth and development. Our results are also in line of Ratan and Reddy (2004), Gurung *et al.* (2014) (Table 2).

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 C_3 (poly house) and the minimum fresh weight (0.55 g) dry weight (0.15 g) were noted in C_1 (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, S_4 (GA_3 600 ppm) were found significant and it was maximum fresh weight (0.57 g) and dry weight (0.19 g). The treatment S_1 (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 C_3S_4 (poly house condition and GA_3 600 ppm) and the minimum fresh weight (0.52 g) and dry weight (0.12 g) under treatment combination C_1S_1 (open condition and control).

Increase in fresh weight of roots is due to the influence of GA_3 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 GA_3, 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 C_3 (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 C_1 (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 S_4 (GA_3 600 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 S_1 (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 C_3S_4 (poly house and GA_3 600 ppm). However, the minimum dry matter (0.13 g) was recorded under treatment combination C_2S_1 (net house and control). Seedling vigour index II (48.27 g) under C_1S_1 (open condition and control). 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 GA_3 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 cm^2.day) were recorded under C_3 (poly house). The minimum Leaf Area Index (LAI) (0.29) and Leaf Area Duration (LAD) (5008.69 cm^2.day) were recorded under C_1 (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 cm^2.day) were recorded at 120 days after sowing with S_4 (GA_3 600 ppm). Whereas, minimum Leaf Area Index (0.27) and Leaf Area Duration (LAD) (4758.87 cm^2.day) were recorded in S_1 (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 cm^2.day) were noted under treatment combination C_3S_4 (poly house and GA_3 600 ppm) while minimum Leaf Area Index (LAI) (0.26) and Leaf Area Duration (LAD) (4663.77 cm^2day) were noted under C_1S_1 (open condition and control). The increase of Leaf Area Index due to rich source of nutrient and presence of 600 ppm GA_3. 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 C_3 (poly house) whereas, maximum Light Transmission Ratio (LTR) 46.97 % was recorded under C_1 (open condition). As regards the seed treatment, the minimum LTR 42.75 % was noted under S_4 (GA_3 600 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				
C_1	Open condition	13.19	1.71	9.44	68.03
C_2	Net house condition	31.59	1.63	13.43	100.44
C_3	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				
S_1	Water soaking	25.08	1.61	11.30	87.39
S_2	GA_3 200ppm	26.45	1.68	12.41	90.12
S_3	GA_3 400ppm	26.30	1.71	11.89	89.97
S_4	GA_3 600ppm	27.39	1.76	13.01	92.97
S_5	Thiourea 0.5%	25.76	1.71	12.09	89.32
S_6	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					
C_1S_1	Open condition+ Water soaking	12.03	1.52	8.73	64.73
C_1S_2	Open condition+ GA_3 200ppm	12.84	1.72	10.00	69.30
C_1S_3	Open condition+ GA_3 400ppm	13.84	1.74	8.93	68.33
C_1S_4	Open condition+ GA_3 600ppm	14.58	1.77	11.20	72.40
C_1S_5	Open condition+ Thiourea 0.5%	13.34	1.68	9.00	66.57
C_1S_6	Open condition+ Thiourea 1.0%	12.51	1.70	8.77	66.83
C_2S_1	Net house+ Water soaking	31.04	1.65	12.93	99.20
C_2S_2	Net house+ GA_3 200ppm	31.70	1.58	13.33	100.60
C_2S_3	Net house+ GA_3 400ppm	31.67	1.67	13.27	100.53
C_2S_4	Net house+ GA_3 600ppm	32.45	1.71	13.87	103.07
C_2S_5	Net house+ Thiourea 0.5%	31.48	1.70	13.53	100.67
C_2S_6	Net house+ Thiourea 1.0%	31.16	1.61	13.67	100.20
C_3S_1	Poly house+ Water soaking	32.18	1.65	12.23	98.23
C_3S_2	Poly house+ GA_3 200ppm	34.81	1.73	13.90	100.47
C_3S_3	Poly house+ GA_3 400ppm	33.38	1.71	13.47	101.03
C_3S_4	Poly house+ GA_3 600ppm	35.14	1.80	13.97	103.73
C_3S_5	Poly house+ Thiourea 0.5%	32.44	1.75	13.73	100.43
C_3S_6	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				
C_1	Open condition	2.89	0.62	0.55	0.15
C_2	Net house condition	2.92	0.63	0.55	0.15
C_3	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				
S_1	Water soaking	2.85	0.61	0.53	0.14
S_2	GA_3 200ppm	2.93	0.63	0.56	0.15
S_3	GA_3 400ppm	2.89	0.63	0.55	0.14
S_4	GA_3 600ppm	2.97	0.67	0.57	0.19
S_5	Thiourea 0.5%	2.87	0.62	0.55	0.16
S_6	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					
C_1S_1	Open condition+ Water soaking	2.80	0.61	0.52	0.12
C_1S_2	Open condition+ GA_3 200ppm	2.92	0.62	0.55	0.15
C_1S_3	Open condition+ GA_3 400ppm	2.85	0.62	0.56	0.16
C_1S_4	Open condition+ GA_3 600ppm	2.94	0.63	0.57	0.19
C_1S_5	Open condition+ Thiourea 0.5%	2.86	0.59	0.56	0.17
C_1S_6	Open condition+ Thiourea 1.0%	2.92	0.62	0.56	0.16
