Advancement and efficacy of plant growth regulators in Ber (Ziziphus mauritiana Lamk) - A review

Pushpraj Singh
Krishi Vigyan Kendra, BK-II, S. D. Agricultural University, Tharad - 385535 (Gujarat), India
Kapil Mohan Sharma
Date palm Research Station, SDAU, Mundra, Kachchh - 370421 (Gujarat), India

*Corresponding author. Email: pushprajsgnh9@gmail.com

How to Cite
Singh and Sharma (2020). Advancement and efficacy of plant growth regulators in Ber (Ziziphus mauritiana Lamk) - A review. Journal of Applied and Natural Science, 12(3): 372 - 379. https://doi.org/10.31018/jans.v12i3.2326

Abstract
Ber (Ziziphus mauritiana) is an important minor fruit crop of India. Over the years the crop is now widely domesticated and commercial orchards of Ber are now available. With wide commercialization, many physiological problems, i.e. flowers and fruit drop, embryo abortion, poor flowering and fruit setting, abnormal and small size fruits etc. were observed which cause huge loss to the growers. In order to minimize these problems, over the years many experiments and advancement have been done, and among them, usage of plant growth regulators is one of the most adopted methods and is utilized to improve flowering fruiting and yield with improved fruit quality. The current review discusses the role of different plant growth regulators and how they influence each fruit character. This information could be useful to the researchers in planning further advance research in this aspect and for the commercial growers to decide the proper treatments to mitigate the problems.

Keywords: Ber, Fruit drop, Fruit retention, GA3, IAA, NAA, Plant growth regulators

INTRODUCTION
Ber (Ziziphus mauritiana Lamk.) is an important arid fruit crop that belongs to the family Rhamnaceae. The crop is originated in India but one of its related species Z. jujube is widely cultivated in the hills of Himalayas. It is well known for its specificity on hardiness and adaptive nature in the adverse soil and climatic condition. It is one of the fruit crops which can give good returns even under rainfed conditions and can be grown in a variety of soils and climatic conditions (Krishna et al., 2014). This fruit crop is commonly grown in India and also in other countries i.e., China, Afghanistan, Iran, Russia, Syria, Myanmar, Australia and USA. In India, ber is cultivated in various part of the country particularly in arid and semi-arid regions comprising of 50000 ha area producing 5.13 lakh MT of fruits (Anonymous, 2016). The major growing regions are Rajasthan, Madhya Pradesh, Uttar Pradesh, Haryana, Punjab, Gujarat, Bihar, Maharashtra, Andhra Pradesh and Tamil Nadu. Ber is a nutritious and delicious table fruit. The fruit is a rich source of ascorbic acid, vitamin B-complex and minerals and the root, stem bark, flower and seed are used in Ayurveda to treat indigestion, headache, cough etc. The leaves are good fodder for animals, especially goats and ships. The ber is a hardy plant and shows summer-deciduous nature and can grow under low-inputs which makes the plant sustain salinity and drought and becomes a popular fruit crop of arid and semi-arid regions. In spite of having vast potential, the ber fruit has limited cultivation, unlike the other fruit crops as for commercial production. It needs proper care and adequate plant management. Generally, ber growers faced various problems like low and inferior quality yield, flower and fruit drops and poor fruit setting. These problems occur due to various factors, i.e. improper nutrition management, inadequate cultivation practices and changes in environment variables. Plant nutrition’s help in the production of raw materials that require the plant to sustained normal growth. However, the hormones help in translocation of raw materials and regulate the normal physiological process in plants. Imbalance of hormones in the plant altered normal physiological processes (Singh et al., 1991; Singh and Bal 2006; Karole and Tiwari 2016) that directly affects on the reproductive response of the plants.
Application of plant growth regulators is an integral part of modern crop production practice for increasing production of quality fruits (Kumari et al., 2018). Plant growth regulators like NAA, IAA, IBA, 2,4-D, 2,4,5-T; GA, TIBA and Ethephon are widely used for improving the flowering, fruit set, size and quality of fruit as well as yield. Plant growth regulators play a great role in the regulation of physiological phenomena, growth, yield and quality of various fruit crops (Suman et al., 2017). In ber, the PGRs are widely used for increasing fruit set, controlling fruit drop, enhancing the quality and uniform maturity (Sahoo, et al., 2019; Kumar et al., 2017). During last two decades considerable research has been done on use of various plant growth regulator, time and amount of application (Lawes, and Woolley 2001; Petracek et al., 2003; Ram et al., 2005; Singh and Randhawa 2001; Singh and Bal 2008; Ghosh et al., 2009; Gill and Bal 2013; Arora and Singh 2014; Karole and Tiwari 2016; Majumder et al., 2017); Kumar et al., 2018; Sheoran et al., 2019; Devi et al., 2019). The main objective of this article was to summarize the recent advances in the use of various plant growth regulators in increasing production efficacy of ber (Ziziphus mauritiana) fruit.

