Article AR1967

DOI: HTTPS://DOI.ORG/10.23910/IJBSM/2019.10.2.1967

International Journal of Bio-resource and Stress Management

April 2019

Print ISSN 0976-3988
Online ISSN 0976-4038

IJBSM 2019, 10(2):128-136

Research Article *Natural Resource Management*

Influence of Seed Priming on Germination and Seedling Vigour of Wood Apple (*Feronia limonia* Swingle)

Sayan Sau[1,2]*, Binayak Pal[2], Sukamal Sarkar[3] and Tanmoy Sarkar[2]

[1]Purba Medinipur Krishi Vigyan Kendra, BCKV, Mulakhop, Dayaldasi, Nandakumar, East Medinipur, W.B. (721 632), India
[2]Dept. of Fruits and Orchard Management, [3]Dept. of Agronomy, BCKV, Mohanpur, W.B. (741 252), India

Open Access

Corresponding Author
Sayan Sau
e-mail: sayan.bckv@yahoo.com

Citation: Sau et al., 2019. Influence of Seed Priming on Germination and Seedling Vigour of Wood Apple (*Feronia limonia* Swingle). International Journal of Bio-resource and Stress Management 2019, 10(2):128-136. HTTPS://DOI.ORG/10.23910/IJBSM/2019.10.2.1967

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Conflict of interests: The authors have declared no conflict of interests exist.

Abstract

The present experiment was conducted to study the influence of seed priming treatments on germination and seedling vigour of wood apple (*Feronia limonia* Swingle) at Horticulture experimental and learning unit, Faculty of Horticulture, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal, India (22°5643''N, 88°32'03 ''E and 397 m above mean sea level) during December to June of 2016-2017. The treated seeds were raised on polythene bags under shade net house (covered with 200-micron thickness polythene shade net) condition to avoid climatic irregularities. The experiment was laid out in a completely randomized design comprising eight treatments (GA_3 50 ppm and 100 ppm, KNO_3 50 ppm and 100 ppm, Thiourea 50 ppm and 100 ppm, water soaking, and directly sown seed i.e. control) and replicated for five times. The result of the present investigation revealed that amongst the different concentrations of used chemicals, GA_3 100 ppm was most efficient to ensure the maximum germination percentage (81.67%) which was 96.01% higher than the control. Similar trend of obtaining highest values from GA_3 treated seed on most of the seedling growth parameters was also observed such as highest seedling height (442.23 mm), shoot (2.51 mm) and root diameter (3.22 mm), leaf number (12.00), seedling fresh (2.14 g) and dry weight (1.01 g), leaf chlorophyll content [chlorophyll a (78.51 mg g^{-1} FW), chlorophyll b (98.70 mg g^{-1} FW) and total chlorophyll (135.70 mg g^{-1} FW), respectively] and leaf nitrogen (3.40%) and potassium content (3.42%).

Keywords: Wood apple, germination, seed priming, seedling vigour

1. Introduction

Wood apple (*Feronia limonia* Swingle), the only species of genus *Feronia* (family Rutaceae), is one of the most medicinally rich underutilized fruit. Though, India and Sri Lanka is considered as native place of wood apple, well-managed orchard is rare in both the countries but road side and field-edge planting is common. With the passage of time, cultivation of wood apple spread over Southeast Asia, including northern Malaysia and Penang Island (Hossain et al., 1994; Islam et al., 2006). Dual purpose use of wood apple *i.e.* raw as well as processed products makes it more economically preferred commodity. Pulp of wood apple is loaded with immense quantity of medicinally important compounds like umbelliferol, dictamnine, xanthotoxol, sco-parone *etc*. those could be used in the pharmaceuticals industries. From ancient time, in India the ripe fruits are used as a liver and cardiac tonic, while unripe ones as an astringent for

Article History
RECEIVED in 18th March 2019 RECEIVED in revised form 11th April 2019 ACCEPTED in final form 18th April 2019

checking diarrhoea and dysentery. In addition, the fruits serve as effectual treatment for sore throat, hiccough, and diseases of the gums (O'Neill and Lewis, 1993). The fruit pulp is also used for the preparation of chutney, fruit bar, jam, jelly, and ready-to-serve beverages (Vidya and Narain, 2011).

Seed propagation in fruit plants are well acknowledged where seed is the only means of multiplication. Though, commercial method of propagation in wood apple is chiefly through seeds, vegetative propagation by budding, cutting, softwood grafting (Raghavendra et al., 2011), and inarching is also successful. Nevertheless, decline in seed viability is noticed within a very short period following its (seed) extraction from fresh fruits of wood apple. As a consequence, low seed viability along with poor germination is encountered as a severe menace during commercial cultivation of wood apple. Such low viability coupled with poor germination occurs presumably due to the physiological event of low metabolic activity referred as 'dormancy' or 'quiescence' that is associated with hard seed coat, immature embryo or with the result of endogenous chemical germination inhibitors (Wareing and Phillips, 1981; Sharma et al., 2014).

Multiple researches have been conducted on pre-germination treatments of seeds with different seed priming chemicals (GA_3, KNO_3, thiourea, salicylic acid, hot water as well as cow dung slurry) in different fruit crops like custard apple, passion fruit, fig, yoshino cherry, papaya *etc* (Farooq et al., 2005; Basra et al., 2007; Kim, 2019). These chemicals and multiple other seed priming treatments improve seed germination and seedling growth mainly by reducing internal growth inhibitor content (Agrawal and Dadlani, 1995; Hassini et al., 2017) and increasing the growth promoter concentration in seed; improving entry of water into the cell (Arteca, 1996; Sharma et al., 2014) and improving enzymatic activity to initiate several metabolic processes (Maiti et al., 2011).

