CHAPTER II
REVIEW OF LITERATURE

The propagation of papaya seedlings is mainly done by sexual method i.e. seed propagation. Different containers and PGR play an important role for percent germination, earliness in germination, healthy and vigorous growth of seedling. The information regarding the effect of suitable type of container along with GA$_3$ on growth of seedling is scanty. Therefore, the present research work was undertaken to study the “Effect of GA$_3$ and different containers on seed germination and seedling growth of papaya cv. Madhubindu”.

The relevant literatures available on different aspect have been reviewed on papaya and some important horticultural and forest crops under the following heads.

2.1 Effect of GA$_3$ on seed germination

Chacko and Singh (1966) reported that the GA$_3$ 50, 100, 500 and 1000 ppm enhanced the rate of germination percentage of papaya seeds.

Burns and Coggnies (1969) observed that the germination of seeds was significantly increased when seed soaked for 24 hours in GA$_3$ 100 ppm solution.

Shrivastava and Singh (1969) noted that increase in germination of Hill lemon and Malta when seeds were treated with different concentrations of GA 0, 5, 10, 15 and 50 ppm for 6 hrs soaking. In Hill lemon and Malta, the best germination recorded with 20 and 15 ppm, respectively.

Shanmugavelu (1971) reported in jack seed, GA in all the concentration (100-500 ppm) for 48 hrs uniformly recorded 100% germination as against 80% in control.

Achuituv and Mendel (1973) reported that GA$_3$ not only promoted seed germination but also increased the number of germinating seeds when the seed of sweet lime treated with 500 ppm solution of GA$_3$.

Shant and Rao (1973) observed that 550 ppm GA$_3$ promoted the seed germination of Kagzilime when seeds were soaked for 12 hrs before sowing.

Abohassan et al. (1979) found adverse effect of GA 500 ppm and 1000 ppm GA hastened the germination of apricot and lime, respectively.

Hundal and Khajura (1979) reported that seeds of Matchless and Sarbati cultivars of peach soaked in GA$_3$ 200 ppm for 24 hrs resulted in the highest
germination whereas, the cultivars Khurmani and Sufeda recorded better germination in seeds soaked in 5000 and 7000 ppm thiourea for 24 hrs.

Choudhari and Chakrawar (1981) studied the effect of some chemicals on the germination of Kanzilime seeds and reported that seeds soaked in 40 ppm GA$_3$ and 40 ppm NAA for 12 hrs resulted in the highest germination (40.83% and 32.50%, respectively).

Heikal et al. (1982) studied the effect of gibberellic acid on germination of Kanzilime seeds. It was found that rate of seed germination and final seed germination percentage increased due to pre soaking with gibberellic acid.

Hore and Sen (1985) reported that bael seed germination was the highest when seeds were treated with GA$_3$ 100 ppm (51.66%) and found to be superior over the untreated seeds.

Rodríquez (1986) stated that the highest seed germination was observed in guava when the seeds were soaked in water for 4 days followed by 24 hrs soaking in 1000 ppm GA$_3$.

Furutani and Nagao (1987) reported that papaya (Carica papaya L.) seeds soaked in GA$_3$ or KNO$_3$ for 15 min exhibited an increased percentage of emergence and a reduced time for 50% seedling emergence in comparison to seeds soaked in water. Plants grown from KNO$_3$ treated seeds appeared normal, whereas plants grown from GA$_3$ treated seeds had elongated hypocotyls.

Ghosh and Sen (1988) studied the effect of seed treatment on germination, seedling growth and longevity of ber seeds and reported that seeds treated with 100 ppm GA$_3$ recorded maximum germination percentage followed by one per cent KNO$_3$ treated seeds.

Dey (1989) studied the effect of seed treatment of Kanzilime with GA$_3$ 250 ppm. The effect was found to increase germination percentage and subsequent growth whereas control showed minimum germination percentage.

Pandey (1992) studied influence of gibberellic acid on seed germination of Khasi mandarin and noticed that freshly extracted seeds treated with GA$_3$ 50 ppm for 24 hrs gave maximum germination per cent.

Pampanna et al. (1995) studied seed germination and seedling growth of sapota following GA and ethereal treatment at different concentrations on (200, 300 and 400 ppm) pre soaking of sapota seed with cracked seed coat. GA 300 ppm for 24 hrs resulted in the highest germination.
Ak et al. (1995) studied the effect of GA3 (0, 125, 250, 500 and 1000 ppm for 24 h or 48 h) on the germination of pistachio (*Pistachio vera*) seeds. The best germination (73.33%) was observed with GA3 at 125 ppm for 48 h.

Prasad et al. (1996) found that the use of GA3 at 100 ppm increased the germination rate of litchi seeds in all varieties studied, suggesting that gibberellic acid played an important role in the germination process of these seeds.

Dhankhar et al. (1997) studied on aonla (cv. Gujarat Aonla 1) seeds were treated with 250, 500 and 750 ppm gibberellic acid (GA3). Seed germination was the earliest and percentage germination was the highest in seeds treated with 250 ppm GA3.

Pawashe et al. (1997) revealed that custard apple seeds had early and highest seed germination when seeds were treated with gibberellic acid 100 ppm for 24 hrs over water soaking for 24 hrs.

Bertocci et al. (1997) observed that papaya seeds dessicated in the sun for 3, 6, 9, 12 or 15 days and stored in paper bags at 20°C for two months and then soaked in 300 ppm GA3 for 24 h showed variations in germination percentage. Germination percentage increased in seeds dessicated and treated with GA3.

Ananthakalaisevi and Dharmalingam (1998) stated that papaya seeds soaked in 100 ppm GA3 solution for 16 hrs showed better germination as compared to untreated seeds.

Verma et al. (1998) studied the effect of GA3 on seed germination of kiwifruit cultivars Abbot, Allison, Bruno, Hayward and Monty. The extracted seeds were soaked in water or in 10, 20, 30 or 40 ppm solution of GA3 for 24 hrs and sown in pots. The highest seed germination was recorded under period of soaking in 30 ppm GA3.

Helail et al. (1999) reported that the effect of pre sowing treatments on the seed germination, seedling growth and blooming of pawpaw cv. Fairchild. The treatments consisted of untreated control (dry seeds), soaking for 24 hours in tap water and soaking for 24 hours in GA3 (500 or 1000 ppm), enhanced germination percentage, reduced the time required to attain 50% germination and improved germination rate compared with the control.

