The Pharma Innovation Journal 2022; 11(5): 2542-2546

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(5): 2542-2546
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www.thepharmajournal.com
Received: 01-02-2022
Accepted: 09-03-2022

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Effect of chemical priming on seed germination and seedling growth in papaya (*Carica papaya* L.)

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Abstract
The present investigation was conducted in controlled glasshouse conditions during October 2021 to March 2022. The experiment was performed on papaya varieties Red Lady and Pusa Delicious. Nine seed pre-treatments, *viz*., T_1 Control- double-distilled water), T_2 (GA_3 @ 100 ppm), T_3 (GA_3@ 200 ppm), T_4 (kinetin @ 50 ppm), T_5 (kinetin @ 100 ppm), T_6 (potassium nitrate @ 1000 ppm), T_7 (potassium nitrate @ 2000 ppm), T_8 (thiourea @ 1000 ppm), and T_9 (thiourea @ 2000 ppm) soaked for 48 h, replicated thrice in factorial randomized block design (FRBD). The seeds were sown in sand: soil: vermiculite: perlite (2:1:1:1) and maintained under controlled glasshouse conditions. Pre-treatment of papaya seeds with thiourea @ 1000 ppm in var. Red Lady was found to be superior in terms of days to 50% germination (16.21), germination (96.00%), attaining plant height (8.64 cm), stem girth (1.83 mm) at 75 days of sowing, length of primary root (6.96 cm), root thickness (0.28 mm), average leaf area (42.42 cm^2), total chlorophyll (6.39 mg/g FW), and total phenols (14.84 mg/g FW). On the basis of the above results, it is concluded that the pre-treatment of seed in thiourea @ 1000 ppm in var. Red Lady and GA_3 @ 100 ppm in Pusa Delicious were found most effective for enhancing seed germination when raised under controlled glasshouse conditions during winter months.

Keywords: Papaya, red lady, Pusa delicious, gibberellic acid, kinetin, potassium nitrate, thiourea

Introduction
Papaya (*Carica papaya* L.) is an important fruit crop of tropical and sub-tropical it belongs to the family Caricaceae and it is a small dicotyledonous family consisting of 6 genera and 35 species. Papaya is generally propagated by seed (Cheema and Dani, 1990) [10]. The germination of papaya seeds is generally reported to be slow, erratic and is incomplete (Chako and Singh, 1966) [9]. The role of seed pre-treatment helps in relation to break dormancy, germination improvement, reduction of germination time and increases seed germination and reduce losses from late plantation in papaya. Pre-treatment of seeds is a simple technique that is a low-cost and low-risk solution to improve seed germination process and subsequent effect on seedling growth, plant growth and development.
At nursery stage, the germination in Red Lady papaya seeds is faced with certain problems mainly high seedling mortality due to soil borne diseases. In heavy soils, root development becomes suppressed and also the plants are susceptible to soilborne diseases. Incomplete germination and high mortality rate reduce the survival of papaya seedlings. Collar rot is a serious problem at seedling stage and mosaic leaf curl and mites are also very destructive at the flowering stage of plants. The best time for raising seedlings is the middle of June to the end of October and March-April under sub-tropical conditions. Sowing after this period is not satisfactory due to lowering of temperature during winter season (Cheema and Dani, 1990) [10]. However, occurrence of frost is common in north India during December-January, which limits successful papaya cultivation. Therefore, keeping the above points in view the present studies was carried out so that quality seedlings could be produced in glasshouse for early sowing in spring.

Materials and Methods
The experiment was conducted in controlled glasshouse conditions with temperature ranging from 20-24^{0}C, relative humidity ranging from 75-80%, with supplemental light intensity 69 µmol m^{-2} s^{-1} under 16/8 h light and dark photoperiod at ICAR-Indian Agricultural Research Institute, New Delhi during October 2021-March, 2022.