In breeding programmes, wood apple seeds are the key component for developing hybrid plants to enrich genetic diversity, and to produce quality rootstock plant (Morton, 1987). It has been proven that seed priming is one of the competent approaches to obtain uniform and healthy seedling but exhaustive information of this approach in wood apple is still scarce. Keeping these facts in concern, the present experiment was conceived to study the effect of seed priming on germination and seedling vigour of wood apple.

2. Materials and Methods

2.1. Experimental site and details of seed priming techniques

The experiment was carried out at the shade net house (covered with 200-micron thickness polythene shade net) of Horticulture experimental and learning unit, Faculty of Horticulture, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal, India (22°5643''N, 88°32'03 ''E and 397 m above mean sea level) during December to June of 2016-2017 . Fresh healthy seed of wood apple were collected from Horticulture Research Farm, Palli Siksha Bhavana, Visva Bharati (identified and validated by Dr. Prahlad Deb, Department of Crop Improvement, Horticulture and Agricultural Botany, Palli Siksha Bhavana (Institute of Agriculture), Visva Bharati, Sriniketan, West Bengal, India) and stored for 45 days in ploythelene bags, and then these stored seeds were used for this experiment. The experiment was laid out in completely randomized design (CRD) having eight distinct seed priming treatments (GA_3 50 and 100 ppm, KNO_3 50 and 100 ppm, Thiourea 50 and 100 ppm, water soaking, and one control *i.e.* directly sown seed), replicated five times. To allow the seed priming treatments, 100 numbers of seeds for each treatment were poured in to a large sized Petridis containing 300 ml of respective priming solution for 24 h except the control. Primed seeds after removal from solution immediately allowed to air drying for half an hour and then sowed in 8 × 10cm size polythene bags(of 200 µM) filled with potting mixture of soil+FYM (farm yard manure)+coir peat+sand (1:1:1:1; *w/w*). The potting mixture was sterilized with Blitox solution (2 g l^{-1} of water) before sowing of seeds to prevent the diseases.

2.2. Observations recorded

2.2.1. Germination percentages

Germination percentages were calculated as the average of three replicates of 100 seeds upto 30 days from the day of seed sowing. The germination percentage was calculated using the following equation by Maguire (1962):

Germination percentage=(Number of seeds germinated/ Number of seeds sown)×100

2.2.2. Growth parameters

Growth parameters such as shoot and root length; shoot and root diameter, Number and length of root laterals, number of leave were assessed at monthly interval upto 90 days from date of seed sowing. Length and diameter determined with the help of digital slide calipers (6"/150 mm, accuracy §0.02 mm, LR44, 2006/66/EC). Seedling fresh and dry weight measured using digital weighing balance (1 mg to 100 g precision). The percent tissue water content (TWC %) of the seedlings was determined using the following equation by Black and Pritchard (2002) :

TWC (%)=(Fresh weight-Dry weight)/Fresh weight×100

2.2.3. Seedling vigor Index

Seedling Vigor Index-I (SVI-I) and Seedling Vigor Index -II (SVI-II) were calculated with using the following equations given by Kharb et al. (1994):

Seedling vigor-I=(Seedling length×Germination %)/100

Seedling vigor-II=(Seedling dry weight×Germination %)/100

2.2.4. Leaf chlorophyll content

To determine chlorophyll content (chlorophyll a, b and total chlorophyll) fresh leaves of 0.5 g was used and soaked in 10 ml methanol (85%) for 24 h, in the presence of little amount of Na_2CO_3; after that homogenized and centrifuged. Then the

optical density of supernatant was spectrophotometrically measured, and chlorophyll content calculated using following formula as described by Normal (1982):

Chlorophyll "a" (mg g^{-1} fresh weight)= {12.7(A_{663})-2.63(A_{645})}×{v/(1000×W×a)}

Chlorophyll "b" (mg g^{-1} fresh weight)= {22.9(A_{645})-4.68(A_{633})}×{v/(1000×W×a)}

Chlorophyll (mg g^{-1} fresh weight)= {20.2(A_{645})-8.02(A_{633})}×{v/(1000×W×a)}

Where, A = Absorbance at specific wave length (663 and 645 nm); V=Final volume of the chlorophyll extract (ml); W=Fresh weight of the sample (g); a=Path length of light (1 cm)

2.2.5. Leaf mineral composition analysis

To determine leaf N, P, and K content 50 leaves from each replication collected at seedling age of three month. These leaves were rinsed with tap water, followed by 0.2% (*v/v*) Teepol® solution, 0.1 N HCl, and finally cleaned with double-distilled water. The surface sterilized leaf samples were individually arranged in labelled paper bags and dried in a hot air oven at 70 °C temperature. Then, the dried samples were ground and digested in wet di-acid using nitric acid (HNO_3) and perchloric acid ($HClO_4$). The digested materials were then diluted and filtered through Whatman No.1 filter paper and used to determine N content in leaves with the aid of Digestion Block method (Bremner, 1965), P content by vandomolybdophosphoric yellow colour method (Jackson, 1973), K contents with a microprocessor-based flame photometer (Jackson, 1980).

2.3. Statistical analysis

Results are represented in tables and figures as the means of five replicates. Data were subjected to one-way analysis of variance with the GenStatSoftware ver. 19.1(VSNI, UK) and all means of physical and bio-chemical properties were compared using Duncan's Multiple Range test. Significant differences were assessed at the $p \leq 0.05$ probability level.

3. Results and Discussion

Application of chemicals for seed priming, significantly ($p \leq 0.05$) affects the germination percentage of wood apple seeds in comparison to control (directly sown) (Figure 1).