Gholap et al. (2000) studied the effect of plant growth regulators on seedling growth of aonla (cv. Banarasi) under climatic conditions of Akola, India. Fresh seeds were treated with 3 different concentrations of gibberellic acid GA3, NAA
or thiourea viz., 100, 200 and 300 ppm. GA₃ at 200 ppm resulted in the shortest time to initial germination (15.33 days) and highest germination percentage (67.58%).

Vincent and Thandapani (2000) studied the effect of storage containers and growth regulators on seed performance of papaya at Madurai, India and reported that seeds treated with GA 200 ppm recorded the highest germination percentage (89%).

Pandit et al. (2001) studied on improving papaya (Carica papaya) seed germination and seedling growth by pre sowing treatments at Karnal, Haryana and opined that papaya seeds gave the highest germination (79.9%) under the GA₃ treatment (2.0 mM).

Khan et al. (2002) observed that the effect of pre sowing seed treatment of gibberellic acid solutions on rate of germination and final percentage germination of grapefruit (Citrus paradisi), kinnnow mandarin (C. reticulata) and rough lemon (C. limon) seeds was investigated. The seed size, coat thickness, thousand seed weight and polyembryony were higher in grapefruit followed by kinnnow mandarin and rough lemon while moisture content was higher in kinnnow mandarin followed by grapefruit. No significant effect of GA₃ treatment on final percentage germination was observed and it only had a marginal effect on the rate of germination of both the citrus species. The treatments have not shown any effect on final percentage germination.

Kalalbandi et al. (2003) conducted a field experiment to investigate the effect of GA₃ at 40, 60 and 80 ppm; NAA at 40, 60 and 80 ppm and KNO₃ at 1% on the germination and growth of Kagzilime. They observed that the seed soaked in GA₃ 80 ppm and NAA 80 ppm for 12 h resulted in high germination.

Maiti et al. (2003) concluded that seeds of jackfruit soaked in 100 ppm gibberellic acid for 24 hrs recorded maximum germination percentage (98.0%) compared to control.

Ratan and Reddy (2004) soaked the seeds of custard apple (Annona squamosa) cv. Balanagar in 200, 400 and 600 ppm GA₃ for 12 and 24 hrs to determine their effect on seed germination and seedling growth. Treatment with 400 ppm GA₃ for 12 hrs gave the highest seed germination percentage (69.00).

Zhao Chun Xiang et al. (2004) observed that papaya seed germination was promoted most with 50 mg GA₃ per liter, resulting in (83.7%) germination.

Koyuncu (2005) studied on the effects of cold stratification and application of gibberellic acid in black mulberry. Increasing the concentration of GA₃ resulted in an
increase in germination percentage. Application of 1000 ppm GA$_3$ proved more effective than any of the other concentrations of GA$_3$ applied.

Venkatarao and Reddy (2005) conducted an experiment to study the effect of osmopriming on germination of mango stone and reported that osmopriming treatment significantly increases the germination per cent on mango stone. They found that seed treated with GA$_3$ 200 ppm for 24 hr recorded maximum germination.

Gunes and Gubbuk (2006) studied the effect of different pre sowing treatments on seed germination of different papaya cultivars (Sunrise Solo, Red Lady, Tainung, SS-45, BH-65 and Sel-42). The following pretreatment were treated respectively; (a ) control; (b) cutting the seed tips (1-2 mm); (c) soaking seeds in cool water (18 ± 20°C) for 24 and 48 hours; (d) soaking seeds in hot water (40°C) for 10, 15 and 20 second; and (e) soaking the seeds in 250, 500, 750 and 1000 ppm GA$_3$ solutions for 24 hours. Germination of the cultivars varied from 6.67% to 97.77% and germination time ranged from 7 to 14 days. Pre treatment with GA$_3$ (250 and 1000 ppm) for 24 hours was the best treatment for germination percentages and germination time for ‘Sunrise Solo’, ‘Red Lady’ and ‘Tainung’, but optimum GA$_3$ concentration varied with the cultivars. Fast germination was produced with the GA$_3$ treatments depending on concentration. ‘Red Lady’ seeds treated with 750 ppm GA$_3$ for 24 hours had the highest germination percentage with 97.78%. ‘Tainung’ had the shortest germination time when treated with 500 ppm GA$_3$ for 24 hours and germinated in 7 days.

Ameen and Imam (2007) found that percentage of seed germination was maximum with treatment of GA$_3$ 200 ppm in pistachio seed.

Yogeesha et al. (2007) conducted experiment on effect of temperature and chemical pre treatment on seed germination of papaya cultivars (Surya, CO 2 and CO 7) and observed that soaking seeds in GA$_3$ at 200 ppm for 48 hrs before sowing greatly improved the germination. GA$_3$ at 200 ppm was found effective at 25 °C in all cultivars with germination of 85.0, 69.3 and 75.0% in Surya, CO 2 and CO 7 cultivars, respectively.

Rajwar et al. (2007) reported that the seeds of wild ber (Zizyphus mummularia) treated with growth regulators (250 and 500 ppm GA$_3$, and Thiourea) affected seed germination and seedling growth. The highest seed germination percentage was recorded with 500 ppm GA$_3$. 
Tokuhisa et al. (2007) studied on dormancy overcoming in papaya seeds. Seeds with and without sarcotesta extracted from papaya fruits of the Formosa group and hybrid Tainung 01. The following treatments to overcome dormancy were applied on seeds without sarcotesta: soaking in KNO$_3$ 1M for 30, 60, 90 and 120 min., soaking in GA$_3$ 400, 600 and 800 ppm for 24h, substratum moistened with GA$_3$ 400, 600 and 800 ppm, storage for 3, 6 and 9 months and heat shock at 15-35 ºC. After each treatment, germination at 15 and 30 days was evaluated. Seeds with sarcotesta had lower germination speed and percentage. The best treatments to overcome dormancy in papaya seeds were the use of substratum moistened with GA$_3$ 600 ppm or the immersion of the seeds GA$_3$ 600 ppm for 24 hours and immersion of the seeds in KNO$_3$ 1M for 30, 60 and 90 minutes.

Kumar et al. (2008) conducted an experiment to study the effect of organics and chemicals on germination of mango. They recorded the GA$_3$ 100 ppm had showed the highest germination percentage.