C_2S_1	Net house+ Water soaking	2.84	0.59	0.54	0.14
C_2S_2	Net house+ GA_3 200ppm	2.94	0.62	0.56	0.16
C_2S_3	Net house+ GA_3 400ppm	2.84	0.64	0.55	0.13
C_2S_4	Net house+ GA_3 600ppm	2.98	0.68	0.57	0.18
C_2S_5	Net house+ Thiourea 0.5%	2.97	0.63	0.55	0.17
C_2S_6	Net house+ Thiourea 1.0%	2.97	0.63	0.56	0.13
C_3S_1	Poly house+ Water soaking	2.91	0.61	0.53	0.13
C_3S_2	Poly house+ GA_3 200ppm	2.92	0.65	0.55	0.14
C_3S_3	Poly house+ GA_3 400ppm	2.98	0.62	0.55	0.13
C_3S_4	Poly house+ GA_3 600ppm	3.00	0.69	0.59	0.21
C_3S_5	Poly house+ Thiourea 0.5%	2.79	0.64	0.54	0.14
C_3S_6	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			
C_1	Open condition	0.21	1825.04	51.92
C_2	Net house condition	0.24	2608.51	56.01
C_3	Poly house condition	0.25	2630.34	56.88
	S.Em±	0.004	86.00	0.001
	C.D.5% level	0.012	247.66	0.004
	Seed treatment			
S_1	Water soaking	0.15	1841.14	50.67
S_2	GA_3 200ppm	0.19	2350.09	55.11
S_3	GA_3 400ppm	0.24	2485.51	55.49
S_4	GA_3 600ppm	0.32	2641.62	60.20
S_5	Thiourea 0.5%	0.26	2402.35	54.83
S_6	Thiourea 1.0%	0.23	2407.07	53.31
	S.Em±	0.006	121.62	0.002
	C.D.5% level	0.017	350.25	0.005
(B) Interaction Effect of growing conditions and seed treatment on aonla seedlings				
C_1S_1	Open condition+ Water soaking	0.173	1308.08	48.27
C_1S_2	Open condition+ GA_3 200ppm	0.220	1691.39	57.77
C_1S_3	Open condition+ GA_3 400ppm	0.183	1893.77	57.67
C_1S_4	Open condition+ GA_3 600ppm	0.248	2033.53	58.20
C_1S_5	Open condition+ Thiourea 0.5%	0.218	1993.91	53.13
C_1S_6	Open condition+ Thiourea 1.0%	0.219	2029.59	57.93
C_2S_1	Net house+ Water soaking	0.132	2225.24	52.40
C_2S_2	Net house+ GA_3 200ppm	0.188	2454.05	58.10
C_2S_3	Net house+ GA_3 400ppm	0.251	2576.77	59.30
C_2S_4	Net house+ GA_3 600ppm	0.339	2893.43	60.17
C_2S_5	Net house+ Thiourea 0.5%	0.333	2454.47	58.02
C_2S_6	Net house+ Thiourea 1.0%	0.227	2997.90	53.26
C_3S_1	Poly house+ Water soaking	0.151	1990.09	48.73
C_3S_2	Poly house+ GA_3 200ppm	0.171	2904.84	49.47
C_3S_3	Poly house+ GA_3 400ppm	0.292	2986.00	49.50
C_3S_4	Poly house+ GA_3 600ppm	0.362	3178.08	62.23
C_3S_5	Poly house+ Thiourea 0.5%	0.215	2758.67	53.33
C_3S_6	Poly house+ Thiourea 1.0%	0.251	2013.55	51.33
	S.Em±	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	Open condition	0.29	5008.69	46.97
C_2	Net house condition	0.30	5041.79	45.21
C_3	Poly house condition	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	Water soaking	0.27	4758.87	49.93
S_2	GA_3 200ppm	0.32	5033.96	43.23
S_3	GA_3 400ppm	0.29	5033.62	47.58
S_4	GA_3 600ppm	0.33	5624.74	42.75
S_5	Thiourea 0.5%	0.31	5040.02	44.41
S_6	Thiourea 1.0%	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				
C_1S_1	Open condition+ Water soaking	0.263	4663.77	50.00
C_1S_2	Open condition+ GA_3 200ppm	0.320	4772.60	40.92
C_1S_3	Open condition+ GA_3 400ppm	0.277	5308.12	45.25
C_1S_4	Open condition+ GA_3 600ppm	0.313	5417.10	46.47
C_1S_5	Open condition+ Thiourea 0.5%	0.300	5219.39	42.09
C_1S_6	Open condition+ Thiourea 1.0%	0.320	4869.75	45.51
C_2S_1	Net house+ Water soaking	0.267	4903.61	42.98
C_2S_2	Net house+ GA_3 200ppm	0.323	5198.15	44.63
C_2S_3	Net house+ GA_3 400ppm	0.297	4962.15	49.37
C_2S_4	Net house+ GA_3 600ppm	0.330	5672.13	44.00
C_2S_5	Net house+ Thiourea 0.5%	0.323	5220.27	47.83
C_2S_6	Net house+ Thiourea 1.0%	0.297	4795.89	46.21
C_3S_1	Poly house+ Water soaking	0.270	4709.23	42.70
C_3S_2	Poly house+ GA_3 200ppm	0.303	5131.12	42.71
C_3S_3	Poly house+ GA_3 400ppm	0.287	4830.58	48.12
C_3S_4	Poly house+ GA_3 600ppm	0.347	5785.00	30.67
C_3S_5	Poly house+ Thiourea 0.5%	0.300	4680.39	43.31
C_3S_6	Poly house+ Thiourea 1.0%	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_1S_1	Open condition+ Water soaking	0.30	7.33
C_1S_2	Open condition+ GA_3 200ppm	0.44	7.87
C_1S_3	Open condition+ GA_3 400ppm	0.38	7.97
C_1S_4	Open condition+ GA_3 600ppm	0.44	8.11
C_1S_5	Open condition+ Thiourea 0.5%	0.38	7.49
C_1S_6	Open condition+ Thiourea 1.0%	0.34	7.94
C_2S_1	Net house+ Water soaking	0.33	7.42
C_2S_2	Net house+ GA_3 200ppm	0.40	7.53
C_2S_3	Net house+ GA_3 400ppm	0.44	7.79
C_2S_4	Net house+ GA_3 600ppm	0.46	8.13
C_2S_5	Net house+ Thiourea 0.5%	0.43	8.12
C_2S_6	Net house+ Thiourea 1.0%	0.38	7.61
C_3S_1	Poly house+ Water soaking	0.32	7.73
C_3S_2	Poly house+ GA_3 200ppm	0.28	8.21
C_3S_3	Poly house+ GA_3 400ppm	0.35	8.18
C_3S_4	Poly house+ GA_3 600ppm	0.50	8.46
C_3S_5	Poly house+ Thiourea 0.5%	0.33	8.44
C_3S_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 S_1 (control). The minimum LTR 30.67 % was recorded under C_3S_4 (poly house and GA_3 600 ppm) while, the maximum Light Transmission Ratio (LTR) 50.00 % was recorded under C_1S_1 (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 C_3 (poly house) (Table 5).