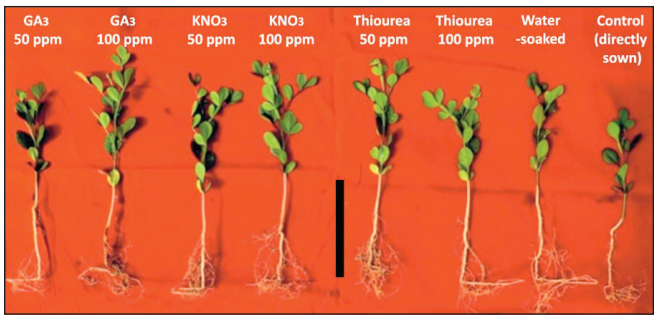

Figure 1: Influence of seed priming treatments on wood apple (*Feronia limonia* Swingle) seedling heights following 3rd month growth stage

The highest number of germination percentage (81.67) was recorded from the seeds that were treated with GA_3 100 ppm, followed by Thiourea 50 ppm (76.67), which was 96.01% and 84.01% higher than the control, respectively (Figure 2).

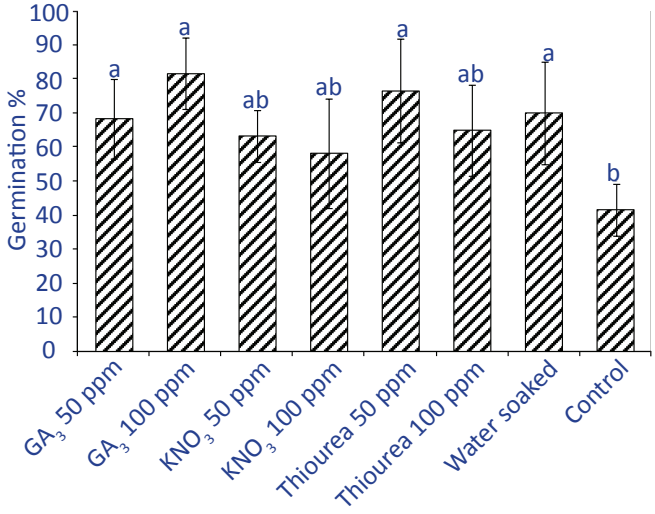

Figure 2: Effect of seed priming chemicals on germination % of wood apple (*Feronia limonia* Swingle)

This improvement in germination of wood apple seeds might be due to the stimulating effect of imbibitions on seed germination caused by increased water absorbing capacity (Cho and Lee, 2018). It might be also because GA_3, which is involved in the activation of cytological enzymes, stimulates the α-amylase enzyme that in turn transforms insoluble starch into soluble sugars, and it also sets off the radical growth by eliminating some metabolic blocks (Babu et al., 2010). Another physiological basis on favouring germination with GA_3 priming is that it also acts directly on embryo to break the seed dormancy, through the promotion protein synthesis and elongation of coleoptiles and leaves and helps in the production of ethylene which invokes the synthesis of hydrolases, especially amylase (Stewart and Freebarin, 1969). Similar results were obtained by Athani et al. (2013) in guava; Singh et al. (2001) in jujube; Moustafa and Al Zidgali (1995) in citrus and Rajput et al. (1999) in wood apple, jujube and *Manilkara* sp.

Data in Table 1 and 2 represent significant variation in shoot, root and seedling length of wood apple upon exposure to various seed priming treatments. A gradual progression in both root and shoot elongation was recorded up to the 3rd month, from the date of seed sowing. The maximum length of shoot (7.43 mm), at the 1st month was observed in the seedlings developed from the GA_3-(100 ppm)-treated seeds, which was statistically at par with that of the Thiourea-(50 ppm)-treated seeds. However, at the transplanting stage (*i.e.* 3rd month growth stage of the seedlings),the resultant shoot lengths showed a non-significant variation irrespective of treatments except the control (non-primed/directly sown seed), though the maximum shoot length (118.92 mm) was

Table 1: Effect of chemicals on shoot length and root length of wood apple

Treatment	Shoot length (mm)			Root length (mm)		
	1st month	2nd month	3rd month	1st month	2nd month	3rd month
T_1: GA_3 50 ppm	5.86±0.52^{bc}	101.92±16.35^{ab}	105.89±8.13^{a}	97.11±7.75^{b}	138.81±15.36^{c}	177.51±6.93^{c}
T_2: GA_3 100 ppm	7.43±0.23^{a}	112.71±10.24^{a}	118.92±10.9^{a}	131.33±14.88^{a}	290.87±19.95^{a}	327.06±13.4^{a}
T_3: KNO_3 50 ppm	6.32±1.32^{ab}	98.63±12.65^{ab}	103.49±10.23^{a}	135.58±6.51^{a}	239.69±81.87^{ab}	277.69±61.62^{ab}
T_4: KNO_3 100 ppm	5.92±0.34^{bc}	106.27±5.81^{ab}	113.79±5.41^{a}	127.59±4.03^{a}	234.59±44.34^{ab}	248.12±44.13^{b}
T_5: Thiourea 50 ppm	7.25±0.25^{a}	93.21±3.34^{b}	100.86±3.12^{a}	152.28±9.15^{a}	191.78±61.17^{bc}	248.27±32.46^{b}
T_6: Thiourea 100 ppm	6.58±0.77^{ab}	90.17±9.89^{bc}	102.82±19.52^{a}	157.46±36.08^{a}	212.03±23.97^{abc}	241.73±24.32^{b}
T_7: Seed soaked in water	6.79±0.42^{ab}	100.99±8.01^{ab}	110.45±18.64^{a}	149.86±21.64^{a}	202.93±65.14^{abc}	246.54±16.44^{b}
T_8: Control (directly sown)	4.78±0.7^{c}	74.21±4.2^{c}	79.35±1.46^{b}	80.46±13.35^{b}	160.67±30.52^{bc}	183.89±26.9^{c}

Mean values followed by different letters are significantly different at $p \leq 0.05$ by Duncan's multiple range tests