Hassani et al. (2009) evaluated the effects of temperature and GA$_3$ on germination of Ferula assafoetida L. Treatment of the seeds by GA$_3$ showed the higher germination percentage than control or untreated seeds. The concentration of GA$_3$ had a positive effect on the improvement of the germination indexes and percentages after 12 weeks of incubation in all temperature conditions.

Dhaka and Pal (2009) conducted an experiment with three concentrations of GA$_3$ (450, 500 and 550 ppm) and applied by long dip method for 30, 35 and 40 hours to lime seeds. After long dipping, seeds were sown in pots in the month of July. They reported that the GA$_3$ at 500 ppm with seed soaking period of 40 hours resulted in better germination, growth and survival compared to other treatments.

Lopes et al. (2009) studied papaya (Carica papaya L.) hybrid group ‘Tainung 01’ seeds germination and seedling vigour as a function of fruit maturation stage (semi-mature and mature), combined with immersion of the seeds for 4 h in different concentrations of gibberellic acid (0, 250, 500 and 1000 mg/lit). Seeds from semi mature fruits showed higher germination percentage than those from mature fruits, when soaked on solution 250 and 500 ppm GA$_3$. Seeds treated with 1000 ppm GA$_3$ showed the highest germination percentage from ripe fruits.

Anburani and Shakila (2010) stated that papaya seeds soaked in GA$_3$ 200 ppm for 12 hrs reduced the time taken for 50% germination compared to control.
Babu *et al.* (2010) studied on seed germination, seedling growth and vigour of papaya under North East Indian condition. The seeds were soaked overnight in different concentrations of gibberellic acid (0, 50, 100, and 150 ppm). Increasing the GA$_3$ concentration from 0 to 100 ppm significantly improved the germination (66.17%) over the control (42.40%) and above 100 ppm the seed germination decreased. GA$_3$ treatment had a favorable effect in hastening the germination of papaya and the time taken for germination was maximum in untreated control (31.86 days) whereas GA$_3$ at 100 ppm recorded the minimum period for germination (29.73 days).

Barche *et al.* (2010) reported that papaya seeds when treated with GA$_3$ 500 ppm for 12 hrs showed the maximum germination (78.50%) and minimum days required for completion of germination (15 days) over control.

Deb *et al.* (2010) studied the improvement of seed germination and seedling growth of papaya (*Carica papaya* L.) through different pre-sowing seed treatments. Seeds were soaked with GA$_3$ (at 100, 150 and 200 ppm), sodium thiosulphate (at 20, 25 and 30 ppm) and micronutrient mixtures (4 different combinations of borax and zinc sulphate). Among the different treatments, GA$_3$ at 150 ppm was found best in respect to seed germination (72.2%) followed by sodium thiosulphate at 20 ppm (68.1%).

Pal and Dhaka (2010) studied the seeds of orange were treated with gibberellic acid at 0, 450, 500 and 550 ppm by long dipping method for 30, 35 and 40 hrs and observe that seeds treated with GA$_3$ at 500 ppm for 40 hrs recorded better responses regarding seed germination.

Khatana *et al.* (2011) reported that Kagzilime seeds treated with 100 ppm GA$_3$ recorded maximum germination, under the climatic condition of Anand.

Singh *et al.* (2011) studied the effect of pre soaking treatments on germination and growth of cashew (*Anacardium occidentale* L.) rootstocks at west Bengal and reported that treatment of GA$_3$ 40 ppm recorded shortest duration (9 days) and maximum germination (82%) in cashew seeds.

Gharge *et al.* (2011) studied the effect of various concentrations of GA$_3$ and soaking period on seed germination of custard apple. The maximum germination percentage was recorded when seed treated with GA$_3$ at 400 ppm, with regard to the period of soaking, soaking of seeds for 24 to 48 hrs gave early and maximum germination percentage. In respect of interaction effect of GA$_3$ concentration and
soaking period, soaking of seeds in GA\textsubscript{3} 400 ppm for 12 hrs gave maximum germination percentage.

Anjanawe \textit{et al.} (2012) studied the effect of plant growth regulators on seed germination and growth vigour of papaya (\textit{Carica papaya} L.) seedling cv. Barwani red and observed maximum seed germination (65.4\%) under the application of 100 ppm GA\textsubscript{3}.

Athani \textit{et al.} (2013) conducted an experiment to study the effect of seed treatment on germination of guava seed. They revealed that soaking of seeds in GA\textsubscript{3} 400 ppm for 5 minutes gave maximum germination percent and took least time for germination as compare to control.

Lay \textit{et al.} (2013) studied on optimum fruit maturity stages, ideal temperature, media and dormancy breaking methods on seed quality parameters of papaya (\textit{Carica papaya} L.) cv. Surya at Bangalore. Seeds extracted from fruits, after ripening were subjected to dormancy breaking treatments, the result revealed that higher germination (93.00) was recorded in GA\textsubscript{3} @ 300 ppm for 12 hrs. Thus, in seed extracted from complete yellow/orange fruits can enhance the germination percentage.

Padma \textit{et al.} (2013) conducted an experiment on effect of seed treatments to enhance seed quality of papaya cv. Surya and revealed that the highest seed germination (93\%) was recorded in 300 ppm GA\textsubscript{3} for 12 hrs followed by 2\% KNO\textsubscript{3} for 24 hrs (91\%).

Kalyani \textit{et al.} (2014) studied the effect of pre sowing seed treatments like water soaking, gibberellic acid, thiourea, hot water and acid treatments on germination percentage in guava cv. Sardar at Akola, (Maharashtra) during 2012 to 2013. The highest germination (83.79) and (80.30) percentage was recorded with GA\textsubscript{3} (1000 ppm) and (500 ppm), respectively.

Khopkar \textit{et al.} (2014) observed that soaking of freshly harvested pummelo seeds in GA\textsubscript{3} 50 ppm for 24 hrs gave better results in terms of percent seed germination.

Ishwar (2015) studied on response of jackfruit (\textit{Artocarpus heterophyllus} Lam.) seeds to plant growth regulators and thiourea and concluded that GA\textsubscript{3} @ 200 ppm was the best treatment among all treatments which recorded maximum percentage of germination (80.01\%).
Pratibha et al. (2015) studied the effect of chemical treatments on the germination and subsequent seedlings growth of papaya (*Carica papaya* L.) seeds cv. Pusa nanha. The results revealed that among the various seed treatment chemicals minimum days taken for seed germination (12.33 days), maximum germination percentage (88.89%), germination index (2.90) and highest cost benefit ratio (2.57) were recorded in seeds treated with GA$_3$ 300 ppm for 24 hrs.

