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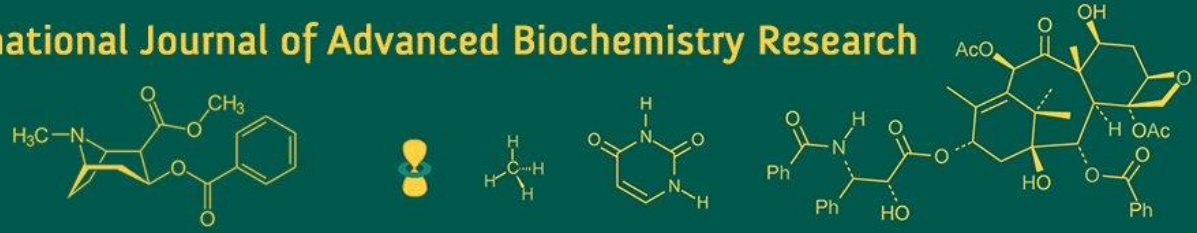

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Assessment of various plant growth substances on germination rates and seedling vigor in acid lime seedlings (*Citrus aurantifolia* Swingle) *Cv.* PDKV lime

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Abstract
The investigation entitled "Assessment of various plant growth substances on germination rates and seedling vigor in acid lime seedlings (*Citrus aurantifolia* Swingle) PDKV Lime" was carried out at All India Coordinated Research Project on fruits, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, during the years 2020-21 and 2021-22. The experiment was laid out in Randomized block design followed by pooled over-season analysis with fourteen treatments, including a check treatment, these treatments were replicated three times. The treatments included variations in concentrations and a combination of gibberellic acid, 6-benzyl adenine, brassinolide, and urea.
The results indicated significant variations among the treatments under shade net conditions. The least number of days for first germination (5.67 days), 50 percent germination (13.00 days), and complete germination (17.50 days) were observed. However, maximum values for germination percentage (96.83%), seed vigor index-I (1450.28), seed vigor index II (36.52), root length (7.31 cm), and shoot length (7.69 cm) was recorded with treatment T13 (GA3 50 ppm + 6 BA 25 ppm + Brassinolide 2 ppm).

Keywords: Acid lime, PGRs pre-soaking, germination, nursery seedlings

Introduction
Acid lime (*Citrus aurantiifolia* Swingle) is one of the most important commercially grown fruits in the tropical and subtropical regions of Maharashtra. Believed to have originated in India, it belongs to the family Rutaceae with a chromosome number of (2n =18) the potential of acid lime cultivars in our region presents a promising avenue for boosting both production and productivity in agriculture. However, it is crucial to recognize that the performance of these cultivars can exhibit significant variations influenced by factors such as cultivar type, geographical location, agro-climate, and soil characteristics.
The diverse growth and bearing habits, yield, color, and quality of different acid lime cultivars have been extensively documented by researchers like (Ranpise *et al.*, 1995) [8] across various regions in the country. The intervention of new generation growth promoters along with traditionally used growth regulation at an appropriate time, growth stage, and concentration could help the nurseryman to overcome the problems. At the many gibberellins, cytokinins like 6-benzyl adenine as well as steroid like brassinolide along with nitrogen source urea could be exploited for raising the nursery of acid lime in particularly as having various key roles in growth. Ensuring a supply of quality planting material becomes a prerequisite for farmers to realize potential yields, particularly with the looming threat of soil-borne diseases in acid lime cultivation. The production of disease-free planting material in the nursery serves as an initial defense against the introduction of diseases to the field.
Generally, seed germination is the common procedure for large-scale production of acid lime. Due to its recalcitrant nature, the seeds have to be sown immediately after extraction. Seed germination is one of the critical stages in nursery production. Some problems encountered in the process of producing acid lime seedlings include slow seed germination as well as the long period between the first and last seeds to germinate. The slow seed germination may be due to certain inhibitors in the seed coat, deficiency of some endogenous growth promoters, or excess of endogenous growth inhibitors. Therefore, the entire process of seed germination and seedling growth will be time-consuming, labor-intensive, and