**Plant growth regulators:** Plant growth regulators are the non-naturally occurring synthetic compounds (Su et al., 2017) requires in minute quantity to promote or inhibit the plant physiological process (Rademacher 2015). PGRs regulate the growth and development of plants by regulating the internal processes (Bons et al., 2015). An exogenous application of these substances modifies the growth responses. Auxins were the first group of growth regulators discovered during 19th to early 20th century (Masuda and Kamisaka 2000). Subsequently, during the middle of the 20th century, the other growth regulators i.e. abscisic acid, cytokinins, gibberellins and ethylene were also identified as synthetic plant hormones (Kende and Zeevinart, 1997; Ferguson and Lessenger 2006). Since then marked experiments has done to identify their efficacy in the regulation of plant physiological process (Sara et al., 2014; Su, 2017). Discovery of plant hormones and identification of their efficacy in the improvement of yield and qualitative parameters had a great impact on the fruit production (Bisht et al., 2018). Between various groups of growth regulators, auxin and gibberellins are widely used to control the fruit drop and to improve the quality of fruit (Suman et al., 2017). However, gibberellins and cytokinins had shown marked improvement in fruit characteristics, i.e. size, colour, shape and enhancement of shelf life (Lawes, and Woolley 2001). In ber, plant growth regulators are widely used to regulate various physiological phenomena viz. flowering, fruit seating, size and quality improvement (Kumar et al., 2017).

**Effect of growth regulators on propagation:** The ber is propagated sexually by seed as well vegetative-ly using the budding technique. The germination responses of ber seed are not adequate due to its stony endocarp present in the fruit that makes the seed impermeable to water and air and normally takes about 3-4 weeks for germination (Sinohrot et al., 1970). Among the many cultural practices, Bhambhota and Singh (1971) reported higher seed germination (76%) by sowing the kernels as compared to that by sowing the whole seed (54%). Whereas Yazdanpanah et al., (2013) showed the high percentage of germination (65%) were obtained with the treatment of scarification with sandpaper and the treatment of sulphuric acid for 10 min (46%). However, among the growth regulators, gibberellic acid and benzyladenine widely used to break dormancy in ber (Murthy and Reddy, 1990; Sheoran et al., 2019). Hore and Sen (1994) treated the ber seed with GA3 at 200 ppm and found maximum germination 98.76% and further extended seed longevity. They also reported the combination of gibberellic acid with nutrient (composed of 1% Microshakti and 1000 ppm K2HPO4) caused maximum seedling growth. However, seeds treated with gibberellic acid at 400 ppm combined with 1000 ppm chloromequat increased the polyembryony (Sheoran et al., 2019). Among the various scarification treatments under nursery condition, gibberellic acid-soaked with 250 ppm for 24 hours was best. It resulted into highest plant height (97.1cm), seedling diameter (4.77mm), inter-nodal length (31.3mm), number of leaves/plant (116.3), leaf area (6.29 cm2) at 120 days after sowing or at the time of budding followed by gibberellic acid @ 500 ppm for 24 hours.

**Response of growth regulators with pruning intensities:** Pruning is an important operation for better flowering and fruiting in ber fruit. In India flowering period of ber varies from early June to late November in different varieties and under different agroclimatic conditions (Neeraja et al., 1995, Josan et al., 1980). Flowering can, however, be regulated to some extent by timing the pruning operation. In India, after the fruit harvesting, the branches of the ber tree are heavily pruned just keeping the main stem which also coincides with the summer at many places when the plant naturally shed their leaves and enter into dormancy. The flower buds in ber are borne on both mature as well as current season's growth, and the inflorescence is an axillary cyme (Pareek et al., 2007). The newly emerged healthy shoots produce better flowers and fruits. The intensities of pruning affect the flowering and fruiting in ber. Application of growth regulators after pruning improves shoots health resulting in better yield and quality of fruit (Singh et al., 2017). The highest number of sprouted shoots per branch and shoot length have been obtained by 75% pruning + GA3.
10 ppm. Significantly maximum number of fruit set (60.14%), fruit retention (43.80%) were recorded with 50% pruning + GA3 10 ppm followed by 50% pruning + NAA 10 ppm. Singh et al. (2019) experimented four different pruning intensity of previous season growth, i.e. no pruning, 25% pruning, 50% pruning, 75% pruning and sprayed plant growth regulators viz. GA3 @ 10 ppm and NAA @ 10 ppm. He found significantly higher fruit weight (23.69 g) with 75% pruning intensity + NAA 10 ppm followed by 75% pruning intensity + GA3 10 ppm and least being in control. However, maximum fruit yield (110.54 kg/plant) has been achieved by employing 50% severity of pruning with NAA 10 ppm, which found significantly superior over 25% pruning intensity + NAA 10ppm and control.

Effect of PGRs on flowering and fruit set: The flowering and fruiting process is the most important and periodic phenomenon of the plants (Kebede and Isotalo, 2016). Duration of flowering in ber is prolonged and the time of blossoming largely depends on climatic conditions (Pareek et al., 2007). However, flowering and fruiting is a complex network where more than one plant hormone is involved in controlling various aspects of fruit development (Kumar et al., 2014). Flower formation and development are known to be influenced by hormones, especially by cytokinin, gibberellins, and auxins (Chandler, 2010). Endogenous hormones level of the plant plays a great role in flowering and fruit set. Alteration or disturbance of these substances reduces metabolic activities and affects the normal physiology of the plant. According to Bons and Kaur (2019) application of plant growth regulators improves the internal physiology of developing fruits that induce fruit seating and also reduce fruit drop. Growth regulators play a great role in flowering induction and fruit set in ber. Various researches have demonstrated the use of different growth regulators at various concentrations, also at various stages that have a significant influence on flowering and fruit set in ber. Sandhu and Thind (1968) achieved maximum fruit set with the application of NAA 5 and 10 ppm in ber cv. Umran. Application of paclobutrazol 60 ppm sprayed at fruit set stage and at active growth phase improved in fruit setting (Rattan and Bal, 2008). However, Angamuthu et al., (2004) observed that the fruit set was increased with the application of IAA (indole acetic acid) 100 ppm but decreased with IAA 200 ppm in ber cv. Tikdi. Bhosale (2012) recorded maximum fruit set (26.67%) with GA3 20 ppm on Mehrun cultivar of ber. Results of Majumder et al., (2017) investigation revealed that the application of 2, 4-D @ 10 mgL−1 was better for inducing the highest fruit set 48.80 %. Kumar et al. (2018) studied the effect of NAA, GA3 and 2,4,5-T on fruit set in ber and they found highest initial fruit set (162) with 2,4,5-T 20 ppm followed by 2,4,5-T 25 ppm and GA3 25 ppm, while the lowest (159) was registered in NAA 10 ppm.