Ramteke et al. (2015) studied on seed germination and seedling growth of papaya as influenced by GA$_3$ and propagation media at Raipur, Chhattisgarh and revealed that GA$_3$ 200 ppm is found to be the most effective for better germination (82.22%) of papaya seeds.

Mali et al. (2015) studied the effect of pre sowing seed treatment with plant growth regulators on germination and growth of papaya (*Carica papaya* L.) and observed that the gibberelic acid @ 500 ppm gave the maximum seed germination percentage (47.50%).

Padma et al. (2015) concluded that the maximum germination was observed in seeds treated with GA$_3$ @ 300 ppm for 12 h (93.00 %).

Shabaq (2015) concluded that GA$_3$ at 250 mg per liter gave best response in germination percentage (71.19%, 86.80% and 98.75%) at first, second and third weeks after sowing in loquat (*Eriobotrya japonica* L.).

Parmar et al. (2016) studied the influence of seed priming treatments on germination and seedling vigour of custard apple. The treatments comprised of different concentrations of chemicals (GA$_3$ @ 100 and 200 mg per liter KNO$_3$ @ 1 and 2%, Thiourea @ 500 and 1000 mg per liter, fresh cow dung and urine slurry (1:2 ratio) and hot water treatment. Soaking the seed in GA$_3$ @ 200 mg per liter for 12 hours recorded the minimum days taken to germinate (24.00 days), maximum germination percentage (63.99 %).

Patel et al. (2017) observed that treatment of GA$_3$ 200 mg per liter had significant influence on different germination parameters like minimum days required for seed germination (20.25 days), highest germination (80.07%), minimum germination period (23.63 days), highest seed vigour (2853 cm) and germination index (3.22) of custard apple seedling.

Dilip et al. (2017) studied the influence of gibberellic acid GA$_3$ at different concentrations in different time intervals on seed germination and seedling growth of
kagzilime at Uttar Pradesh, India. The results revealed that maximum germination percentage (95%) was recorded under treatment with GA₃ 80 ppm for 12 hours. Therefore, it may be concluded that the GA₃ at 80 ppm has a significant effect on the seed germination.

Panda (2017) revealed that the treatment GA₃ 100 ppm recorded the highest germination percentage (55.22%), minimum days (26.00) taken to start germination and the highest vigour index (1436.94 cm and 104.07 g) in citrus cv. Kagzilime.

Palepad et al. (2017) studied the effect of seed treatments on seed germination and seedling vigour of custard apple during the year 2015-16 at department of horticulture, Dr. Panjabrao Deshmukh Krishi Vidypeeth, Akola by using completely randomized design with twelve treatments. The seeds treated with GA₃ 1000 ppm solution minimized the days (10.27) taken for germination and improved the germination percentage (83.33%).

Patel et al. (2016) studied the effect of pre sowing treatments on stone germination of mango (Mangifera indica L.) seedlings and recorded that the maximum germination percentage (66.33 %) was observed in GA₃ at 100 ppm.

2.2 Effect of GA₃ on seedling growth

Chacko and Singh (1966) reported that the GA₃ 50, 100, 500 and 1000 ppm enhanced the stem length, fresh and dry weight of seedling was increased with increasing concentration of GA₃. The growth of root was not significantly affected.

Burns and Coggnies (1969) observe that the growth and uniformity of seedling of sweet orange were reported the highest under seed treated with GA₃ at 100 ppm.

Shant and Rao (1973) observed that of Kagzilime seedling growth increased with spray of 300 ppm solution of GA₃.

Begum et al. (1987) found that papaya seedling acquired the maximum seedling height and fresh weight when seeds treated with gibberellic acid 100 ppm for 24 hrs as compared to other chemicals.

Palaniswamy and Ramamoorthy (1987) reported that pre soaking of papaya seeds with GA 100 ppm was found to be effective in breaking the dormancy and recorded maximum root length (16.0 cm), shoot length (6.8 cm) and dry weight of the seedling (0.036 g) as compared to other chemicals and untreated control.

Singh et al. (1989) reported that Mosambi seeds treated with 600 ppm GA₃ increased the height of seedlings (6.05 to 9.23 cm) and number of leaves per plant (9.24 to 13.10).
Chandra and Govind (1990) recorded the maximum seedling height (13.15 cm) and more number of leaves per plant (16.70) when guava seeds treated with 3000 ppm GA₃.

Pandey (1992) studied influence of gibberellic acid on seed germination of Khasi mandarin and noticed that freshly extracted seeds treated with GA₃ 50 ppm for 24 hrs gave minimum duration days, maximum shoot length, number of leaves and plant height.

Pampanna et al. (1995) studied seed germination and seedling growth of sapota following GA and ethereal treatment at different concentrations on (200, 300 and 400 ppm) pre soaking of sapota seed with cracked seed coat. GA 400 ppm recorded the highest seedling height and the maximum number of leaves per seedling.

Ak et al. (1995) studied the effect of GA₃ (0, 125, 250, 500 and 1000 ppm for 24 h or 48 h) on the germination of pistachio (Pistachio vera) seeds and observed that maximum seedling height and internodal length were also observed with GA₃ at 1000 ppm.

Dhankhar et al. (1997) studied on aonla (cv. Gujarat Aonla 1) seeds were treated with 250, 500 and 750 ppm gibberellic acid (GA₃). This treatment gave the best results in terms of plumule and radical length, seedling height, seedling girth and seedling fresh and dry weight.

Morales et al. (1998) observed that papaya seeds treated with various concentrations of ethanol (0, 5, 10, 15 or 20% v/v) and GA₃ (0, 10, 20 or 30 ppm w/v) varying in shoot height and dry weight. In all cases, height increased with increasing GA₃ concentration regardless of ethanol concentration.

Pampanna and Sulikeri (1999) studied the growth of sapota seedlings influenced by pre sowing seed treatment with growth regulators and found that seeds soaked in 400 ppm GA₃ resulted in highest shoot length (10.65 cm), root length (6.73) and more number of leaves per seedling (6.62).

Misra et al. (2000) conducted an experiment on effect of plant growth regulators on growth of Malta common seedlings in Garhwal hills. They revealed that GA₃ 200 ppm with 12 hrs soaking treatment responded significantly on the plant height, number of leaves and leaf area per plant.

