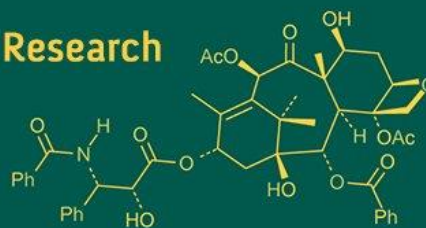
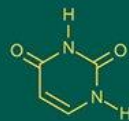
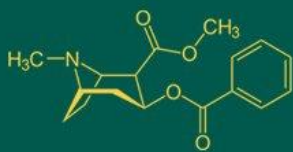


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Influence of gibberellic acid and bio-inoculants on germination, growth and root development of Aonla (*Emblia officinalis* Gaertn.) seedlings

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Abstract

The present investigation was undertaken to evaluate the influence of pre-sowing treatments with gibberellic acid (GA₃) and bio-inoculants on germination, seedling growth and root development of aonla (*Emblia officinalis* Gaertn.) under nursery conditions. The experiment comprised fourteen treatments, including GA₃ (200 and 500 ppm), *Azospirillum*, *Azotobacter*, phosphate-solubilizing bacteria (PSB), their consortium and an untreated control. Significant differences were observed among the treatments for germination, seedling growth and root attributes. Among the treatments, GA₃ @ 500 ppm for 24 h (T₅) exhibited the most pronounced response, recording the earliest initiation of germination (6.16 days), higher germination and superior performance for most seedling growth and root parameters. GA₃ @ 200 ppm for 24 h (T₄) ranked next, while among the bio-inoculants, *Azospirillum* @ 10 ml kg⁻¹ rooting media (T₇) showed a comparatively better response. The improved performance under GA₃ treatments may be attributed to enhanced metabolic activity, mobilization of seed reserves and stimulation of cell division and elongation. Overall, pre-sowing treatment with GA₃ @ 500 ppm for 24 h proved most effective for promoting germination and producing vigorous aonla seedlings under nursery conditions.

Keywords: Aonla, gibberellic acid, bio-inoculants, germination, seedling growth

Introduction

Aonla (*Emblia officinalis* Gaertn.), commonly known as Indian gooseberry, is an important indigenous fruit crop valued for its nutritional, medicinal and therapeutic properties. The fruit is a rich source of vitamin C, polyphenols, tannins, phenolic compounds, minerals and antioxidants, contributing substantially to its high nutraceutical value. Its hardiness, wide adaptability and tolerance to adverse soil and climatic conditions make it suitable for diverse agro-ecological regions (Singh and Pathak, 1987) [17]. However, the production of uniform and vigorous planting material is constrained by slow and erratic seed germination associated with the hard stony endocarp and physiological dormancy (Khan and Srivastava, 2013) [7].

Pre-sowing treatment with gibberellic acid (GA₃) helps overcome seed dormancy by stimulating hydrolytic enzyme activity, mobilizing stored reserves and promoting embryo growth, thereby improving germination and seedling vigour (Yamaguchi, 2008) [20]. Its beneficial effects on aonla seed germination and seedling development have also been reported by Chiranjeevi *et al.* (2017) [4]. Likewise, bio-inoculants such as *Azospirillum*, *Azotobacter* and phosphate-solubilizing bacteria (PSB) promote seedling growth through nitrogen fixation, phosphorus solubilization, improved nutrient availability and phytohormone production (Vessey, 2003) [18]. Therefore, the present investigation was undertaken to evaluate the influence of GA₃ and bio-inoculants on germination, growth, root development and seedling vigour of aonla under nursery conditions.

Material and Methods

The present investigation was conducted during 2025–26 at the Horticulture Nursery, Department of Fruit Science, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur (Chhattisgarh). The experiment was laid out in a Completely Randomized Design (CRD) comprising fourteen treatments with three replications and ten seeds per treatment per replication.