Effect of PGRs on fruit retention: In ber fruit retention varies with varieties. There is a significant relationship between fruit retention and fruit set (Adhikary et al., 2019). Higher fruit setting does not lead to maximum fruit retention. Sharma et al. (1990) recorded higher fruit seating in the cv. Sanur-2 but fruit retention was not up to the mark. Ghosh et al., (2009) examined the effect of NAA at 25, 50 and 100 mgL−1 and GA3 at 10, 20 and 40 mgL−1 in ber cv. Banarasi Karka. They were thoroughly sprayed three times just after fruit set at 21 days interval. Results revealed that the NAA at 25 mgL−1 gave significantly highest fruit retention (75%) which resulted in the highest fruit yield of 120.5 quintals as against 64.7 quintals ha−1 in control. However, GA3 did not show any significant effect on fruit retention. Whereas, Pandey (1999) revealed that the NAA 20 ppm and GA3 15 ppm influence the fruit retention in cv. Banarasi. Bankar and Prasad (1990) reported the effect of GA3 and NAA at 10, 20 or 30 ppm alone or in combination at flowering and after 15 days of the first spray-on eight-year old ber cv. Gola (Gill and Bal, 2009). Results indicated that NAA at 30 ppm spray was better for fruit retention. Majumder et al., (2017) obtained maximum fruit retention (42.83%) and total no. of fruits/tree (514) with the application of NAA @ 20 mgL−1. However, Bhosale (2012) observed fruit retention percentage 48 per cent with GA3 20 ppm on cv. Mehrun. Karole and Tiwari (2016) reported better fruit retention 49.28% from foliar application of NAA 60 ppm+ GA3 30 ppm + 2.0% urea.

Effect of growth regulators on flower and fruit drop: Dropping of immature flower and fruit from the mature tree is a natural tendency of the ber crop. It is a major constraint in ber production. Normally in ber, the number of fruit set is very high, but the extent of fruit retention varies according to the cultivar type and on the level of production of endogenous plant hormones (Azam-Ali et al., 2006). According to Adhikary et al., (2019), there was a highly negative correlation between fruit drop and fruit set and in fruit drop and fruit retention in ber. The problem can be minimized to some extent by the use of plant growth regulators (Suman et al., 2017). Generally, fruit drop occurs due to imbalance of auxin in the plants. If auxin level reduces and the concentration of abscisic acid increases that results in the formation of the abscission layer and dropping of the fruits. Exogenous applications of plant growth regulator can effectively control the fruit drop in ber (Kumar et al., 2018). According to Teotia and Chauhan (1964) maximum fruit drop during early fruit development stage in ber. They recorded the highest fruit drop in cv. Banarasi peweari as compared to Thornless and Banarasi Karaka. Similarly,
Yamdagini et al. (1968) observed only 8-9 per cent fruit of the total fruit set was retained at maturity. Singh and Singh (1976) reported that 30 ppm 2, 4, 5-T reduced the fruit drop by 14.19 per cent over control. However, in their study NAA, 2,4-D, and methyl ester of naphthalene acetic acid could not reduce the fruit drop. Bal et al. (1981) proved 2, 4, 5-T 25 ppm to be the most effective treatment for reducing the fruit drop up to 11.07 per cent in ber cv. Sanaur-2. However, in ber cvs. Sanaur-2 and 5, NAA at 10 ppm and 2, 4, 5-T at 25 ppm were the most effective treatments in reducing the fruit drop (Bal et al., 1982). Singh (2000) observed that the paclobutrazol at 200 ppm was effective in minimizing fruit drop and also for the fruit cracking. Singh and Randhawa (2001) observed that GA3 at 60 ppm accounted for the lowest fruit drop and highest fruit set while Yadav and Chaturvedi (2005) reported that the GA3 at 30 ppm showed minimized fruit drop (80.28%) and increased fruit retention (19.72%) in ber cv. Banarsi Karaka. Ram et al. (2005) revealed the effect of GA3 at 15 and 25 ppm on fruit drop and increasing the fruit retention in ber cv. Banarasi Karaka. Gill and Bal (2008) studied the efficacy of NAA (20, 30 and 40 ppm) by spraying them during the last week of October and again in the last week of November. Minimum fruit drop and maximum fruit retention were recorded with NAA 30 ppm. Devemani et al., (2009) tested GA @ 40 ppm and sprayed twice on 20th October and another on 20th November in ber cv. Banarasi Karaka and decreased fruit drop (74.25 %) was observed. Gill and Bal (2013) found the lowest fruit drop 58.52% with 30 ppm NAA. They also observed that the fruit drop mainly occurred up to in between fruit set during October till 31st January 60 %but, thereafter the fruit drop per cent decreased up to 17.66 till harvest in the Umran cultivar of ber. However, Karole and Tiwari (2016) reported minimum fruit drop 51.72 % recorded with NAA 60 ppm+ GA3 30 ppm+ 2.0 % urea. While Kumar et al. (2018) suggested 2, 4, 5-T 20 ppm as most effective growth regulator to control the fruit drop in ber.