Table 2: Effect of chemicals on seedling length of wood apple

Treatment	Seedling length (mm)		
	1st month	2nd month	3rd month
T_1: GA_3 50 ppm	102.97±7.24^{b}	240.77±13.67^{bc}	290.18±21.05^{bc}
T_2: GA_3 100 ppm	138.25±14.24^{a}	403.59±20.07^{a}	442.23±26.82^{a}
T_3: KNO_3 50 ppm	141.89±7.39^{a}	338.32±93.11^{ab}	363.37±89.68^{b}
T_4: KNO_3 100 ppm	133.52±4.36^{a}	340.86±39.81^{ab}	361.91±45.17^{b}
T_5: Thiourea 50 ppm	159.53±9.33^{a}	284.98±64.43^{bc}	349.12±34.93^{b}
T_6: Thiourea 100 ppm	164.04±36.13^{a}	302.19±33.84^{bc}	344.55±43.77^{b}
T_7: Seed soaked in water	156.65±21.27^{a}	303.93±72.98^{bc}	305.89±20.52^{bc}
T_8: Control (directly sown)	85.24±14.04^{b}	234.88±26.95^{c}	238.77±8.02^{c}

Mean values followed by different letters are significantly different at $p \leq 0.05$ by Duncan's multiple range tests

observed in the seedlings that were raised from GA_3 (100 ppm)-primed seeds. In case of root length, in the 1st month the maximum length (157.46 mm) was observed in the seedlings that were developed from seeds treated with Thiourea 100 ppm, which was statistically at par with rest of the other treatments, except GA_3 50 ppm and control (non-primed/ directly sown seed); and with the progression of time, at 3rd month, the maximum root length (327.06 mm) was recorded in seedlings that received the seed priming treatment *i.e.* GA_3 100 ppm. Similar trends were also recorded in case of total seedling length in different months, and the highest seedling length at the 3rd month stage was recorded from the seedlings that were primed with GA_3 100 ppm, which was 85.21% more lengthy than the control ones.

Effect of seed priming on shoot and root diameter, as shown in Table 3 revealed that gradual increasement occurred from the 1st to 3rd month in both the cases. The seeds, treated with 100 ppm GA_3, 50 ppm KNO_3, 100 ppm KNO_3 or 100 ppm Thiourea-treated exhibited comparable results (based on shoot diameter) with the maximum values (1.52 mm,1.48 mm, 1.44 mm, and 1.46 mm, respectively) recorded at the 1st month of germination. On the other hand, seedlings developed from directly sown seeds recorded minimum (1.09 mm) value (of shoot diameter). At the 3rd month, maximum shoot diameter (of 2.51 mm) was observed in the seedlings that received priming treatment of GA_3 100 ppm followed by KNO_3 50 and 100 ppm. In case of root diameter, in the 1st month, a non-significant variation was observed among the seedlings that were developed from different priming treatments, whilst at the 3rd month the maximum root diameter of 3.22 mm was recorded in seedlings that were developed from seeds primed with GA_3 100 ppm followed by KNO_3 100 ppm (3.16 mm).The minimum values were recorded in those seedlings that were developed from directly sown seeds *i.e.* control.

Data in Table 4 reveals significant improvement in the number of root laterals and leaves of wood apple seedlings when subjected to different seed priming treatments. In the 1st month, the highest number of root laterals were recorded from priming treatment of Thiourea 100 ppm which was statistically at par with KNO_3 50 ppm; and the lowest results were obtained from the directly sown seeds. In the 3rd month similar results were recorded as well, where in, the maximum

Table 3: Effect of chemicals on shoot and root diameter of wood apple

Treatment	Shoot diameter (mm)			Root diameter (mm)		
	1st month	2nd month	3rd month	1st month	2nd month	3rd month
T_1: GA_3 50 ppm	1.38±0.03^{ab}	1.91±0.04^{a}	2.19±0.17^{abc}	0.45±0.03^{a}	1.8±0.15^{a}	2.72±0.20 b
T_2: GA_3 100 ppm	1.52±0.09^{a}	2.04±0.32^{a}	2.51±0.04^{a}	0.53±0.09^{a}	1.89±0.20^{a}	3.22±0.12^{a}
T_3: KNO_3 50 ppm	1.48±0.08^{a}	1.92±0.20^{a}	2.34±0.3^{ab}	0.58±0.06^{a}	1.63±0.28^{ab}	3.03±0.36^{abc}
T_4: KNO_3 100 ppm	1.44±0.13^{a}	1.89±0.15^{a}	2.44±0.25^{ab}	0.58±0.16^{a}	1.62±0.23^{ab}	3.16±0.28^{ab}
T_5: Thiourea 50 ppm	1.46±0.17^{a}	1.94±0.09^{a}	2.14±0.15^{ab}	0.51±0.07^{a}	1.26±0.27^{bc}	2.78±0.18^{bc}
T_6: Thiourea 100 ppm	1.35±0.02^{ab}	1.74±0.09^{ab}	2.22±0.23^{abc}	0.61±0.16^{a}	1.32±0.24 bc	3.08±0.02^{abc}
T_7: Seed soaked in water	1.22±0.13^{bc}	1.85±0.03^{a}	2.22±0.13^{abc}	0.56±0.11^{a}	1.53±0.06^{ab}	2.91±0.27^{abc}
T_8: Control (directly sown)	1.09±0.07^{c}	1.51±0.10^{b}	1.95±0.05^{c}	0.33±0.04^{a}	0.97±0.13^{c}	2.11±0.18^{c}

Mean values followed by different letters are significantly different at $p \leq 0.05$ by Duncan's multiple range tests

Table 4: Effect of chemicals on number of root laterals and number of leaves of wood apple