Gholap et al. (2000) studied the effect of plant growth regulators on seedling growth of aonla (cv. Banarasi) under climatic conditions of Akola, India. Fresh seeds were treated with 3 different concentrations of gibberellic acid GA₃, NAA
or thiourea viz., 100, 200, and 300 ppm. GA₃ at 200 ppm resulted in the tallest seedling height (27.63 cm) and greatest seedling stem girth (0.86%).

Vincent and Thandapani (2000) studied the effect of storage containers and growth regulators on seed performance of papaya at Madurai, India and reported that seeds treated with GA 200 ppm recorded the highest vigour index (1339) and dry matter production (160 mg per 10 seedlings) compared to control.

Dabhi et al. (2000) studied the effect of GA₃, kinetin and thiourea on seed germination and seedling growth of aonla and reported that seeds treated with 200 ppm GA₃ found most effective in increasing seedling height (23.26 cm).

Pandit et al. (2001) studied on improving papaya (Carica papaya) seed germination and seedling growth by pre sowing treatments at Karnal, Haryana and opined that the highest seedling height (8.52 cm), leaves per plant (6.6) and seedling dry weight (0.800 g) under the GA₃ treatment (2.0 mM).

Kalalbandi et al. (2003) conducted a field experiment to investigate the effect of GA₃ at 40, 60 and 80 ppm; NAA at 40, 60 and 80 ppm and KNO₃ at 1% on the germination and growth of Kagzilime. They observed that GA₃ at 80 ppm concentration was the most effective for seedling height and number of leaves.

Meena et al. (2003) studied the effect of seed treatment with gibberellic acid on growth parameters of different papaya cultivars viz., Honey Dew, Coorg Honey Dew, Farm Sel-1 and Hybrid Madhu and reported that 100 ppm GA₃ significantly increased the seedling height (17.83 cm), stem diameter (0.417 cm), number of leaves per plant (10.08), fresh weight (11.54 g) and dry weight of seedling (1.30 g).

Ratan and Reddy (2004) soaked the seeds of custard apple (Annona squamosa) cv. Balanagar in 200, 400 and 600 ppm GA₃ for 12 and 24 hrs to determine their effect on seed germination and seedling growth. Treatment with 400 ppm GA₃ for 12 hrs gave the highest plant height (25.33 cm), root length (12.23 cm) and dry weight of stems (0.245 g) and roots (0.175).

Zhao Chun Xiang et al. (2004) observed that papaya Seedling growth was positively influenced by 50 mg GA₃ per liter.

Venkatarao and Reddy (2005) conducted an experiment to study the effect of osmopriming on germination of mango stone and reported that osmopriming treatment significantly increases the germination per cent on mango stone. They found that seed treated with GA₃ 200 ppm for 24 hr recorded maximum seedling height and vigour of mango stone as compare to control.
Ameen and Imam (2007) found that the seedling length; fresh and dry weight of shoot and root, internodal length of seedling and seedling diameter was maximum with treatment of GA₃ 200 ppm in pistachio seed.

Rajwar et al. (2007) reported that the seeds of wild ber (*Zizyphus munnularia*) treated with growth regulators (250 and 500 ppm GA₃, and Thiourea) affected seed germination and seedling growth. Maximum plant height (34.39 cm) and plant girth (1.43 cm) was recorded with 250 ppm GA₃.

Kumar et al. (2008) conducted an experiment to study the effect of organics and chemicals on germination of mango. They recorded the GA₃ 100 ppm had showed the highest height of seedling.

Babu et al. (2010) studied on seed germination, seedling growth and vigour of papaya under North East Indian condition. The seeds were soaked overnight in different concentrations of gibberellic acid (0, 50, 100, and 150 ppm). GA₃ treatment had a significant effect in enhancing the seedling length and it was maximum with GA₃ 100 ppm (17.38 cm) as against control recording only (10.98 cm). It is concluded that the papaya varieties viz., Coorg Honey Dew, Pant Papaya, Co-2 and Co-7 betters’ seedling growth and vigour are highly suitable for commercial cultivation in north eastern region of India and seedling health can be improved by treating with GA₃ 100 ppm.

Deb et al. (2010) studied the improvement of seed germination and seedling growth of papaya (*Carica papaya* L.) through different pre-sowing seed treatments. Seeds were soaked with GA₃ (at 100, 150 and 200 ppm), sodium thiosulphate (at 20, 25 and 30 ppm) and micronutrient mixtures (4 different combinations of borax and zinc sulphate). Maximum seedling growth (52.32 cm seedling height and 5.18 cm seedling girth) was observed under GA₃ at 200 ppm.

Kadam et al. (2010) concluded that seedling height (18.82 cm) leaves per shoot (26.62), fresh and dry weight of the seedling (25.89 g and 14.46 g, respectively) was recorded maximum with treatment of GA₃ 150 ppm in Kagzilime seeds.

Khatana et al. (2011) reported that Kagzilime seeds treated with 100 ppm GA₃ recorded, the highest plant height, number of leaves, length of seedling, thickness of primary roots, girth of seedling at top, middle and bottom, fresh weight of seedling, dry weight of seedling, total leaf area of seedling as well as survival at 120 DAS under the climatic condition of Anand.
Sehrawat et al. (2011) studied the influence of priming treatments on vigour and viability of papaya seeds at Haryana and revealed that freshly extracted seeds when treated with 1000 ppm GA$_3$ exhibited maximum seedling length (14 cm) followed by 500 ppm GA$_3$.

Supe et al. (2012) conducted an experiment on seed germination and seedling growth of aonla and concluded that seeds soaked in 750 ppm GA$_3$ for 24 hrs combined with Azospirillum recorded maximum shoot length (12.0 cm), root length (18.5 cm), number of leaves per seedling (15.7).

Meena and Jain (2012) studied effect of seed treatment with gibberellic acid on growth parameters of papaya seedlings (*Carica papaya* L.) at Udaipur, Rajasthan and observed that papaya seeds treated with different doses of GA$_3$ showed variations in seedling height and stem diameter. Maximum seedling height (17.83 cm) and stem diameter (0.417 cm) were observed in GA$_3$ 100 ppm as compared to control. Likewise, maximum fresh weight of stem (11.54 g) was observed in GA$_3$ 100 ppm and minimum (10.86 g) in control.