Effect of growth regulators on physical fruit traits and quality: Physical fruit characters of ber like fruit size, weight, volume, specific gravity, colour, surface, palatability rating are the qualitative characters. Quality is an important parameter of the fruit that determines its market value. Market acceptability of ber fruit can be improved with the application of growth regulators. Arora and Singh (2014) found a significant increase in fruit size traits, i.e. fruit length, breadth, weight and volume was recorded with the application of NAA at 30 ppm. While, the palatability rating of fruits in terms of taste, colour and texture of fruit was recorded maximum with the application of GA3 at 50 ppm. Meena et al., (2013) in their experiment revealed that the application of 100 ppm NAA combination with 0.4% FeSO4 during the fruit development stage (pea size) was effective in increasing the fruit weight (18.35 & 22.95%), fruit length (23.11 & 27.95%) and fruit width (20.15 & 17.9%) receptively over the control in ber cv. Gola. According to Gill and Bal (2013), GA3 at20 ppm, 40 ppm and NAA at 30 ppm was effective in increasing size and weight of ber fruit. Similarly, Devi et al.(2019) also reported better results on fruit length (4.71 cm), fruit width (2.76 cm), fruit volume (15.64 cc), fruit weight (15.68 g) and weight of fruit pulp (14.64 g) from GA3 at 20 ppm. However Karole and Tiwari (2016) achieved better fruit length(3.58 cm), fruit diameter (3.31 cm), fruit volume (24.46 ml), pulp thickness (1.21 cm), fruit weight (20.08 g) from pre-harvest foliar application of NAA 60 ppm + GA3 30 ppm + 2.0% urea. Whereas in Case of Verma et al.(2016) GA3 at 150 ppm was proved to be an effective plant growth regulator to enhance the yield and physical character of ber fruits. Gami et al.(2019) reported that maximum fruit length (3.17 cm), fruit diameter (3.00 cm), fruit volume (23.50 ml), fruit weight (22.87 g), stone weight (1.70 g), pulp weight (20.67 g), specific gravity (0.97) with NAA 60 ppm + KNO3 1.5% + ZnSO4 0.5%.

Effect of growth regulators on fruit yield: The yield is a major and foremost important parameter for any crop which determines its commercial value. In general potentiality of yield in ber, depends on cultivars / varieties and also on the crop management practices.

But sometimes the plant physiological process also affects the yielding capacity of the crop. The use of growth regulator to balance the physiological process is practised for many years. The effect of plant growth regulators like GA3 and NAA on the determination of ber yield has been tested by various researches. Pandey (1999) reported that GA3 at 15 ppm followed by NAA at 20 ppm resulted in the highest fruit yield in ber cv. Banarasi Karaka. Singh (2000) reported that a higher dose of paclobutrazol (200 ppm) increased the fruit yield in Gola, Seb and Umran cultivars of ber. Singh and Randhawa (2001) recorded the highest fruit yield in Umran cultivar of ber with NAA 60 ppm. Bhati and Yadav (2003) found that fruit yield was higher with the application of NAA at 20 ppm followed by 2 per cent urea in ber cv. Gola. Kumar and Reddy (2004) obtained the highest fruit yield with a foliar spray of 3 per cent thiourea, followed by 3 per cent potassium nitrate in ber cv. Umran. Singh and Bal (2008) applied foliar sprays of various chemicals viz., potassium sulphate(0.5, 1.0 and 1.5%), potassium nitrate (0.5, 1.0 and 1.5%), paclobutrazol (100, 200, 300 ppm) and naphthalene acetic acid (20, 40 and 60 ppm) along with control at active growth phase of the fruit on nineteen years old trees of ber cv. Umran. Maximum fruit yield (81.30 kg/tree) was recorded with an application of 60 ppm NAA. Ghosh et al., (2009) applied seven
treatments contained growth regulators viz., NAA at 25, 50 and 100 ppm and GA_3 10, 20 and 40 ppm and control (water spray) on 6 years old Banarasi Karaka cultivar of ber. These chemicals were thoroughly sprayed three times just after fruit set at 21 days interval. Results of two years of investigation revealed that application of NAA at 25 ppm gave significantly highest fruit yield of 120.5 quintals as against 64.7 quintals per hectare in control. No beneficial effect of GA_3 on improving fruit yield was observed. In the experiments of Wangbin et al., (2008) with jujube “Dongzao” (Z. Jujube Mill.) the application of Mo 50 ppm + girdling + GA_3 15 ppm and Mo 100 ppm + girdling + GA_3 15 ppm during the flowering period increased the fruit yield per tree by 7.11 kg and 5.95 kg, respectively. Gill and Bal (2013) the highest fruit yield was recorded in trees sprayed with 30 ppm GA_3. Kumar et al., (2017) studied the effect of growth regulators on the yield of ber cv. Banarasi Karaka. They found the highest concentrations of all the growth regulators, i.e. 30, 35, and 25 ppm caused a greater effect in boosting the yield over its lower and medium doses. Maximum fruit yield was recorded with 2, 4, 5-T at 25 and 20 ppm(43.58 and 45.06 kg) succeeded by NAA at 30 and 20 ppm (34.66 and 36.05 kg) and GA_3 25 ppm (28.51 and 29.60 kg) during both year of the experiment. Further, they have noticed that increasing concentrations of all the growth regulators caused a significant increment in the yields. Majumder et al., (2017) obtained the maximum no of fruits/tree (514) with the application of NAA @ 20 mg L^{-1}. Application of GA_3 @ 20 mg L^{-1} recorded significantly higher yield (30.67 kg/tree) in ber cv. BAU-Kul-1.