While it was minimum 0.36 cal. cm^{-2} min^{-1} under C_1 (open condition). Maximum Energy Interception 0.47 cal. cm^{-2} min^{-1} was recorded in S_4 (GA_3 600 ppm) treated seedling and minimum Energy Interception 0.32 cal. cm^{-2} min^{-1} was recorded under S_1 (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 C_3S_4 (poly house and GA_3 400 ppm**)** which was found statistically at par with C_2S_4 (0.46 cal. cm^{-2} min^{-1}), C_2S_5 (0.43 cal. cm^{-2} min^{-1}), C_2S_3 (0.44 cal. cm^{-2} min^{-1}), C_1S_4 (0.44 cal. cm^{-2} min^{-1}), C_1S_2 (0.44 cal. cm^{-2} min^{-1}) and minimum Energy Interception 0.30 cal. cm^{-2} min^{-1} was recorded under C_1S_1 (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 C_3 (poly house) while C_1 registered minimum (7.76) CCI. Among different treatments, S_4 (GA_3 600 ppm) was found to have maximum (8.23) CCI. The S_1 (control) exhibited the minimum (7.49) CCI. Among interactions, significantly maximum (8.46) CCI was noted in C_3S_4. The C_1S_1 registered minimum CCI (7.33).

On the basis of present investigation, it is concluded that among the various treatment combinations, C_3S_4 treatment combination (poly house and 600 ppm GA_3) 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 GA_3 (600ppm) were proved most promising as compare to others.

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How to cite this article:

Rinku Verma, C.S. Pandey, S.K. Pandey and Kumudani Sahu. 2019. Influence of Pre-Sowing Seed Treatment and Growing Conditions on Growth Performance of Indian Gooseberry Seedlings (*Emblica officinalis Gaertn). Int.J.Curr.Microbiol.App.Sci.* 8(03): 1936-1948.
doi: https://doi.org/10.20546/ijcmas.2019.803.230