Anjanawe et al. (2012) studied the effect of plant growth regulators on seed germination and growth vigour of papaya (*Carica papaya* L.) seedling cv. Barwani red and observed that seedling parameters viz. completion of germination (23.75 days), first appearance of plumule (12.69 days), seedling height (17.41 cm), stem diameter (0.441 cm) and length of longest root (25.36 cm) were found maximum with the application of 200 ppm GA$_3$ followed by 50 ppm NAA and 50 ppm BA.

Harshavardhan and Rajasekhar (2012) conducted an experiment to enhance the germination and seedling growth of jack fruit (*Artocarpus heterophyllus* Lam.) by different pre sowing treatments. Seeds from fully ripe fruits were soaked in distilled water (control), GA$_3$ at 100 and 200 ppm, NAA at 25 and 50 ppm and KNO$_3$ at 0.25 and 0.5% for 12 hrs and 24 hrs. GA$_3$ at 200 ppm for 24 hrs recorded the tallest seedlings with more absolute growth rate and less number of days taken for attaining graftable size.

Jeevendra (2014) concluded that the application of GA$_3$ at 150 ppm gave maximum height of seedlings (51.93 cm), Maximum root length (24.22 cm), fresh weight of shoots (4.03 g), dry weight shoots (1.51g), fresh weight roots (1.57 g) dry weight of roots (0.54 g), seedling vigour index (3922.41 cm), seedling vigour index (162.38 g) and survival percentage of seedlings (84.55 %) at 150 days after sowing in citrus cv. Kagzilime.
Ishwar (2015) studied on response of jackfruit (*Artocarpus heterophyllus* Lam.) seeds to plant growth regulators and thiourea and concluded that GA₃ @ 200 ppm was the best treatment among all treatments which recorded maximum number of sprouts per seedling (7.23), maximum number of leaves per seedling (14.60), maximum height of shoot (36.68 cm), maximum girth of shoot (7.15 mm), maximum length of root (31.48 cm), maximum number of roots per seedling (44.68), maximum fresh and dry weight of shoots (18.45 and 2.66 g, respectively) and maximum fresh and dry weight of roots (2.94 and 0.61 g, respectively).

Pratibha *et al.* (2015) studied the effect of chemical treatments on the germination and subsequent seedlings growth of papaya (*Carica papaya* L.) seeds cv. Pusa nanha. The results revealed that among the various seed treatment chemicals maximum root length (15.30 cm) and root dry weight (0.32 g) were recorded in seeds treated with GA₃ 200 ppm for 24 hrs.

Ramteke *et al.* (2015) studied on seed germination and seedling growth of papaya as influenced by GA₃ and propagation media at Raipur, Chhattisgarh and revealed that GA₃ 200 ppm is found to be the most effective in growth of papaya seedlings (height of the seedling (19.20 cm), average leaf area (44.89 cm²), stem diameter (5.78 mm), length of tap root (11.6 cm) as well as survival per cent (78.78%) of seedlings).

Mali *et al.* (2015) studied the effect of pre sowing seed treatment with plant growth regulators on germination and growth of papaya (*Carica papaya* L.) and observed that the gibberellic acid @ 500 ppm gave the maximum plant spread (11.60 cm) at 30 days and seedling height (7.58 cm and 12.60 cm), number of leaves per plant (6.67 cm and 9.78 cm) and stem diameter (0.253 cm and 0.323 cm) at 20 and 30 days, respectively.

Padma *et al.* (2015) concluded that the maximum seedling dry weight (4.00 mg) was recorded in seed treated with GA₃ 400 ppm for 24h, 36h and 48h duration, respectively. Vigour index (1566 cm, were recorded maximum in GA₃ 400 ppm in papaya (*Carica papaya* L.) cv. Surya.

Hemant *et al.* (2016) studied the effect of various plant growth regulators on growth parameters of aonla seedlings after seed germination and observed that seed treatment with GA₃ 200 ppm give the highest result in seedling growth parameters
like seedling height (90.16 cm), diameter of stem (10.0 mm) and number of leaves (100.0) after 180 days of sowing.

Parmar et al. (2016) studied the influence of seed priming treatments on germination and seedling vigour of custard apple. The treatments comprised of different concentrations of chemicals (GA$_3$ @ 100 and 200 mg per liter KNO$_3$ @ 1 and 2%, Thiourea @ 500 and 1000 mg per liter, fresh cow dung and urine slurry (1:2 ratio) and hot water treatment. Soaking the seed in GA$_3$ @ 200 mg per liter for 12 hours recorded the highest height of seedling (64.87 cm), shoot length (45.90 cm), root length (20.00 cm), fresh and dry weight of seedling (7.27 g and 4.36 g), stem girth (0.73 cm), relative growth rate (0.026 gram per day), vigour index I and II (0.99 and 14.68) at 120 days of sowing.

Dilip et al. (2017) studied the influence of gibberellic acid GA$_3$ at different concentrations in different time intervals on seed germination and seedling growth of kagzilime at Uttar Pradesh, India. The results revealed that GA$_3$ 80 ppm for 12 hours gave the highest height of plant (18.79 cm) at 120 DAS, number of leaves per plant (26.53), fresh and dry weight of shoot (25.84 g and 14.44 g), tap root (17.44 cm), secondary and fibrous roots (5.98 and 85.99), fresh as well as dry weight (7.04 and 4.95 g), and survival percentage (85 percent) in similar treatment. Therefore, it may be concluded that the GA$_3$ at 80 ppm has a significant effect on the seedling growth of Kagzilime and can be recommended to the grower for obtaining better growth and yield.

Panda (2017) revealed that GA$_3$ 100 ppm recorded the highest numbers of leaves (19.26), the highest shoot length (11.36 cm), the highest root length (11.36 cm), the highest seedling length (21.67cm), the highest fresh weight (2.09 g), the highest survival percentage (63.85 %) and control recorded the highest polyembryony percentage (21.48%) in citrus cv. Kagzilime.