**Effect of PGRs on biochemical parameters:** The bio-chemical character (TSS, Acidity, TSS: acid ratio, Total sugar, and ascorbic acid) is an important criterion that have been used to evaluate the quality of fruits. Ber fruits ideally enriched with bio-chemicals composition, i.e. total soluble solids 12 to 23%, the acidity of fruit should be less than 0.13 to 1.42 per cent, total sugars 1.4 to 9.7 per cent, and ascorbic acid content in different ber cultivars ranged from 39-166 mg/100 g of pulp (Ghosh and Mathew, 2002); Obeed, et al., (2008). The biochemical properties vary from the variety. These properties are also influenced by the status of nutrient and level of hormones in the plant. Application of growth regulators improved physicochemical attributes of ber (Majumder et al., 2017). If plant imbalances or deficit important nutrient or hormones, that directly affects on biochemical properties of fruits. Application of plant growth regulators at the right time with the right concentration shown significant benefit in biochemical properties of ber fruit. Sandhu et al. (1990) reported that NAA when sprayed during lag phase, increased total sugars in ber cv. Umran. However, Bal et al., (1993) applied ethephon at 0, 100, 200, 300, 400 or 500 ppm to 13-year-old Umran ber trees as a foliar spray when fruits were just changing colour and found that treatment with 400 or 500 ppm ethephon produced fruits with the highest sugar contents. Kale (2000) found better results in improving fruit quality with 20 ppm GA_3 applied at full bloom and 15 days after flowering in ber. Singh (2000) found the best result with a spray of 150 ppm paclobutrazol in increasing the TSS contents in Gola, Seb and Umran cultivars of ber. Yadav and Chaturvedi (2005) found that the GA_3 30 ppm increased total soluble solids content 18.93° Brix in Banarsi Karaka cultivar of ber. Highest total soluble solids content (10.83%) was recorded with 100 ppm paclobutrazol treatment sprayed at the active growth phase of the fruit on nineteen years old trees of Indian jujube cv. Umran (Singh and Bal, 2008). Whereas, Gill and Bal (2008) found maximum vitamin C content with the application of NAA at 30 ppm, applied at last week of October and again in the last week of November. Whereas, Singh and Bal (2008) achieved higher vitamin C (98.77 mg/100 g pulp) with the spray of 200 ppm paclobutrazol in Umran cultivar of ber. Karole and Tiwari (2016) found that pre-harvest foliar application of NAA 60 ppm + GA_3 30 ppm + 2.0% urea increases the total soluble solids (19.68° Brix), reducing sugar (5.42%), non reducing sugar (4.57%) and chlorophyll content (71.0 S pad Value) in cultivar Gola. Gami et al., (2019) found maximum TSS (15.93° Brix), minimum acidity (0.26 %), ascorbic acid (49.47 mg/100g of pulp), reducing sugar (6.11 %), total sugars (11.87 %), non-reducing sugar (5.76 %) from NAA 60 ppm + KNO_3 1.5% + ZnSO_4 0.5%.

**Conclusion**

The present study concluded that being as a hardy crop, ber (*Z. mauritiana* Lamk.) requires minimal management, and it can give handsome economic returns if managed properly. Due to biotic and abiotic stresses and improper management practices, the declining trend has been noticed in productivity and quality. The major problems of growers were faced, i.e. heavy fruit drop, less fruiting, and poor-quality fruits. The results reported from various researchers on the application of plant growth regulators have shown marked improvement in the management of elucidated problems. In recent time the use of plant growth regulators is given prime importance in horticulture crop production system. The remarkable experiment has been done on the use of PGRs for improving fruit set, decreasing fruit drop, improving physical characteristics and biochemical composition. However, there is a need to have more advancements in the use of PGRs in canopy management, fruit quality improvement and increasing shelf life of ber fruit.
REFERENCES

1. Adhikary, T., S. Kundu, S. Shivakumar and Ghosh, B. (2019). Pattern of Fruit Drop, yield, Maturity and Harvesting of Different Varieties of Ber (Ziziphus mauritiana Lamk.) in New Alluvial Zone of West Bengal. International Journal of Current Microbiology and Applied Sciences. 8 (12): 2249-2257. doi: 10.20546/ijcmas.2019.8.1267

2. Angamuthu, M., Sharma, V.P., Singh S. K., Jindal, P.C., Saxena, S.K. and Nath V. (2004). Effect of IAA on compatibility and fruit development in ber (Ziziphus mauritiana Lamk.) Indian Journal of Horticulture, 61 (4) 359-361.

3. Anonymous. (2018). Horticultural Statistics at a Glance, National Horticulture Board, Government of India Pp-09.

4. Arora, R. and Singh, S. (2014). Effect of fruit drop regulators on quality of ber (Ziziphus mauritiana lamk) cv. umran. Agricultural Science Digest. (34):102-106.doi: 10.5958/0976-0547.2014.00024.X

5. Azam-Alli S, Bonkoungou E, Bowe C, DeKock C, Godara A & Williams J.T. (2006). Fruits for the future-2 (Revised edition), Ber and other jujubes. International Centre for Underutilized Crops, University of Southampton, Southampton, UK, pp 1-285.

6. Bai, J. S., Bajwa, G. S. and Singh, S. N. (1993). Effect of ethephon application at turning stage on ripening and quality of Umran ber. Punjab Horticultural Journal 33: 84-87.