The experimental glasshouse is situated at an elevation of 228.61 m above mean sea level at 28.6139^0 North latitude and 77.2090^0 East longitude and average rainfall of 617 mm. The experiment was laid out in Factorial Randomized Block Design (FRBD) having nine treatments, *viz.*, T_1 Control: Double-distilled water, T_2: GA_3 @ 100 ppm, T_3: GA_3 @ 200 ppm, T_4: kinetin @ 50 ppm, T_5: kinetin @ 100 ppm, T_6: potassium nitrate @ 1000 ppm, T_7: potassium nitrate @ 2000 ppm, T_8: thiourea @ 1000 ppm, and T_9: thiourea @ 2000 ppm with three replications of two gynodioecious varieties of which the seeds were soaked in different solutions for 48 h. All the treated seeds were sown at a depth of 2.0-2.5 cm in plastic pro-trays containing sand, soil treated with *Trichoderma*, vermiculite and perlite in 2:1:1:1 ratio then covered with sand and irrigated immediately after sowing. The data were collected on seed germination and seedling growth parameters like days to 50% germination, germination (%), plant height and stem girth at 75 days of sowing and seedling vigour index and in physio-biochemical parameters such as average leaf area, net photosynthetic rate, total phenols and leaf chlorophyll content. The statistical analysis of the data, which were collected for nine treatments having three replications were subjected to factorial randomized block design using Statistical Analysis System (ver. 8.2) to determine significant difference and comparison of means at a significance level of 5%.

Results and Discussion

Seed germination and growth parameters

The results revealed that early seed germination (16.21 days) was recorded in the combination T_8 x Red Lady, while it was most delayed in the interaction treatment T_1 x Pusa Delicious (40.32 days). The maximum seed germination (96.00%) was recorded in the treatment combination T_8 x Red Lady minimum was recorded in the interaction T_1 x Pusa Delicious (70.85%). Pre-treatment or seed priming has been shown to enhance seed germination in papaya. An intermediate category of seed has been identified (Ellis *et al.* 1991) [13]. Dipping in aqueous solutions provided the necessary trigger in early emergence of plumule and radicle. Efficacy of thiourea in inducing early seed germination has earlier been shown by Babu *et al.* (2010) [6] and Kumawat *et al.* (2014) [14] in papaya.

The maximum plant height at 75 days of sowing (8.64 cm) was recorded in the interaction T_8 x Red Lady, while minimum in the interaction T_1x Pusa Delicious (4.69 cm). The maximum papaya seedling stem girth at 75 days of sowing (1.83 mm) was recorded in T_8 x Red Lady minimum in the interaction T_1x Pusa Delicious (0.98 mm).The height of seedling increased with the age due to cell division and cell elongation, which in turn would lead to increase in the internodal length (Anjanawe *et al.* 2013) [2] under all the treatments including control. At all the stages of seedling, application of thiourea 1000 ppm resulted in the maximum seedling height, which was significantly better compared to rest of the treatments. Efficacy of gibberellic acid could be due better cell elongation which has also been reported by several workers (Saraswat *et al.* 2013; Sharma *et al.* 2018; Rana *et al.* 2020) [21, 22, 19].

The maximum length of primary root (6.96 cm) was recorded in T_8 x Red Lady combination, while minimum was recorded in the interaction T_1 x Red Lady (2.03 cm). The maximum mean root thickness (0.28 mm) was recorded in T_8 x Red Lady while it was most delayed in the interaction T_1 x Pusa Delicious (0.09 mm). Among the different treatments of pre-soaking chemicals, the maximum root length was observed under the plants treated with thiourea and potassium nitrate, which might be due to the efficient photosynthesis, thereby the photosynthates are translocated through phloem to the root zone might be responsible for increasing the root length. Similar results were obtained in accordance with present results by Dabhi *et al.* (2000) [10]; Ratan and Reddy (2004) [10]; Anburani and Shakila (2010) [10]; Patil *et al.* (2012) [17]; Bhardwaj (2013) [8]; Arvind *et al.* (2015) [4]; and Rakibuzzaman *et al.* (2018) [18] in papaya.

Seed vigour index-I was calculated for all the seed priming treatments. The maximum seedling vigour index-I value (1314.33) was recorded in T_8 x Red Lady, while the minimum value (515.30) was recorded in interaction T_1 x Pusa Delicious. On similar lines, Anburani and Shakila (2010) obtained higher vigour indices (1826 and 1668) due to GA_3 and thiourea treatments. While, Chumpookam *et al.* (2012) [11] using smoke-water soaking obtained very high index value (38650) for papaya seedlings.

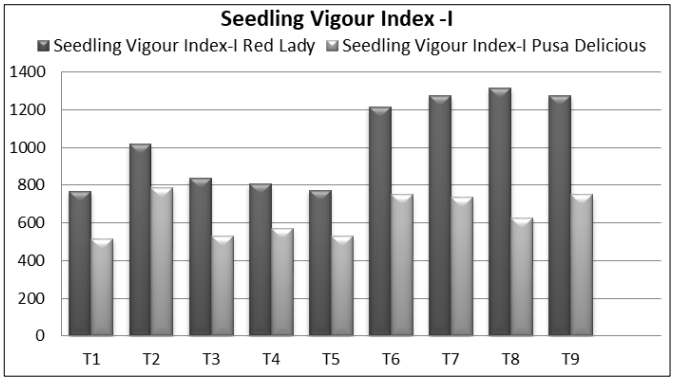

Fig 1: Effect of different chemical priming on seedling vigour index-I in papaya.