increase the cost of production. A large number of plant growth regulators and chemicals in proper concentration may regulate growth behavior in many citrus crops and could lead to increased seed germination and enhancement of seedling growth. The germination behaviors, seedling height, number of leaves, and number of roots are affected by various pre-soaking treatments with growth regulators and chemicals like gibberellic acid, 6-benzyl adenine, brassinolide, and urea in different crop species (Rajamanickam *et al*., 2004) [7]. Application of gibberellin increases the plasticity of the cell wall and reduces water potential in the cell through the hydrolysis of starch to sugar, hence allowing entry of water into the cell which causes elongation. Plant hormones have the most important functions in controlling and coordinating cell division, growth, and differentiation.

Materials and Methodology

The present study was conducted at All India Coordinated Research Project on fruits, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, during the years 2020-21 and 2021-22. The field experiment was laid out in Randomized Block Design with three replications and fourteen treatments. Mature acid lime fruits were manually harvested from trees, and the seeds were carefully extracted by cutting the fruits and squeezing out the seeds. The extracted seeds were thoroughly washed with clean water and later spread on the clean floor in a thin layer under the shade, where they were dried for 1 to 2 days after the implementation of the treatment, seeds were initially soaked for 12 hours in the plant growth regulator solution corresponding to the treatment. This was followed by tying the seeds in muslin cloth impregnated with the same plant growth regulator solution for a duration of 12-16 hours. Similarly, the growth regulator solution was sprayed at 90 and 120 days after sowing, as specified by the treatment.

The seeds of acid lime were treated included variations in concentrations and combination of GA_3, 6-BA, Brassinolide, and urea the treatment were T_1: GA_3 - 50 ppm + Urea 1% (Check), T_2: GA_3 - 25 ppm, T_3: GA_3 - 50 ppm, T_4: 6-BA - 25 ppm, T_5: 6-BA - 50 ppm, T_6: Brassinolide - 2 ppm, T_7: Brassinolide - 4 ppm, T_8: GA_3 - 25 ppm + 6-BA - 25 ppm, T_9: GA_3 - 50 ppm + 6-BA - 50 ppm, T_{10}: GA_3 - 25 ppm + Brassinolide - 2 ppm, T_{11}: GA_3 - 50 ppm + Brassinolide - 2 ppm, T_{12}: GA_3 - 25 ppm +6-BA- 25 ppm + Brassinolide - 2 ppm, T_{13}: GA_3 - 50 ppm + 6-BA - 25 ppm + Brassinolide - 2 ppm, and T_{14}: Control.

Observations were recorded from five randomly selected and labeled saplings in each treatment. The days for first germination were recorded in days from the date of seed sowing to the first emergence of seedling, 50% percent germination was recorded as on that day when 50% seeds germinated out of seeds, and complete germination was recorded from the first day to till complete germination.

The data recorded were statistically analyzed by using the technique of analysis of variance as suggested by Panse and Sukhatme (1987) [5].

Germination percentage (%)

1. The germination count was recorded at weekly intervals.

$$\text{Germination (\%)} = \frac{\text{No. of germinated seeds}}{\text{Total No. of seeds sown}} \times 100$$

2. Seedling vigour index-I (SVI) = Germination percentage (%) × Seedling length (cm)
3. Seedling vigour index-II (SVI) = Germination percentage (%) × dry weight of seedlings (g)
4. Root shoot length measured, root and shoot part from each seedling (cm)

Results and Discussion

Days taken for first germination

The data of the present research work (Table 1) revealed that the plant growth substances showed a significant effect on seed germination characters for days taken to first germination (5.67 days), days taken for 50% germination (13.00 days), and complete germination (17.50 days) were recorded under treatment T_{13} (GA_3 - 50 ppm + 6 BA - 25 ppm + Brassinolide -2 ppm). The promoting of germination may be due to the antagonistic effect of different plant growth substances against the influence of inhibitors as reported by (Brian and Hemming, 1958 and Wareing *et al*., 1968) [1, 11] and endogenous gibberellin increased by soaking. These results are in accordance with the results obtained by Shinde *et al*., (2008) [9] in rangpur lime.