Treatment	No. of root laterals			No. of leaves		
	1st month	2nd month	3rd month	1st month	2nd month	3rd month
T_1: GA_3 50 ppm	13.33±2.08^{c}	27.67±4.73^{bc}	31.67±3.51^{bc}	6.33±0.58^{ab}	8.67±0.58^{bc}	9.67±0.58^{bc}
T_2: GA_3 100 ppm	18.33±2.52^{ab}	46.33±8.50^{a}	42.67±1.15^{a}	7.33±0.58^{a}	10.67±1.15^{a}	12.00±1.00a
T_3: KNO_3 50 ppm	19.33±2.52^{a}	34.33±15.31^{ab}	41.33±10.26^{ab}	6.67±1.15^{ab}	10.00±1.00^{ab}	11.00±1.00^{ab}
T_4: KNO_3 100 ppm	14.67±2.52^{bc}	29.33±8.14^{bc}	38.67±5.03^{abc}	6.67±0.58^{ab}	10.67±0.58^{a}	12.00±1.00^{a}
T_5: Thiourea 50 ppm	18.00±1.00^{ab}	25.33±3.06^{ab}	42.33±5.13^{a}	7.00±1.00^{a}	9.67±0.58^{ab}	11.33±1.53^{ab}
T_6: Thiourea 100 ppm	20.33±4.04^{a}	35.67±3.06^{ab}	43.33±5.13^{a}	6.33±0.58^{ab}	9.33±0.58^{ab}	10.67±0.58^{ab}
T_7: Seed soaked in water	19.00±1.00^{ab}	37.67±1.15^{ab}	34.33±4.04^{abc}	6.67±0.58^{ab}	9.67±0.58^{ab}	10.67±1.53^{ab}
T_8: Control (directly sown)	8.33±1.53^{d}	20.00±2.00^{c}	29±4.58^{c}	4.67±0.58^{b}	7.67±0.58^{c}	8.67±0.58^{c}

Mean values followed by different letters are significantly different at $p \leq 0.05$ by Duncan's multiple range tests

number of root laterals were obtained from GA_3 100 ppm (42.67), Thiourea 100 ppm (43.33) and Thiourea 50 ppm (42.33), respectively. During the observation period of 90 days, a result of monthly gain of 2-4 fully expanded leaves was recorded in wood apple. Priming treatment with GA_3 100 ppm and KNO_3 100 ppm recorded a total number of 12 leaves at the 3rd month stage, which was 38.40% more than that of the seedlings which were developed from directly sown seeds.

The increase in growth parameters like length, diameter of shoot and root, with treatment with GA_3 might be because this plant growth regulator enhanced the osmotic uptake of nutrients, thereby causing greater cell division and elongation (Sen et al., 1990). GA_3 treatment is also responsible for production and translocation of photosynthates across phloem tissue to the root zone, which might be accountable for enhancing the root growth. The increase in the number of leaves might be due to the activity of GA_3 at the apical meristem, ensuing in more synthesis of nucleoprotein that is responsible for increase in the frequency of leaf initiation (Sen and Ghunti, 1976). The observation analogues to the earlier findings of Kumari et al. (2007) and Manekar et al. (2011) in aonla; Anburani and Shakila (2010) in papaya; Patil et al. (2012) in Rangpur lime; Nimbalkar et al. (2012) in karonda.

According to data presented in Table 5, seed treatment of wood apple showed a significant ($p \leq 0.05$) effect on the seedling fresh weight, dry weight and tissue water content of wood apple when compared to control (directly sown). Both the maximum values for fresh and dry weight of seedlings (2.14 g) were obtained from treatment with GA_3 100 ppm, followed by KNO_3 100 ppm, whilst the minimum values were recorded from the control ones. In accordance with the previous result, though the lowest tissue water content was observed in the same treatment GA_3 100 ppm yet, no significant variation among the priming treatments were recorded, with the only exception of those seedlings that were developed from directly sown seeds, which in fact recorded the highest tissue water content (63.37%). It might be due to the overall growth of the seedlings and an increased rate of photosynthesis that led to the overall assimilation and redistribution of photosynthesis within the seedlings and hence, resulted in higher fresh and dry weight, and TWC. Thus, increased growth is a consequence of increased dry matter accumulation. The results are in close conformity with the findings of Pampanna and Sulikeri (1999) in sapota; Meena

Table 5: Effect of chemicals on seedling fresh, dry weight and tissue water content of wood

Treatment	Seedling fresh weight (g)	Seedling dry weight (g)	Tissue water content (TWC)
T_1: GA_3 50 ppm	1.17±0.05^{cd}	0.53±0.03^{bc}	54.70±3.80b
T_2: GA_3 100 ppm	2.14±0.37^{a}	1.01±0.34^{a}	52.80±2.42b
T_3: KNO_3 50 ppm	1.82±0.59^{ab}	0.79±0.32^{ab}	56.60±2.98b
T_4: KNO_3 100 ppm	2.01±0.12^{ab}	0.95±0.13^{a}	52.73±3.15b
T_5: Thiourea 50 ppm	1.65±0.35^{abc}	0.73±0.15^{ab}	55.77±4.57b
T_6: Thiourea 100 ppm	1.44±0.16^{bcd}	0.68±0.11^{abc}	52.77±3.52b
T_7: Seed soaked in water	1.47±0.25^{bcd}	0.67±0.07^{abc}	54.43±2.87b
T_8: Control (directly sown)	1.01±0.11^{d}	0.37±0.06^{c}	63.37±3.23^{a}

Mean values followed by different letters are significantly different at $p \leq 0.05$ by Duncan's multiple range tests

and Jain (2005), Sasikala and Srimathi (2006) in papaya.