Physio-biochemical parameters

The maximum leaf area (42.42 cm^2) was recorded in T_8 x Red Lady, while minimum was recorded in the interaction T_1 x Pusa Delicious (30.51 cm^2). Thiourea is known to induce good foliar growth in custard apple (Ratan and Reddy, 2004) [20]. Leaf area enhancement in papaya due to seed priming had earlier been reported by Barche *et al.* (2010) [7], Anjanawe *et al.* (2012) [2], and Palepad *et al.* (2017) [15]. The maximum photosynthesis in leaf (18.65 µmol CO_2 $m^{-2}s^{-1}$) was recorded in the interaction T_8 x Red Lady minimum was recorded in the interaction T_1x Pusa Delicious (15.43 µmol $CO_2m^{-2}s^{-1}$). Environmental factors significantly affect the photosynthetic processes in papaya and also give better understanding of different environmental factors and their interaction with physiological processes. Therefore, a deeper understanding about the effects of such environmental factors over the physiological processes is of extreme importance, since it will allow us to trace strategies for managing them and will optimize the effects of these factors in relation to the seedling growth and development.

The maximum total leaf chlorophyll (6.39 mg/g FW) was recorded under treatment T_8 (thiourea @ 1000 ppm) in var. Red Lady, while minimum values were recorded (4.21 mg/g FW) in T_1 (control). The maximum total phenolics content in leaf (14.84 mg/g FW) was recorded in T_8 x Red Lady

compared to minimum in the interaction T_1 x Pusa Delicious (9.90 mg/g FW). A significant increase in the phenolics content was noted due to low temperature stress treated papaya plants, which may be due to decrease in the relative water content of leaves. Earlier, it has been noted that increase in the leaf soluble protein content in cucumber, which could be attributed to the same reason leading to the decrease in leaf relative water content along with higher protein accumulation (Anuprarthana *et al*., 2018) [3]. Application of chemical pre-treatments in papaya enhanced the leaf chlorophyll content, which led to increase in nitrogen content in leaf of seedlings due to stimulated nutrient uptake thereby enhancing the bio-synthesis of chlorophyll having a role in the assimilation of numerous amino acids that are subsequently incorporated in proteins and nucleic acid. These components, provide framework for chloroplast bio-synthesis resulting into better leaf chlorophyll content (Awasthi *et al.*, 1996; Chumpookam *et al.*, 2012; Kumawat *et al.*, 2014) [5, 11, 14]. The seedling obtained after pre-treatments were healthy and fit for early transplantation during spring.

Table 1: Effect of different chemicals on days to 50% seed germination and germination percentage in papaya

Treatment	Days to 50% germination			Germination (%) at 50 DOS		
	Red Lady	Pusa Delicious	Mean	Red Lady	Pusa Delicious	Mean
T_1	38.21	40.32	39.25	83.32(52.71)*	70.85(57.29)	77.08
T_2	22.14	28.24	25.13	93.30(75.00)	84.65(66.89)	88.97
T_3	26.13	31.73	28.95	93.35(75.05)	82.88(65.50)	88.11
T_4	27.52	32.14	29.84	86.60(68.53)	74.83(59.87)	80.71
T_5	31.41	35.85	33.63	83.30(65.88)	83.45(65.96)	83.37
T_6	20.62	29.12	24.81	90.00(71.56)	84.23(66.58)	87.11
T_7	17.12	32.33	24.74	95.00(77.08)	76.16(60.73)	85.58
T_8	16.21	30.24	23.25	96.00(78.46)	82.75(65.42)	89.37
T_9	16.43	29.03	22.71	90.00(71.56)	82.35(65.05)	86.17
Mean	24.94	32.52		90.10	79.97	
CD at 5%						
Treatment			0.90			0.945
Variety			0.41			0.445
T x V			1.21			1.337

T1: Control (double-distilled water), T2: GA_3@ 100 ppm, T3: GA_3@ 200 ppm, T4: Kinetin @ 50 ppm, T5: Kinetin @ 100 ppm, T6: Potassium nitrate @ 1000 ppm, T7: Potassium nitrate @ 2000 ppm, T8: Thiourea @ 1000 ppm, T9: Thiourea @ 2000 ppm, T x V= Treatment x Variety.*Arc Sin √% transformed values.