The results of the present investigation show that the germination parameter i.e. The maximum germination percentage (96.83%).

It might be due to the promoting antagonistic effect of different plant growth substances against the influence of inhibitors similarly findings by (Brain and Hemming, 1958 and Wareing *et al*., 1968) [1, 11] and endogenous gibberellin increased by soaking the involvement of gibberellic acid, 6-benzyl adenine, brassinolide, and urea this combination activation of cytological enzymes resulting in the production of energy and substrates, which in turn provide the structural components, essential for the growth and emergence of the embryo along with an increase in cell wall plasticity and better water absorption reflected in quick germination in the shortest time.

Seedling vigor index, and root shoot length

Seedling vigor index I (1450.28), seed vigor index-II (36.52), root length (7.31 cm), shoot length (7.69 cm).

This might be due to providing the structural components, essential for the growth and emergence of the embryo along with an increase in cell wall plasticity and better water absorption reflected in quick germination as well as root biomass can be developed and maintained by the sufficient supply of carbohydrates from shoots that overall growth of seedlings reflected in maximum seedling vigor. Similarly in positive effect on to emergence of new embryo initiation supported polyembryony percentage. The findings are supported by Burns and Coggnies (1969) [12] who reported the growth and uniformity of seedlings of sweet orange (Deepika *et al.* 2014 [2] in Karonda). Additionally, under controlled laboratory conditions, factors such as optimal moisture levels, temperature, and absence of wind disturbance create favorable conditions for the quick activation of embryos. Consequently, with the application of PGRs and conducive environmental factors, seeds often initiate germination more rapidly compared to seedlings grown under shade net conditions. This similar finding is supported by Kumar *et al*. (2008) [4] in mango and Patil *et al*. (2012) [6] in Rangpur lime.

Table 1: Effect of different plant growth substances on days taken for first germination to complete germination of acid lime seedlings under laboratory conditions.

Treatments	Days taken for first germination			Days taken for 50 percent germination			Days taken to complete germination			Germination percentage (%)		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
T_1	6.33	6.00	6.17	16.00	12.33	14.17	23.00	20.00	21.50	88.00 (70.06)	68.33 (72.37)	89.33 (71.04)
T_2	7.67	6.67	7.17	17.00	13.67	15.33	24.67	24.00	24.33	83.67 (66.59)	64.50 (67.93)	84.50 (67.25)
T_3	6.67	6.33	6.50	16.33	13.00	14.67	23.33	22.00	22.67	87.33 (69.28)	67.83 (71.92)	88.33 (70.09)
T_4	8.00	6.67	7.33	17.33	14.00	15.67	25.67	25.00	25.33	82.00 (65.21)	61.50 (67.41)	83.50 (66.07)
T_5	8.33	6.67	7.50	17.33	14.33	15.83	26.67	25.00	25.83	80.67 (64.12)	60.50 (66.86)	82.33 (65.44)
T_6	8.67	7.33	8.00	18.00	14.33	16.17	27.33	25.67	26.50	78.67 (62.87)	58.50 (65.31)	80.50 (64.04)
T_7	9.00	7.67	8.33	18.33	14.67	16.50	28.00	26.00	27.00	78.00 (62.50)	56.83 (64.82)	79.67 (63.64)
T_8	7.00	7.00	7.00	16.33	13.00	14.67	23.67	22.33	23.00	85.00 (67.58)	66.50 (70.19)	86.33 (68.78)
T_9	6.00	6.00	6.00	15.67	13.33	14.50	22.67	19.33	21.00	89.00 (70.95)	69.50 (73.45)	90.17 (71.76)
T_{10}	7.33	6.67	7.00	16.67	13.33	15.00	24.00	23.00	23.50	84.67 (67.32)	65.17 (68.54)	85.50 (67.88)
T_{11}	6.00	6.00	6.00	15.33	11.67	13.50	21.67	18.67	20.17	90.67 (72.69)	70.83 (77.25)	92.83 (74.81)
T_{12}	5.67	6.00	5.83	15.33	12.00	13.67	20.33	17.33	18.83	92.33 (75.38)	72.17 (78.62)	94.17 (76.68)
T_{13}	5.67	5.67	5.67	15.00	11.00	13.00	18.00	17.00	17.50	95.67 (78.49)	74.33 (82.05)	96.83 (80.10)
T_{14}	10.33	9.67	10.00	19.00	16.00	17.50	30.33	28.00	29.17	66.67 (54.77)	49.17 (57.52)	68.67 (56.08)
F test	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig
SE(m)	0.59	0.68	0.48	0.44	0.48	0.32	1.20	0.84	0.84	2.81	1.35	1.85
CD 5%	1.73	1.99	1.41	1.35	1.44	0.96	3.48	2.45	2.44	6.17	3.91	5.37