Figure 3 (A and B) reflects that seed priming treatment had a significant effect on seedling vigour index (both I and II) of wood apple. The increase in vigor index has been parallel to the corresponding enhancement of germination percentage for all the seed priming treatments studied here. Highest values (312.12) for vigour index I and (0.70) vigour index II were obtained from GA_3 100 ppm primed seeds, whereas, lowest values for both the cases were recorded in the control treatment. The highest seedling vigour in GA_3-primed germinated seeds is presumably due to enlargement of embryos, higher rate of metabolic activity and respiration, improved utilization and mobilization of metabolites to growth points and higher activity of enzymes. Enzymatic and hormonal mechanisms stimulate metabolic processes such as sugar mobilization, protein hydrolysis, oxidation *etc*. (Earplus

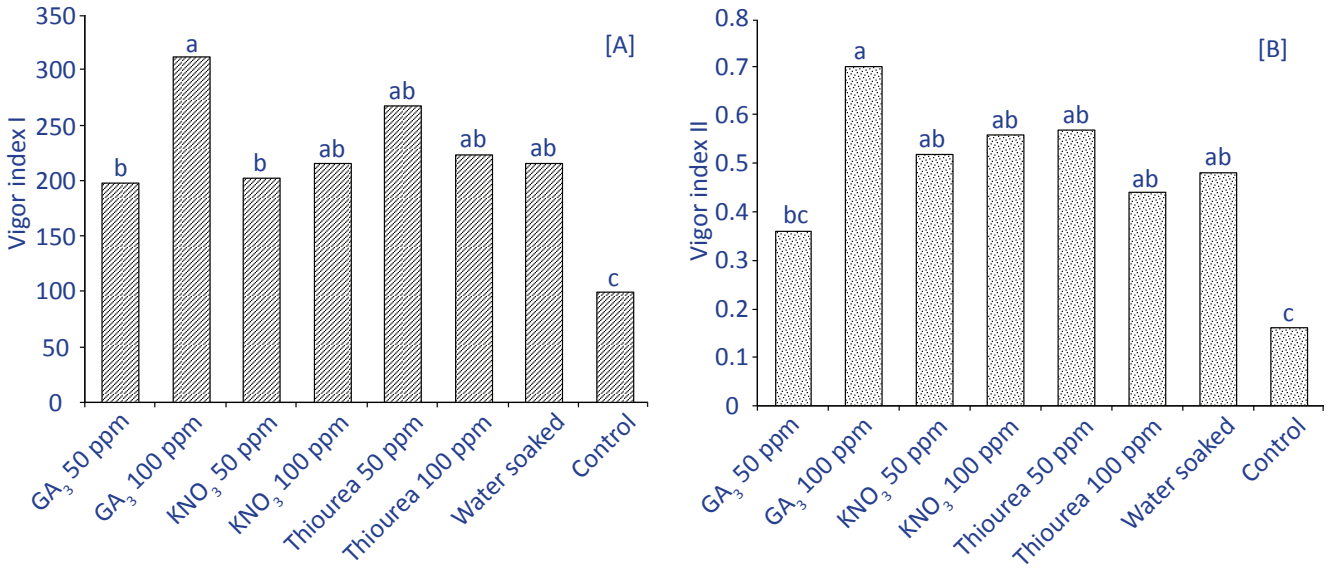

Figure 3: Effect of seed priming chemicals on seedling vigor index I [A] and vigor index II [B] of wood apple (*Feronia limonia* Swingle)

and Lambeth, 1974), which leads to an increase in root length, shoot length, and seedling dry weight that in turn increases seedling vigour. The present results are in conformity with the results of Gurung et al. (2014).

Priming of wood apple seeds significantly influences the leaf chlorophyll contents (Figure 4) as well as the mineral composition of leaf (Table 6). The maximum values of chlorophyll a (78.51 mg g^{-1} FW), chlorophyll b (98.70 mg g^{-1} FW) and total chlorophyll (135.70 mg g^{-1} FW) respectively, were recorded from the seedlings developed from GA_3–(100 ppm)-primed seeds, whereas, in case of control minimum values were recorded for all the three chlorophyll fractions. Highest value for leaf nitrogen content (3.40%) was observed in seedlings that were developed from GA_3-(100 ppm)-primed seeds followed by KNO_3 50 ppm (3.25%), whilst the minimum value of 1.64% was recorded from control. Highest leaf phosphorus content was recorded in seedlings that were developed from GA_3-(50 ppm)-treated seeds (0.26%) followed

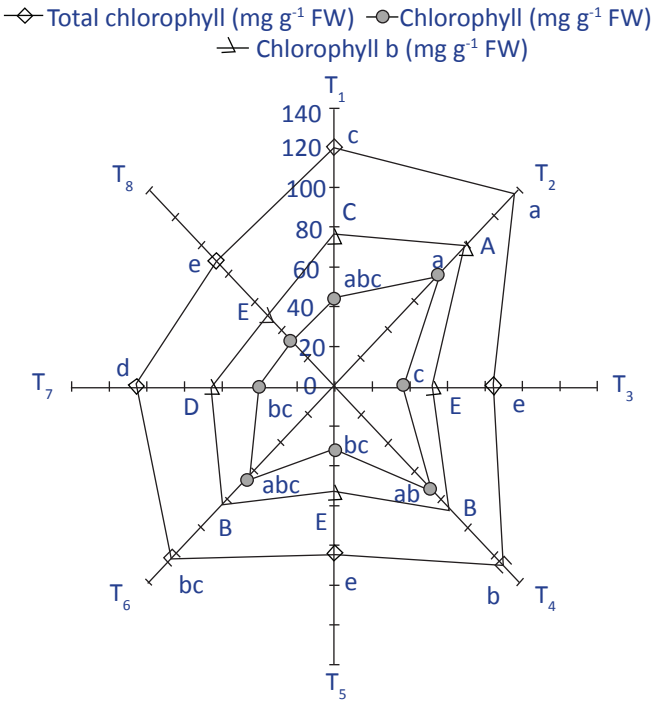

Figure 4: Effect of seed priming chemicals on chlorophyll content of wood apple (*Feronia limonia* Swingle)