Palepad et al. (2017) studied the effect of seed treatments on seed germination and seedling vigour of custard apple during the year 2015-16 at department of horticulture, Dr. Panjabrao Deshmukh Krishi Vidypeeth, Akola by using completely randomized design with twelve treatments. The seeds treated with GA$_3$ 1000 ppm solution gave the highest seedlings height (23.33, 37.54 and 48.31 cm), girth of plant (0.46, 0.62 and 0.93 cm), number of leaves (17.37, 28.60 and 32.64), leaf area (76.42 cm$^2$), fresh and dry weight of plant and survival percentage (72.81.%).
Jaiswal et al. (2018) studied the effect of growth regulators and chemicals on growth of kagzi lime (*citrus aurantifolia* swingle.) seedlings at Parbhani and observed that the maximum plant height (30.02 cm) was produced under the treatment GA$_3$ 80 ppm, maximum numbers of leaves per plant (28.62) were recorded in GA$_3$ 80 ppm. The fresh and dry weight of shoots, were found maximum in GA$_3$ 80 ppm (20.60 g and 10.04 g, respectively). Hence the GA$_3$ 80 ppm was found more productive and the maximum induction in the physiological activities of seedlings than the other growth regulators and chemicals.

### 2.3 Effect of container on seed germination

Bahuguna and Lal (1990) studied the effects of environmental condition and different soil mixtures on germination of *Acacia nilotica* at nursery stage. Seeds were sown in polythene bags (22 × 15 cm), perforated tin trays (40 × 20 × 7 cm) and wooden boxes (52 × 52 × 21 cm), and raised nursery beds (5 × 1 m). They concluded that sowing in polybags or wooden boxes gave better germination percentage.

Saroj et al. (2000) recorded more than nine per cent seeds germinated in polybags (40 cm x 15 cm size) at 5 days after sowing, while in polytubes of same size, it was only five per cent. At final observation, more than 91 per cent seeds germinated in polybags as compared to 82.60 per cent in polytubes. The data revealed that the polybags either perforated or unperforated were better than polytubes (25 cm x 10 cm) with respect to both for earliness and better germination in case of aonla.

Lal et al. (2004) reported that maximum seed germination (86.24%) exhibited by ber (*Zizyphus mauritiana* Lamk.) seeds when sown in the polythene tubes in comparison to seeds sown in the polythene bags (78.03%), nursery beds (77.14%) and *in situ* (69.37%).

Ferdousee et al. (2010) observed that polybags of (12 × 15 cm or 5 × 6 inch) showed the highest germination per cent (55%) followed by polybag of (23 × 15 cm size, or 9 × 6 inch) and root trainer, in *Leucaena leucocephala*.

Jabbar et al. (2010) studied on the growth of *Albizia procera* seedlings grown in different containers and nursery bed and observed that the seedlings raised in polybags of (23 × 15 cm) size revealed best performance in respect to germination (95%) in *Albizia procera*.

Bali et al. (2013) observed the maximum germination (74 %) of *Terminallia bellerica* seedlings in plastic pots of (4000 ml) followed by root trainers and minimum in the polybags.
Athulya (2016) indicated that polybags recoded significantly minimum days (16.38) for final germination and gave highest germination percentage (68.82 %) in papaya cv. Madhubindu.

### 2.4 Effect of container on seedling growth

Whitcomb (1981) indicated that root system quality can be improved in the propagation container. Vertical air-root-pruning was accomplished by removing slits in the corners of small containers. As the root grows downward and outward, it contacts the openings and roots are air-pruned, stimulating secondary branching and producing a more fibrous root system.

Midnawati and Rostiwati (1989) observed that height and diameter of seedlings are significantly and positively affected by increase in container size/volume seedling of *Agathis loranthifolia* raised in plastic bags of three capacities (0.5, 1.0 and 2.0 kg potting medium).

Chadhar *et al.* (1999) concluded that about 4 months old seedlings of *Dalbergia sissoo* and *Acacia procera* raised in root trainer can be used for field plantations in place of conventional planting (about one year old) to get almost same survival. The *Albizia procera* seedlings raised in polybags (23 x 11 cm) with perforations at bottom performed best in respect of seedling growth parameters. However, the polybag of 11 x 6 cm dimensions with 6 perforations at bottom recorded best values for most of the seedling quality parameters viz., Root/shoot ratio, Sturdiness and Dickson’s index.

Saroj *et al.* (2000) recorded the perforated polybag (40 cm x 15 cm) was better than the polytube (25 cm x 10 cm) with respect to root length (61.25 cm), root diameter (0.48 cm), root volume (19.00 ml), fresh and dry weight of root (5.00 g and 1.35 g). However, the numbers of secondary and tertiary roots were more in seedlings grown in polytubes (4.25 and 3.75) than polybags (3.25 and 2.00) in case of aonla.

Ginwal *et al.* (2001) reported that the root trainers of 300 cc cell volume is the best size of root trainer for *Acacia nilotica*, however, when there is a space constraint in nursery and the objective is to raise more number of seedlings per unit area of the nursery space, the hiko tray 150 cc volume is equally good.

Gera and Ginwal (2002) reported that field assessment of seedling after one and a half year of planting revealed that root trainer (150 cc) raised seedlings registered maximum growth increment for all growth parameters except collar diameter in case of *Dalbergia sissoo*.
Annapurna et al. (2003) studied overall growth of sandal wood seedlings at Bangalore. The height of seedling, collar diameter and seedling biomass were best in root trainers followed by plastic container and finally polybags. Among the root trainers, the 600 ml size was optimum for most of the parameters of seedling quality, including height (20.4 cm), total dry weight (3.06 g), shoot dry weight (1.66 g), root dry weight (1.41 g) and quality index (0.37). The highest root: shoot ratio (1.00) in root trainer grown sandal wood seedlings which are at par with the plastic container (1000 ml), while lowest root: shoot ratio was found with polybags (0.45).

Lal et al. (2004) reported that the maximum seedling height (73.10 cm) and diameter (0.76 cm) in in-situ (control) followed by the nursery beds (65.28 cm and 0.69 cm) and polythene tubes (60.71 cm and 0.60 cm) with minimum in polythene bags (54.27 cm and 0.53 cm). They concluded that polythene tubes are best container for raising rootstock for ber than polythene bags.

Rathore et al. (2004) reported that seedlings of Casuarina equisetifolia raised in 300 cc single cell root trainer have the maximum growth parameter at the age of 3 months.

Fatema (2005) conducted an experiment to observe the effect of different polybag size on the growth of kalokoroi (Albizia lebbeck), rain tree (Albizia saman) and Ipil-ipil (Leucaena leucocephala) seedlings. Polybag size showed significant influence on different growth parameters of the seedlings. All species grown in 23 cm × 15 cm sized polybag was observed to be superior to other treatments. The combined effect of different polybag sizes and species was also highly significant in all the parameters. The best performance was observed in rain tree grown in 23 cm × 15 cm size polybag followed by Ipil-ipil grown in 23 cm × 15 cm size polybag and the lowest performance showed in Ipil-ipil grown in 17 cm × 11 cm size polybag.