Table 2: Effect of different plant growth substances on seed germination and seedling vigour of acid lime seedlings under laboratory conditions.

Treatments	Seedling vigor index (SVI) - I			Seedling vigor index (SVI) - II			Root length (cm)			Shoot length (cm)		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
T_1	1164.70	1239.11	1201.91	26.20	28.34	27.27	6.18	6.59	6.38	6.78	6.87	6.83
T_2	1015.83	1079.56	1047.70	22.45	24.20	23.33	5.75	5.97	5.86	6.18	6.23	6.21
T_3	1132.56	1192.26	1162.41	24.98	27.19	26.09	6.07	6.44	6.25	6.59	6.68	6.64
T_4	991.22	1071.72	1031.47	22.07	23.75	22.91	5.71	5.96	5.83	6.15	6.20	6.18
T_5	950.33	1017.65	983.99	19.26	22.85	21.06	5.45	5.61	5.53	6.11	6.16	6.14
T_6	910.37	990.70	950.54	18.85	21.37	20.11	6.51	6.78	6.64	6.00	6.05	6.03
T_7	878.09	942.14	910.12	18.42	20.38	19.40	6.62	6.81	6.71	5.94	5.99	5.97
T_8	1080.77	1156.11	1118.44	24.53	26.36	25.45	6.04	6.38	6.21	6.48	6.57	6.53
T_9	1216.52	1274.56	1245.54	26.32	28.92	27.62	6.31	6.64	6.48	7.05	7.14	7.10
T_{10}	1048.26	1107.96	1078.11	23.53	25.11	24.32	6.38	6.69	6.54	6.22	6.27	6.25
T_{11}	1260.97	1347.46	1304.22	27.71	32.07	29.89	6.72	6.89	6.81	7.21	7.30	7.26
T_{12}	1337.89	1426.48	1382.19	32.13	34.88	33.51	7.09	7.33	7.21	7.46	7.53	7.50
T_{13}	1418.12	1482.44	1450.28	35.13	37.91	36.52	7.21	7.41	7.31	7.65	7.72	7.69
T_{14}	751.74	802.21	776.97	13.83	16.74	15.29	5.32	5.41	5.36	5.93	5.98	5.96
F test	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig
SE(m)	39.15	37.64	28.27	2.57	2.18	1.32	0.08	0.006	0.042	0.20	0.15	0.12
CD 5%	113.46	109.07	81.94	7.47	6.34	3.84	0.24	0.019	0.12	0.59	0.44	0.36

Conclusion

From the above both years of investigation, it can be concluded that in treatment T_{13} was found to be best for all germination-related attributes and significantly took less time for germination, least span of time for first germination, 50% germination, complete germination and for maximum germination percentage (%). The combination of this treatment was effectively useful for maximum germination percent, seedling height, and overall growth of seedlings. Therefore, the present study will be helpful to the farmers for the cultivation of these important fruit crops as well as the commercialization of acid lime nurseries.

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