Table 2: Effect of different chemicals on plant height, stem girth, length of primary root and root thickness in papaya (at 75 days of sowing)

Treatment	Av. leaf area (cm^2)			Net photosynthetic rate (*A*)			Total chlorophyll (µg/g FW)			Total phenols (mg/g FW)		
	Red Lady	Pusa Delicious	Mean	Red Lady	Pusa Delicious	Mean	Red Lady	Pusa Delicious	Mean	Red Lady	Pusa Delicious	Mean
T1	32.45	30.51	31.48	16.22	15.43	15.82	5.23	4.21	4.72	12.30	9.90	11.10
T2	37.51	37.45	37.48	17.43	17.66	17.54	6.13	6.05	6.09	13.26	12.95	13.12
T3	36.43	36.30	36.36	17.26	16.77	17.01	6.08	5.23	5.65	12.94	11.15	12.03
T4	35.53	32.43	33.98	16.48	16.51	16.49	6.05	4.34	5.19	12.85	10.25	11.50
T5	34.86	36.33	35.59	16.32	17.52	16.91	6.04	5.92	5.98	12.47	11.37	11.92
T6	39.24	37.44	38.34	18.56	17.43	17.41	6.20	5.97	6.08	14.10	11.75	12.90
T7	39.84	33.44	36.64	18.45	16.44	17.54	6.30	4.42	5.36	13.65	10.24	11.93
T8	42.42	35.42	38.92	18.65	16.54	17.99	6.39	5.61	6.00	14.84	11.15	12.94
T9	41.48	34.57	38.02	18.29	16.37	17.39	6.34	5.56	5.95	13.26	11.05	12.15
Mean	37.28	34.91		17.40	16.78		6.05	5.21		13.30	11.09	
CD at 5%												
Treatment			1.22			1.07			0.01			0.71
Variety			0.57			0.50			0.005			0.33
T x V			1.73			1.52			0.01			1.00

Table 3: Effect of different chemicals on papaya seedling physiological parameters in papaya seedlings (at 75 days of sowing)

Treatment	Plant height (cm)			Stem girth (mm)			Length of primary root			Root thickness		
	Red Lady	Pusa Delicious	Mean	Red Lady	Pusa Delicious	Mean	Red Lady	Pusa Delicious	Mean	Red Lady	Pusa Delicious	Mean
T_1	5.74	4.69	5.21	1.21	0.98	1.09	2.03	2.11	2.07	0.10	0.09	0.09
T_2	6.94	5.38	6.16	1.51	1.27	1.39	4.83	5.11	4.97	0.10	0.18	0.14
T_3	6.24	5.22	5.73	1.43	1.19	1.31	3.73	4.08	3.90	0.10	0.15	0.12
T_4	6.33	4.81	5.57	1.37	1.08	1.22	3.56	2.16	2.86	0.13	0.10	0.11
T_5	6.07	5.30	5.68	1.26	1.21	1.23	2.36	4.11	3.23	0.10	0.17	0.13
T_6	7.35	5.34	6.34	1.63	1.22	1.42	6.16	4.48	5.32	0.23	0.17	0.20
T_7	7.69	4.95	6.32	1.71	1.11	1.41	5.71	2.19	3.95	0.19	0.12	0.15
T_8	8.64	5.14	6.89	1.83	1.14	1.48	6.96	3.95	5.45	0.28	0.13	0.20
T_9	7.38	5.02	6.21	1.72	1.13	1.42	6.76	3.82	5.29	0.24	0.11	0.17
Mean	6.87	5.10		1.49	1.15		4.41	3.52		0.15	0.13	
CD at 5%												
Treatment			0.87			0.01			0.98			0.04

Variety			0.41			0.06			0.46			0.02
T x V			1.23			0.02			1.39			0.06

Conclusion

The results from the present investigation concluded that seed primed with chemicals, *i.e.* thiourea @ 1000 ppm in var. Red Lady and GA_3 @ 100 ppm for var. Pusa Delicious induced overall beneficial effect on the seedlings compared control. On comparison amongst two varieties with regard to seed germination and seedling vigour parameters, Red Lady was found to be superior to Pusa Delicious.

Acknowledgements

Authors are thankful to the Director, ICAR-NBPGR, New Delhi and ICAR-IAR, New Delhi for providing the laboratory and glasshouse facilities.

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