7. Bai, J. S., Singh, S. N., Randhawa, J. S. and Jawanda, J. S. (1981). Effect of plant growth regulators on fruit drop, size and quality of ber (Ziziphus mauritiana Lamk.). Proceedings of National Symposium on Tropical and Subtropical fruit crops. pp 117.

8. Bai, J. S., Singh, S. N., Randhawa, J. S. and Sharma, S. C. (1982). Effect of naphthalene acetic acid and trichlorophenoxy acetic acid on fruit drop, size and quality of ber. Progressive Horticulture 14/148-151.

9. Bankar, G.J. and Prasad, R.N. (1990). Effect of gibberellic acid and NAA on fruit set and quality of fruits in ber cv. Gola. Progressive Horticulture 22(1-4): 60-62.

10. Bhambhota, J.R. and Singh, A. (1971). A quick method of raising ber root stock. Punjab Hort. J., 11 : 251-253.

11. Bhati, B. S. and Yadav, P. K. (2003). Effect of foliar application of urea and NAA on the quality of ber (Ziziphus mauritiana Lamk.) cv. Gola. Haryana Journal of Horticultural Sciences 32: 32-33.

12. Bhosale, G.H. (2012). Effect of plant growth regulators on growth, yield and quality of ber (Ziziphus mauritiana lamk.) cv. mehrun under saurashtra region. Unpublished thesis submitted to Junagad Agricultural University, Gujrat, pp155.

13. Bisht, T., Rawat, L., Chakraborty, B. And Yadav, V. (2018). A Recent Advances in Use of Plant Growth Regulators (PGRs) in Fruit Crops - A Review. International Journal of Current Microbiology and Applied Sciences. 7. 1307-1336. doi:10.20546/ijcmas.2018.7.05.159.

14. Bons, H., Kaur, N. and Harinder, R. (2015). Quality and Quantity Improvement of Citrus: Role of Plant Growth Regulators. International Journal of Agriculture, Environment and Biotechnology. 8. 433. doi:10.5958/2230-732X.2015.00051.0

15. Bons, H.K. and Kaur, M. (2019). Role of plant growth regulators in improving fruit set, quality and yield of fruit crops: a review, The Journal of Horticultural Science and Biotechnology, 95(2). 137-146.doi.org/10.1080/14620315.2019.1660591

16. Chandler, John. (2010). The Hormonal Regulation of Flower Development. Journal of Plant Growth Regulation. 30. 242-254.

17. Devenmani, T., Pandey, A.K., Pal, A.K. and Yadav, M.P. (2009). Studies on effect of plant growth regulators on fruit drop, development quality and yield of ber (Ziziphus mauritiana Lamk.) cv. Banarasi, Progressive Horticulture 41 (2): 184-186.

18. Devi, P., Gautam, R.K.S., Singh, J., Maurya, S.K. and Chaudhary, A. (2019). Effect of Foliar Application of NAA, GA3 and Zinc Sulphate on Fruit Drop, Growth and Yield of Ber (Ziziphus mauritiana Lamk.) cv. Banarasi Karaka. International Journal of Current Microbiology and Applied Sciences. 8 (01): 1679-1683.doi.org/10.20546/ijcmas.2019.8.01.177

19. Ferguson L, Lessenger JE (2006) Plant growth regulators. In: Lessenger JE (ed.) Agricultural medicine. Springer, New York, pp 156–166.

20. Gami, J., Sonkar, P.A. Haldar and Patidar, D.K. (2019). Effect of Pre harvest Spray of ZnSO4, KNO3 and NAA on Growth, Yield and Quality of Ber (Ziziphus mauritiana Lamk.) cv. Seb under Malwa Plateau Conditions. International Journal of Current Microbiology and Applied Sciences. 8 (03): 1977 1984.doi.org/10.20546/ijcmas.2019.803.235

21. Ghosh, S.N. and Mathew, B. (2002): Performance of nine ber (Ziziphus mauritiana Lamk) cultivars on top working in the semi-arid region of West Bengal. J. App. Hortic., 4(1): 49-51.

22. Ghosh, S.N., Bera, B., Kundu, A. and Roy, S. (2009). Effect of plant growth regulators on fruit retention, yield and physico-chemical characteristics of fruits in ber ‘banarasi karka’ grown in close spacing. Acta Hortic. 840, 357-362

23. Gill, K.S. and Bal, J.S. (2013). Impact of application of growth regulators on indian jujube. Acta Hortic. 993, 119-124.doi:10.17680/ActaHortic.2013.993.17

24. Gill, P. S. and Bal, J. S. (2008). Studies on Fruit Drop, Size and Quality of Indian Jujube under Submontane Zone of Punjab. Proceedings of 1st International Jujube Symposium. pp 50-51.

25. Gill, P.P.S. and Bal, J.S. (2009). Effect of growth regulator and nutrients spray on control of fruit drop, fruit size and quality of ber under sub-montane zone of Punjab, J. Hort. Sci. 4 (2): 161-163.

26. Hore, J. K. and Sen, S. K.(1994). Role of pre sowing seed treatment on germination, seedling growth and longevity of ber (Ziziphus mauritiana Lam) seeds. Indian Journal of Agricultural Research 28 (4): 285-289.

27. Josan, J.S., Jawanda, J.S., Bal, J.S., Singh, R. (1980) Studies on the floral biology of ber. Flowering habit, flower bud development, time and duration of flowering, floral morphology, time of anthesis and dehiscence. The Punjab Hortic J 20: 289.

28. Kale, V.S., Dod, V.N., Adpawar, R.M., Bharad, S. (2000). Effect of plant growth regulators on fruit characters and quality of ber (Ziziphus mauritiana L.). Crop Research. 20. 327-333.
29. Karole, B and Tiwari, R. (2016). Effect of pre-harvest spray of growth regulators and urea on growth, yield and quality of ber under malwa plateau conditions, Annals of Plant and Soil Research 18(1): 18-22.