The treatments were T₀ = Control, T₁ = Water soaking for 24 hours, T₂ = Cow urine @ 5 ml/kg rooting media, T₃ = Cow urine @ 10 ml/kg rooting media, T₄ = GA₃ @ 200 ppm for 24 hours soaking, T₅ = GA₃ @ 500 ppm for 24 hours soaking, T₆ = *Azospirillum* @ 5 ml/kg rooting media, T₇ = *Azospirillum* @ 10 ml/kg rooting media, T₈ = *Azotobacter* @ 5 ml/kg rooting media, T₉ = *Azotobacter* @ 10 ml/kg rooting media, T₁₀ = PSB @ 5 ml/kg rooting media, T₁₁ = PSB @ 10 ml/kg rooting media, T₁₂ = bio-inoculant consortium @ 5 ml/kg rooting media and T₁₃ = bio-inoculant consortium @ 10 ml/kg rooting media. Healthy and uniform aonla seeds were sown in 15 × 20 cm polybags filled with soil, sand and well-decomposed FYM in a 2:1:1 ratio. Seeds under GA₃ and water-soaking treatments were soaked for 24 hours, while cow urine and bio-inoculants were mixed with the rooting media as per the respective treatments. One seed was sown per polybag and uniform cultural practices were followed throughout the experimental period. Observations were recorded on days taken to initiate germination, days taken to 50% germination, germination percentage, seedling height, number of leaves per seedling, collar diameter, root length, number of primary roots and number of secondary roots. Seedling height, number of leaves and collar diameter were recorded at 30, 60, 90 and 120 days, while root parameters were recorded at 120 days. The experimental data were subjected to analysis of variance (ANOVA) for CRD and treatment differences were tested for significance at the 5 per cent level.

Results and Discussion

Germination parameters

Days taken to initiate germination

As per the data presented in Table 1, the different treatments significantly influenced the time required for initiation of germination in aonla. The earliest germination (6.16 days) was recorded under T₅ (GA₃ @ 500 ppm for 24 hours soaking), which was statistically at par with T₄ (GA₃ @ 200 ppm for 24 hours soaking), recording 6.20 days, whereas the maximum time (10.27 days) was observed under T₀ (control). The reduction in germination time under GA₃ treatments might be attributed to enhanced enzymatic activity and rapid mobilization of stored food reserves, promoting embryo growth and seedling emergence. These findings are in close agreement with Lalitha *et al.* (2020) [10], Singh and Kaur (2021) [16] and Baby *et al.* (2022) [1], who also reported earlier germination and seedling emergence in aonla with GA₃ treatments.

Days taken to 50 per cent germination

Among the different treatments, T₅ (GA₃ @ 500 ppm with 24 hours soaking) recorded the shortest duration to attain 50 per cent germination (16.62 days) and was statistically at par with T₄ (GA₃ @ 200 ppm with 24 hours soaking), which recorded 16.91 days. In contrast, the longest duration (23.29 days) was observed under T₀ (control). The faster attainment of 50 per cent germination under GA₃ treatments might be attributed to enhanced enzymatic activity and efficient mobilization of stored food reserves, which stimulated embryo growth and promoted rapid and uniform germination. These findings are in close conformity with those of Dhankhar and Singh (1996) [5], Gholap *et al.* (2000) [6] and Chiranjeevi *et al.* (2017) [4], who also reported improved germination behaviour and earlier germination in aonla following GA₃ application.

Germination percentage (%)

Among the different treatments evaluated, T₅ (GA₃ @ 500 ppm with 24 hours soaking) exhibited the highest

germination percentage (91.11%), followed by T₄ (GA₃ @ 200 ppm with 24 hours soaking) (88.89%), while T₀ (control) recorded the lowest germination (55.56%). The superior germination observed with GA₃ application could be associated with its ability to overcome seed dormancy and activate hydrolytic enzymes, resulting in efficient utilization of stored food reserves and enhanced embryo development also documented by Kumari *et al.* (2007) [8], Laishramlilabati and Sahoo (2015) [9] and Lalitha *et al.* (2020) [10].

Seedling growth parameters

Seedling height (cm)

Seedling height increased progressively across the growth period and varied among the treatments. T₅ (GA₃ @ 500 ppm) recorded the maximum seedling height of 8.35, 10.26, 12.68 and 15.24 cm at 30, 60, 90 and 120 DAS, respectively. At 120 DAS, it was followed by T₇ (*Azospirillum* @ 10 ml/kg rooting media) with 14.96 cm and T₄ (GA₃ @ 200 ppm) with 14.83 cm, while the minimum (9.86 cm) was recorded under T₀ (control). The enhanced growth may be attributed to GA₃-induced cell division and elongation and improved nutrient availability and growth-promoting activity of *Azospirillum*. Similar findings were reported by Bhaduria *et al.* (2000) [2] and Rajamanickam and Anbu (2001) [14].

Number of leaves per seedling

The number of leaves per seedling increased progressively with seedling age and varied significantly among the treatments. T₅ (GA₃ @ 500 ppm with 24 hours soaking) recorded 4.60, 5.03, 8.00 and 10.20 leaves at 30, 60, 90 and 120 DAS, respectively, followed by T₄ (GA₃ @ 200 ppm) with 4.00, 5.01, 7.11 and 9.40 leaves, respectively. At 120 DAS, the minimum number of leaves (5.80) was recorded under T₀ (control). The increased leaf production under GA₃ treatment might be attributed to enhanced cell division, elongation and vigorous shoot development, resulting in greater leaf formation and expansion. Similar favourable effects of GA₃ on leaf production in aonla seedlings were reported by Bhujbal (1975) [3] and Wagh *et al.* (1998) [19].