Table 6: Effect of chemicals on Nitrogen, Phosphorus and Potassium content of wood apple

Treatment	Total nitrogen percentage (%)	Total phosphorus percentage (%)	Total potassium percentage (%)
T_1: GA_3 50 ppm	2.76±0.13^{c}	0.26±0.05^{a}	3.30±0.08^{ab}
T_2: GA_3 100 ppm	3.40±0.11^{a}	0.25±0.02^{ab}	3.42±0.27^{a}
T_3: KNO_3 50 ppm	3.25±0.24^{ab}	0.18±0.01^{abc}	3.26±2.03^{ab}
T_4: KNO_3 100 ppm	2.82±0.17^{bc}	0.16±0.01^{bc}	3.14±0.21^{ab}
T_5: Thiourea 50 ppm	2.66±0.40^{c}	0.17±0.06^{abc}	3.32±0.09^{ab}
T_6: Thiourea 100 ppm	1.77±0.20^{d}	0.16±0.04^{bc}	2.56±0.17^{bc}
T_7: Seed soaked in water	2.82±0.08^{bc}	0.23±0.04^{ab}	1.92±0.17^{c}
T_8: Control (directly sown)	1.64±0.45^{d}	0.13±0.09^{c}	1.70±0.09^{c}

Mean values followed by different letters are significantly different at $p \leq 0.05$ by Duncan's multiple range tests

by GA_3-(100 ppm)- (0.25%) and water soaked-seeds (0.23%), whilst the minimum value (0.13%) was recorded in control seedling. Leaf potassium content significantly varied in the developed seedlings due to the influential role of different seed priming chemicals, and the maximum value for leaf potassium content (3.42%) was recorded from GA_3-(100 ppm)-primed seedlings, that was at par with results of GA_3 50 ppm, KNO_3 50 ppm, KNO_3 100 ppm and Thiourea 100 ppm. The propitious effects of GA_3 in regulating metabolic activities of photosynthetic pigments was reported by Afroz et al. (2005) in mustard. Application of GA_3 in seed treatment ameliorated the primary growth potential, activity of carbonic anhydrase, and NPK use efficiency. As a consequence, the available nutrients in the growth medium might have been absorbed more rapidly due to their maximum utilization by the developing seedlings (Khan et al., 2009).

4. Conclusion

GA_3 (100 ppm) proved best seed priming treatment for wood apple as it helps in increasing germination percentage to an extent of 96.01% higher than control beside enhancing vegetative growth (85.21% more lengthy seedling than control), increasing leaf chlorophyll content, and leaf mineral composition in order to procure seedlings with vigorous growth.

5. Reference

Afroz, S., Mohammad, F., Hayat, S., Siddiqui, M.H., 2005. Exogenous application of gibberellic acid counteracts the ill effect of sodium chloride in mustard. Turkish Journal of Biology 29, 233–236.

Agrawal, P.K., Dadlani, M., 1995. Techniques in Seed Science and Technology (2nd Ed). India: South Asian Publishers Limited.

Anburani, A., Shakila, A., 2009. Influence of seed treatment on the enhancement of germination and seedling vigour of papaya. ActaHorticulturae 851, 295–298.

Arteca, R.N., 1996. Plant growth substances: Principle and applications. Springer US.

Athani, S.I., Allolli, T.B., Gopali, J.B., Kotikal, Y.K., 2013. Studies on effect of seed treatment on germination of guava seeds. Paper presented in National Seminar on Tropical and Subtropical Fruits, held at Navsari, Gujarat, India on January, 9–11.

Babu, K.D, Patel, R.K, Singh, A., Yadav, D.S., De, L.C., Deka, B.C., 2010. Seed germination, seedling growth and vigour of papaya under North east Indian condition.Acta Horticulturae 851, 299–306.

Basra, S.M.A., Farooq, M., Rahman, H., Saleem, B.A., 2007. Improving the germination and early seedling growth in melon (*Cucumis melo* L.) by pre-sowing salicylicate treatments. International Journal of Agriculture and Biology 10, 238–240.

Black, M., Pritchard, H.W., 2002. Desiccation and survival in plants drying without dying, CABI publishing, NY, USA.

Bremner, J.M., 1965. Total nitrogen. In: Black, C.A. (Ed.), Methods of Soil Analysis, Part 2. American Society of Agronomy, Madison, 1149–1178.

Cho, J.S., Lee, C.H., 2018. Effect of germination and water absorption on scarification and stratification of kousa dogwood seed. Horticulture, Environment, and Biotechnology 59, 335–344.

Farooq, M., Basra, S.M.A., Hafeez, K., Asad, S.A., Ahmad, N., 2005. Use of commercial feritilzers as osmotica for rice primimng. Journal of Agriculture and Social Sciences1, 172–175.

Gurung, N., Swamy, G.S.K., Sarkar, S.K., Ubale, N.B., 2014. Effect of chemicals and growth regulators on germination, vigour and growth of passion fruit (*Passiflora edulis* Sims.). The Bioscan 9, 155–157.

Hassini, I., Martinez-Ballesta, M.C., Boughanmi, N., Moreno, D.A., Carvajal, M., 2017. Improvement of broccoli sprouts (*Brassica oleracea* L. var. italica) growth and quality by KCl seed priming and methyl jasmonate under salinity stress. ScientiaHorticulturae 226, 141–151.

Hossain, M., Biswas, B.K., Karim, M.R., Rahman, S., Islam, R., Joarder, O.I., 1994. In vitro organogenesis of elephant apple (*Feronia limonia*). Plant Cell, Tissue and Organ Culture 39, 265–268.