30. Kebede, M.and Isotalo, J (2016). Flowering and fruiting phenology and floral visitation of four native tree species in the remnant moist Afrotomontane forest of Wondo Genet, south central Ethiopia. Tropical Ecology 57(2): 299-311.

31. Kende, H., and Zeevaart, J. A. D. (1997). The five “Classical” plant hormones. Plant Cell 9, 1197–1210. doi: 10.1105/tpc.9.7.1197

32. Krishna H, Parashar A, Awasthi O P and Singh K. (2014). Ber (in) Tropical and Sub Tropical Fruit Crops: Crop Improvement and Varietal Wealth Part-I, pp 137–155. Ghosh S N (Ed). Jaya Publishing House, Delhi.

33. Kumar, B. P. and Reddy, Y. N. (2004). Growth, yield and quality of ber (Zizyphus mauritiana Lamk.) as influenced by pruning and chemicals. Indian Journal of Horticulture 61: 179-180.

34. Kumar, R., Khurana, A. and Sharma,A. K. (2014). Role of plant hormones and their interplay in development and ripening of fleshy fruits. Journal of Experimental Botany, 65, (16), 4561–4575. doi:10.1093/jxb/eru277

35. Kumar, S., Kumar U. and Naresh, P. (2017). Effect of Plant Growth Regulators on Yield of Indian Ber (Zizyphusmauritiana L.) Fruit, Int. J. Pure App. Biosci. 5 (1): 966-969.doi.org/10.18782/2320-7051.2524

36. Kumar, S., Kumar, U. and Premnaresh (2018). Effect of plant growth regulators on initial fruit set, fruit set retention and fruit drop of Indian ber (Zizyphus mauritiana lamk.) Life Sciences Leaflets 101, 25-31.

37. Kumari, S., Bakshi, P. Sharma, A., Wali, V.K., Jasrotia, A and Kour, S. (2018). Use of Plant Growth Regulators for Improving Fruit Production in Sub Tropical Crops. International Journal of Current Microbiology and Applied Sciences, 7 (03): 659-668. doi.org/10.20546/ijcmas.2018.703.077

38. Lawes, G.S. and Woolley, D.J. (2001). The commercial use of plant growth regulators to regulate fruit development. Acta Hort. 553, 149-150. doi: 10.17660/ActaHortic.2001.553.29

39. Majumder, I., Sau, S., Ghosh, B., Kundu, S, Roy, D and Sarkar, S. (2017). Response of growth regulators and micronutrients on yield and physico-chemical quality of Ber (Zizyphus mauritiana Lamk) cv. BAU Kul-1 Journal of Applied and Natural Science 9 (4): 2404 – 2409.doi: 10.31018/jans.v9i4.1545

40. Masuda Y, Kanisaka S (2000). Discovery of auxin. Discov Plant Biol 3:43–57. doi:10.1142/978981 2813503_0003

41. Meena, V., Eyarkai, N., Kashyap, P. and Meena, K.K. (2013). Naphthalene acetic acid and ferrous sulphate induced changes in physico-chemical composition and shelf-life of ber. Indian Journal of Horticulture. 70. 37-42.

42. Murthy, B. N.S. and Reddy, Y. N. (1990). Temperature dependence of seed germination and seedling growth in ber (Z. mauritianaLamk.) and their modification by pre-sowing treatments. Sci. Technol., 18 (3) : 621-627.

43. Neeraja, G., Reddy, S.A. and Babu, R.S.H.(1995). Fruit set, fruit drop and fruiting behavior in certain Ber (Ziziphus mauritiana Lamk.) cultivars. J. Res. Andhra Pradesh Agricultural University 23:17-21.

44. Obeed, R.S., Harhash, M.M. and Abdel-Mawgood, A. L. 2008. Fruit properties and genetic diversity of five Ber (Ziziphus mauritiana Lamk.) cultivars. Pakistan. J. Biol. Sci., 11(6): 888-893

45. Pandey, V. (1999). Effect of NAA and GA3 spray on fruit retention, growth, yield and quality of ber (Zizyphus mauritiana Lamk.) cv. Banarasi Karaka. Orissa Journal of Horticulture 27 : 69-73.

46. Pareek S., Mukherjee S. and Palilwal, R. (2007). Floral Biology of Ber - A Review, Agric. Rev., 28 (4) : 277-282.

47. Petracek, P.D., Silverman, F.P. and Greene, D.W. (2003). A History of Commercial Plant Growth Regulators in Apple Production, Hort.Sci., 38 (5), 937-942.

48. Rademacher, W. (2015). Plant Growth Regulators: Backgrounds and Uses in Plant Production. Journal of Plant Growth Regulation. 34. 845-872. 10.1007/s00344-015-9541-6.

49. Ram, R. B., Pandey, S. and Kumar, A. (2005). Effect of plant growth regulators (NAA and GA3) on fruit retention, physicochemical parameters and yield of ber (Zizyphus mauritiana Lamk.) cultivar Banarasi Karaka. Biochemical and Cellular Archives 5: 229-232.

50. Rattan, C. S., Bai, J. S. (2008). Effect of nutrients and growth regulators on fruit yield and quality of ber. Journal of Research 45, (3-4), 144-147.

51. Sahoo, A., Ranjan, T., Srivastava, A.K. and Sayan, S. (2019). Plant Growth Regulators in Ber. In Plant Growth Regulators in Tropical & Sub-Tropical Fruit Crops (Part I), pp.1-250.