Collar diameter (mm)

Collar diameter increased progressively with seedling growth and varied among the treatments. T₅ (GA₃ @ 500 ppm with 24 hours soaking) recorded the maximum collar diameter of 1.32, 1.75, 3.00 and 3.38 mm at 30, 60, 90 and 120 DAS, respectively, followed by T₄ (GA₃ @ 200 ppm) with 1.30, 1.73, 2.91 and 3.21 mm, respectively, while the minimum collar diameter (2.54 mm at 120 DAS) was observed under T₀ (control). The improvement under GA₃ treatments may be attributed to enhanced cell division, expansion and nutrient mobilization, promoting better stem development and biomass accumulation. Similar findings were reported by Mane *et al.* (2018) [11] and Manekar *et al.* (2011) [12].

Root growth parameters

Root length (cm)

Root development varied considerably among the treatments, with the maximum root length (14.39 cm) recorded under T₀ (control) at 120 DAS, followed by T₇ (*Azospirillum* @ 10 ml/kg rooting media) with 14.02 cm and T₅ (GA₃ @ 500 ppm with 24 hours soaking) with 13.80 cm. The greater root elongation observed in untreated seedlings might be associated with relatively greater allocation of assimilates towards root extension, whereas the favourable response under *Azospirillum* treatment could be attributed to improved nutrient availability and the production of growth-promoting substances in the rhizosphere. Similar beneficial effects of

bio-inoculants on root development and seedling growth were reported by Meena *et al.* (2018) and Raut *et al.* (2015) [13, 15].

Number of primary roots

The number of primary roots varied significantly among treatments, with the maximum (38.18) recorded under T₅ (GA₃ @ 500 ppm), followed by T₄ (GA₃ @ 200 ppm) with 34.82 roots. Among bio-inoculants, T₉ (Azotobacter @ 10 ml/kg rooting media) recorded 28.78 roots, while the minimum (13.78) was observed in the control. The improved root development under GA₃ may be attributed to enhanced cell division, elongation and mobilization of stored reserves, whereas bio-inoculants promoted root growth through improved nutrient availability and rhizospheric activity. These favourable physiological and nutritional effects might have stimulated greater root initiation and proliferation,

resulting in a more developed root system. Similar findings were reported by Meena *et al.* (2018) and Raut *et al.* (2015) [13, 15].

Number of secondary roots

The maximum number of secondary roots (49.77) was recorded under T₅ (GA₃ @ 500 ppm), followed by T₄ (GA₃ @ 200 ppm) with 47.62, while T₉ (Azotobacter @ 10 ml/kg rooting media) recorded 41.57. The increase in secondary roots may be attributed to enhanced cell division, root initiation and nutrient availability, promoting better root branching. Moreover, the favourable response to Azotobacter could be associated with improved nutrient mobilization and rhizospheric activity, supporting root proliferation. Similar improvement in secondary root development of aonla was reported by Wagh *et al.* (1998) [19].

Table 1: Effect of GA₃ and bio-inoculants on germination and root growth parameters of aonla (*Emblia officinalis* Gaertn.) seedlings

Notations	Treatments	Initiate germination	50 percent germination	Germination percentage	Root length at 120 DAS	Number of primary roots	Number of secondary roots
T0	Control	10.27	23.29	56.79	11.00	13.78	26.60
T1	Water soaking 24 hours	9.21	21.43	58.78	11.40	16.60	26.42
T2	Cow urine @ 5 ml/kg	8.14	20.18	63.91	12.20	15.41	27.25
T3	Cow urine @ 10 ml/kg	8.22	19.90	64.65	12.20	27.79	34.24
T4	GA ₃ @ 200 ppm 24 hours soaking	6.20	16.91	86.85	13.60	34.82	47.62
T5	GA ₃ @ 500 ppm 24 hours soaking	6.16	16.62	88.75	14.02	38.18	49.77
T6	Azospirillum @ 5 ml/kg	7.17	17.97	80.76	13.20	26.54	36.30
T7	Azospirillum @ 10 ml/kg	7.24	18.10	79.11	14.39	27.42	37.40
T8	Azotobacter @ 5 ml/kg	8.26	19.28	73.04	12.00	28.06	37.83
T9	Azotobacter @ 10 ml/kg	8.16	18.88	74.93	11.31	28.78	41.56
T10	PSB @ 5 ml/kg	9.30	21.67	70.91	11.41	23.57	34.37
T11	PSB @ 10 ml/kg	9.25	19.95	68.16	13.80	27.64	35.00
T12	Bio-inoculants consortium @ 5 ml/kg	8.22	20.08	77.78	13.40	27.42	36.40
T13	Bio-inoculants consortium @ 10 ml/kg	8.16	19.29	75.91	13.00	26.33	39.22
	SE(m) ±	0.07	0.20	0.84	0.39	0.96	1.31
	CD (5%)	0.20	0.59	2.27	0.49	2.85	3.8