Qaisar and Mishra (2005) reported that container type and size significantly influenced the growth of Acacia catechu seedlings, side perforated polybag raised seedlings gained maximum height, while root trainer 250 cc closely followed by bottom perforated polybag grown seedling exhibited maximum collar diameter. Biomass parameters increased with increase in container size and were maximum for polybags. However, biomass parameters were highest in hiko tray raised Pinus roxburghi plants.

Araujo et al. (2006) concluded that the seedlings of papaya raised in polyethylene bags of 20 x 32 cm size gave superior performance in all the characters
like plant height (25.52 cm), diameter of stem (6.57 mm) and leaf number (17.00) than polyethylene bags of 15 x 20 cm size and polystyrene trays of 72 cells.

Barad (2006) studied the influence of media and root trainer on growth of rayan seedlings and revealed that root trainer size 300 cc performed best for seedling height (7.98 cm), collar diameter (2.06 mm), number of leaves (6.85), total biomass (1.29 g) and root length (7.65).

Hall et al. (2009) observe that over 22 % of growers surveyed indicated that they had used biocontainers in their operations. Of the remaining 78 % that participated in the study, only 6% noted that they would like to add biocontainers to their current nursery processes.

Costa et al. (2009) concluded that the polyethylene bag produced the best papaya seedlings with highest fresh mass of aerial portion (7.44 g) and dry mass of aerial portion (0.92 g) as compared to polystyrene trays with 0.49 g and 0.08 g fresh and dry mass of aerial portion of papaya seedlings, respectively. The highest fresh mass of root portion (3.13 g) and dry mass of root portion (0.24 g) as compared to polystyrene trays with 0.51 g and 0.05 g fresh and dry mass of root portion of papaya seedlings, respectively.

Ferdousee et al. (2010) observed that Polybags of (23 × 15 cm size, or 9 × 6 inch) produced the best seedlings with highest root dry weight (12.28 g), maximum number of root nodules (50), maximum nodule fresh weight (0.41 g) and maximum nodule dry weight (0.16 g) followed by (12 × 15 cm or 5 × 6 inch), nursery bed and root trainer. Polybags of (12 × 15 cm or 5 × 6 inch) produced the seedlings with highest root: shoot ratio (0.86) followed by root trainer and polybags of (23 × 15 cm or 9 × 6 inch) which was significantly differing from nursery bed produced seedlings. The maximum vigour index (10460) with the seedlings raised under nursery bed followed by root trainer while polybags of (12 × 15 cm or 5 × 6 inch) and polybags of (23 × 15 cm or 9 × 6 inch) produced seedlings with minimum vigour index in Leucaena leucocephala.

Jabbar et al. (2010) studied on the growth of Albizia procera seedlings grown in different containers and nursery bed and observed that The highest shoot length (109.0 cm), shoot dry weight (18.50 g), collar diameter (6.6 mm), leaf dry weight (16.30 g) mean number of leaves (15), root length (41.3 cm), root fresh weight (20.16 g), root dry weight (17.25 g), number of nodules (65), nodules fresh weight (1.76 g) and nodules dry weight (0.57 g) with the treatment of polybags of (23 × 15 cm size, or
9 × 6 inch) followed by polybags of (12 × 15 cm or 5 × 6 inch), which was significantly differ than nursery bed and root trainer. The maximum root: shoot ratio (1.50) with the treatment root trainer followed by nursery bed, polybags of (23 × 15 cm or 9 × 6 inch) and polybags of (12 × 15 cm size, or 5 × 6 inch). The maximum vigour index (8825.5) with nursery bed followed by polybags of (12 × 15 cm size, or 5 × 6 inch) and polybags of (23 × 15 cm or 9 × 6 inch), while root trainer produced seedlings with minimum vigour index in *Albizia procera*.

Berko *et al.* (2011) studied the influence of size of polythene bag on cashew (*Anacardium occidentale*) seedlings. Polybags of different sizes viz., 4 x 6 inches, 4 x 7 inches, 5.5 x 6 inches, 5 x 7 inches, 5.5 x 7 inches and 7 x 10 inches were used in the experiment. The results showed that seedlings in polythene bag sizes 5.5 x 7 inches and 7 x 10 inches were superior to the polythene bag sizes of 4 x 6 inches, 4 x 7 inches, 5.5 x 6 inches and 5 x 7 inches. The size of the nursery bag had a significant influence on seedling vigour, number of leaves, plant height, stem girth, leaf area and root length at nursery growth. It was concluded that optimum performance was observed with bag size of 5.5 x 7 inches.

Bali *et al.* (2013) observed the maximum shoot height (42.5 cm) in plastic pots of (4000 ml) followed by poly bag (36.10 cm) and minimum in root trainers (19.30 cm) after 12 months of seed sowing. However, maximum collar diameter (8.6 mm) was observed in root trainers followed by plastic pots (8.5 mm) and minimum (7.7 mm) in polybag *Terminallia bellerica* seedlings.

Haldankar *et al.* (2014) conducted an experiment for optimizing the size of poly bag for cv. Alphonso and Kesar for vigorous growth of epicotyl grafts. Among all the treatments, the larger size bags of 10” × 14” improved the vigour of grafts remarkably by producing longer tap root, greater root spread and more number of secondary roots with increased plant height, girth at collar, number of leaves per graft and plant spread over the small sized bags of 6” × 8” size.

Ritesh *et al.* (2015) recorded that the earthen pot grown papaya seedling showed significantly maximum leaf area (37.09 cm²), fresh weight of seedling (6.73 g), and dry weight of seedling (0.597 g).

Athulya (2016) indicated that polybags gave the seedling growth parameter also significantly influenced by polybags where it recorded maximum height of seedling (11.12 cm, 15.44 cm, 18.61 cm and 22.45 cm), stem girth (2.60 mm, 3.14 mm, 3.44 mm and 3.76 mm) at 45, 60, 75 and 90 DAS, respectively and number of
leaves where found maximum (7.03, 7.52 and 7.83) at 45 to 75 DAS, respectively in papaya cv. Madhubindu.