52. Sandhu, S. S. and Third, S. S. (1988). Effect of NAA sprayed on at fruit set on general appearance and quality of Umran ber. Indian Journal of Horticulture 45:274-282.

53. Sandhu, S. S., Third, S. S. and Bai, J. S. (1990). Effect of NAA on physico-chemical characters of Umranber. Punjab Horticulture Journal 30:123-130

54. Sara, B., Gurmukh, S. J. and Nicola, C. (2014). The role of auxin transporters in monocots development. Front. Plant Sci. 5 : 1-12.; doi.org/10.3389/fpls.2014.00393

55. Sharma, V. P., Raja, P. V. and Kore, V. N. (1990). Flowering, fruit set and fruit drop in some ber (Zizyphus mauritiana Lamk.) varieties. Annals of Agriculture Research Institute 11: 14-20.

56. Sheoran,V., Kumar, M Sharma, J.R., Gaur, K.R. and Saini, H. (2019). Effect of scarification treatments on growth parameters of ber seedling. Journal of Pharmacognosy and Phytochemistry, 8(1): 658-661.

57. Singh C. and Bai, J.S. (2006) Effect of nutrients and growth regulators on fruit drop, size and yield of ber (Zizyphus mauritiana Lamk.) Internat. J. agric. Sci. 2 (2): 358-360.

58. Singh, C. and Bai, J. S. (2008). Effect of Nutrients and Growth Regulators on Physico-chemical Characteristics of Indian Jujube (Zizyphus mauritiana Lamk.). Proceedings of 1st International Jujube Symposium. pp 49. Agricultural University of Hebei, Baoding, China.

59. Singh, D. K. (2000). Effect of paclobutrazol on yield and quality of different cultivars of ber (Zizyphusmauritiana). Indian Journal of Agricultural Sciences 70: 20-22.

60. Singh, K. and Randhawa, J. S. (2001). Effect of growth
regulators and fungicides on fruit drop, yield and quality of fruit in ber cv. Umran. *Journal of Research PAU* 38:181-184.

61. Singh, S., Pratap, B., Yadav, A., and Shivam. (2017). Assess the effect of pruning and plant growth regulators on growth, flowering and fruiting of ber tree. *Journal of Pharmacognosy and Phytochemistry*., 6(5): 735-738.

62. Singh, U. R. and Singh, N. (1976). Effect of plant regulators on fruit drop, size and quality of ber (Zizyphus mauritiana Lamk.) var. Banarsi. *Haryana Journal of Horticultural Sciences* 5: 1-8.

63. Singh, Z., Dhillon, B.S. and Sandhu, A.S. (1991). Relationship of embryo degeneration with fruit drop and its pattern in different cultivars of ber. *Indian J. HORT.* 48:277-281.

64. Singh, S., Pratap, B., Gupta, S., Yadav, D., Kumar, A., Behera, D.S and Singh, M. (2019). Assess the Effect of Pruning and Plant Growth Regulators on Yield and Quality of Ber Fruit. *International Journal of Current Microbiology and Applied Sciences*, 8(01): 539-547. DOI: 10.20546/ijcmas.2019.801.060

65. Sinohrot, R.S., Bakhshi, J.C. and Singh, K. (1970). Vegetative propagation of ber (Z. mauritiana Lamk.) Relative performance of seedling raised in field and in alkathene bags. *Punjab Hortic. J.*, 10 (3-4) : 181-186.

66. Su, Y., Xia, S., Wang, R., and Xiao, L. (2017). Phytohormonal quantification based on biological principles in Hormone Metabolism and Signaling in Plants. Eds.J. Li,C. Li and S. M. Smith (London, UK: Academic Press). 431–470. doi:10.1016/B978-0-12-811562-6.00013-X.

67. Suman, M., Sangma, P.D., Meghawal, D.R. and Sahu, O.P. (2017), Effect of plant growth regulators on fruit crops. *Journal of Pharmacognosy and Phytochemistry*, 6 (2): 331-33.

68. Teotia, S. S. and Chauhan, R. S. (1964). Flowering pollination fruit set and fruit drop studies in ber. *Indian Journal of Horticulture* 21: 34-40.

69. Verma, S. S., Verma, R. S., Verma, S. K., Pathak, S. (2016). Effect of chemicals and growth regulators on yield and quality of ber cv. Gola. *Environment and Ecology*, 34 (4A):1874-1877.

70. Wangbin, I., Wang, Y., Yue-hua, Z., Liu, J. and Xulin. (2008). Effect of Molybdenum Foliar Sprays on Fruiting, Yield and Fruit Quality of Jujube. *Proceedings of 1st International Jujube Symposium*. 55-56.

71. Yadav, D. N. and Chaturvedi, O. P. (2005). Influence of GA3 and trace elements on fruit drop growth and quality of Ber (Zizyphus mauritiana Lamk.) cv. Banarsi Karaka. *FarmScience Journal* 14: 27-28.

72. Yamdagini, R., Bajpai, P. N. and Misra, R. S. (1968). Pol- lination, fruit set and fruit development studies in ber (Zizyphus mauritiana Lamk.). *Labdev. Journal of Scientific Technology* 6b: 101-103.

73. Yazdanpanah, E., Armand, N., Mohsenzadeh, S., Moradshahi, A., Katayoun, A, and Esfandiar, J. (2013). Seed dormancy breaking of ziziphus nummularia. *World Applied Sciences Journal*, 28. 1831-1833. doi: 10.5829/idosi.wasj.2013.28.11.1890