Table 2: Effect of GA₃ and bio-inoculants on seedling growth parameters of aonla (*Emblia officinalis* Gaertn.) at different stages of growth

Notations	Treatments	Seedling height (cm)				Number of leaves				Collar diameter (mm)			
		30 DAS	60 DAS	90 DAS	120 DAS	30 DAS	60 DAS	90 DAS	120 DAS	30 DAS	60 DAS	90 DAS	120 DAS
T0	Control	4.62	5.71	7.22	9.86	2.20	4.81	4.95	5.80	1.12	1.46	2.04	2.54
T1	Water soaking 24 hours	5.42	7.15	8.56	12.88	3.20	4.41	5.25	6.40	1.14	1.58	2.18	2.67
T2	Cow urine @ 5 ml/kg	6.06	8.22	10.25	12.62	2.80	4.40	5.00	6.40	1.12	1.54	2.14	2.82
T3	Cow urine @ 10 ml/kg	5.88	7.25	10.08	11.82	2.80	4.20	6.00	6.80	1.14	1.70	2.21	2.66
T4	GA ₃ @ 200 ppm 24 hours soaking	7.24	8.25	11.62	14.96	4.00	5.01	7.11	9.40	1.30	1.73	2.91	3.21
T5	GA ₃ @ 500 ppm 24 hours soaking	8.35	10.26	12.68	15.24	4.60	5.03	8.00	10.20	1.32	1.75	3.00	3.38
T6	Azospirillum @ 5 ml/kg	6.72	8.68	10.52	13.42	3.20	3.81	6.60	7.60	1.22	1.60	2.24	2.82
T7	Azospirillum @ 10 ml/kg	6.92	8.76	10.82	14.83	3.59	4.85	6.00	7.00	1.14	1.62	2.24	2.84
T8	Azotobacter @ 5 ml/kg	7.17	8.01	11.13	13.75	3.39	4.75	5.80	7.40	1.28	1.54	2.26	2.70
T9	Azotobacter @ 10 ml/kg	6.83	8.05	10.85	12.26	3.39	4.43	5.80	7.00	1.10	1.64	2.20	2.88
T10	PSB @ 5 ml/kg	5.85	7.25	10.06	11.44	3.41	4.41	5.60	6.30	1.26	1.64	2.22	2.74
T11	PSB @ 10 ml/kg	5.96	7.42	11.55	12.18	3.43	4.43	5.37	6.40	1.26	1.62	2.30	2.99
T12	Bio-inoculants consortium @ 5 ml/kg	5.70	7.85	10.43	11.96	3.00	3.61	5.20	7.20	1.16	1.58	2.06	2.66
T13	Bio-inoculants consortium @ 10 ml/kg	6.96	8.22	10.92	12.18	3.59	3.40	6.80	7.80	1.14	1.54	2.18	2.80
	SE(m) ±	0.07	0.09	0.09	0.09	0.04	0.03	0.04	0.05	0.02	0.02	0.03	0.04
	CD (5%)	0.204	0.200	0.201	0.202	0.12	0.10	0.13	0.16	0.06	0.08	0.14	0.11

Conclusion

The present study demonstrated that pre-sowing treatments with GA₃ and bio-inoculants significantly improved germination and seedling growth of aonla. Among the treatments, GA₃ @ 500 ppm with 24 hours soaking (T₅) showed superior performance for most germination and growth parameters. It promoted faster germination, higher

germination percentage, greater seedling height, leaf production, collar diameter and enhanced root development. The improved response under GA₃ treatment may be attributed to enhanced physiological activity, efficient mobilization of stored reserves and stimulation of cell division and elongation. Bio-inoculants also improved seedling establishment and root development through better

nutrient availability and rhizospheric activity. GA₃ @ 200 ppm (T₄) also exhibited consistently favourable results. Overall, GA₃ @ 500 ppm with 24 hours seed soaking proved to be the most effective pre-sowing treatment for producing vigorous and well-established aonla seedlings under nursery conditions.

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