Islam, M.R., Nasirujjaman, K., Zaman, S., 2006. Production of plantlets from in vitro cultured cotyle-dons of *Aegle marmelos* Corr. Life Earth Science 1, 31–33. http://dept.ru.ac.bd/flife/5.pdf

Jackson, M.L., 1973. Vanadomolybdophosphoricyellow colour method for determination of phosphorus. In: Soil Chemical Analysis, Prentice Hall of India Pvt. Ltd., New Delhi, 151–154.

Jackson, M.L., 1980. Soil chemical analysis. PrenticeHall of India Pvt. Ltd., New Delhi, 452.

Khan, N.M., Mohammad, F., Siddiqui, H.M., 2009. Pre-sowing seed treatment and foliar application of gibberellic acid improve seed and fibre yield by inducing net photosynthetic rate and carbonic anhydrase activity of linseed genotypes. The International Journal of Developmental Biology 3, 34–38.

Kharb, R.P.S., Lather, B.P.S., Deswal, D.P., 1994. Prediction of field emergence through heritability and genetic advance of vigor parameters. Seed Science and Technology 22, 461–466.

Kim, D.H., 2019. Practical methods for rapid seed germination from seed coat-imposed dormancy of *Prunusyedoensis*. ScientiaHorticulturae 243, 451–456.

Kumari, A.V., Palanisamy, V., Jayaraj, T., Arumugum, R., 2007. Studies on certain seed technological aspects in guava (*Psidium guajava* L.). South Indian Horticulture 39, 315–316.

Maguire, J.D., 1962. Speed of germination-aid in selection and evaluation for seedling emergence and vigor. Crop Science 2, 176–177.

Maiti, R., Rajkumar, D., Jagan, M., Pramanik, K., Vidyasagar, P., 2013. Effect of seed priming on seedling vigour and yield of tomato and chilli. International journal of Bio-resource and Stress Management, 4(2), 119–125.

Manekar, R.S., Sable, P.B., Rane, M.M., 2011. Influence of different plant growth regulators on seed germination and subsequent seedling growth of aonla (*Emblica officinalis* Gaertn.). Green Farming 2, 477–478.

Meena, R.R., Jain, M.C., 2005. Effect of seed treatment with gibberellic acid on growth of papaya seedlings (*Carica papaya* L.). Progressive Horticulture 37, 194–196.

Morton, J., 1987. Wood-Apple. In: Fruits of warm climates. Julia F. Morton, Miami, FL, 190–191.

Moustafa, S.S., Al Zidgali, T.M., 1995. Effect of some treatments on seed germination responses and seedling development of citrus rootstocks. Bulletin of Faculty of Agriculture, University of Cairo, 46, 205–214.

Nimbalkar, S.D., Jadhav, Y.S., Adat, S.S., Savvashe, A.Y., 2012. Effect of different seed treatments on germination and growth of karonda (*Carissa congesta* W.). Green Farming 3, 340–342.

Nornal, R., 1982. Formula for determination of chlorophyllous pigments extracted with N - dimethyleformamide. Plant Physiology 69, 1371–1381.

O'Neill, M.J., Lewis, A.J., 1993. Human medicinal agents from plants. In: Kinghorn, A.D., Balandrin M.F., ACS symposium Series 534, Washington, DC, 48.

Pampanna, Y., Sulikeri, G.S., 1999. Growth of sapota (*Manilkara achras* Mill. Foseberg) seedlings as influenced by pre-sowing seed treatment with growth regulators. Seed Research 27, 49–53.

Patil, S.R., Sonkamble, A.M., Khobragade, H.M., 2012. Influence of some growth regulators on germination and growth of rangpur lime (*Citrus limonia* O.) seeds under shade net conditions. Green Farming 3, 690–693.

Raghavendra, V.N., Angadi, S.G., Mokashi, A.N., Allolli, T.B., Venugopal, C.K., Mummigatti, U.V., 2011. Studies on softwood grafting in wood apple (*Feronia limonia* L.). ActaHorticulturae 890, 165.

Rajput, S.G., Gunjkar, S.N., Jintukar, S.P., Nikam, N.R., Shinde, N.N., 1999. Studies on seed propagation in some dry land fruit crops. Journal of Applied Horticulture 2, 27–33.

Sasikala, S., Srimathi, P., 2006. Influence of storage period and GA_3 on germination and vigour of papaya seed. Progressive Horticulture 38, 195–198.

Sen, S.K., Ghunti, P., 1976. Effect of pre-sowing seed treatment on the germination and seedling growth in papaya. Orissa Journal ofAgricultural Research 2, 160–164.

Sen, S.K., Hore, I.K., Bandhopadhyay, A., 1990. Pre-sowing seed treatment and its role in germination, seedling growth and longevity of papaya. Orissa Journal of Agricultural Research 2, 160–164.

Sharma, A.D., Rathore, S.V.S., Srinivasan, K., Tyagi, R.K., 2014. Comparison of various seed priming methods for seed germination, seedling vigour and fruit yield in okra (*Abelmoschus esculentus* L. Moench). ScientiaHorticulturae 165, 75–81.

Singh, S., Singhrot, R.S., Bhatia, S.K., 2001. Effect of seed treatment on germination, growth and budding success in ber rootstock (*Zizyphus rotundifolia* Lank.) sown in nursery beds and polythene tubes. Haryana Journal of Horticultural Science 30, 156–159.

Stewart, E.R., Freebairn, H.T., 1969. Ethylene, seed germination and epinasty. Plant Physiology 44, 955–958.

Vidhya, R., Narain, A., 2011. Formulation and evaluation of preserved products utilizing under exploited fruit, wood apple (*Limonia acidissima*). American-Eurasian Journal of Agricultural & Environmental Sciences 10, 112–118.

Wareing, P.F., Phillips, I.D.J., 1981. Growth and differentiation in plants. Pergamon Press, Oxford, UK.