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Response of growth regulators and micronutrients on yield and physico-chemical quality of Ber (*Zizyphus mauritiana* Lamk) cv. BAU Kul-1

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Abstract: Ber (*Zizyphus mauritiana* Lamk.) is an indigenous delicious, nourishing fruit grown widely throughout the India but faces heavy fruit drop due to several biotic and abiotic stress factors resulted in declining trend of ber production over the year. Keeping these facts in foreground, replicated field experiment was conducted during 2013-14 and 2014-15 at HRS, Mondouri, BCKV, West Bengal with eleven treatments consist two different levels of NAA, GA_3, 2,4-D, $ZnSO_4$ and H_3BO_3 along with a control (water spray). Results of investigation revealed that application of 2,4-D @ 10 mg/l recorded highest fruit set (48.80%). Maximum fruit retention (42.83%) and total no. of fruits/tree (514) were obtained with the application of NAA @ 20 mg/l. Application of GA_3 @ 20 mg/l recorded significantly ($p \leq 0.05$) higher yield (30.67 kg/tree), fruit weight (60.5 g), fruit length (5.8 cm), fruit breadth (5.1 cm), pulp to seed ratio (13.9) and specific gravity (1.104) as well as economic returns over control during both the year of experiment. Among the treatments H_3BO_3 at 0.4% recorded the highest TSS (11.7°Brix), total sugar (8.33%), reducing sugar (5.21%) and TSS: Acid (107.36) ratio with lowest fruit acidity (0.10 %) whereas highest vitamin-C content of fruit was recorded with GA_3 at 20 mg/l (64.68 mg / 100 g) followed by NAA at 20 mg/l. Results suggest that twice spraying of GA_3 @ 20 mg/l and H_3BO_3at 0.4% is vital for optimizing yield components, yield and quality of ber (cv. BAU Kul-1) in trans-Gangetic plains of West Bengal.

Keywords: Ber, Growth regulators, Micronutrients, Yield, Quality

INTRODUCTION

Ber (*Ziziphus mauritiana* Lamk.) is one of the hardy fruit suitable for cultivation mainly in arid and semi-arid condition where most of the trees fail to grow due to lack of irrigation. It is cultivated for its fresh fruits and popularly called as poor man's apple due to its high nutritional quality such as higher protein (0.8g), β -carotene (70 IU), vitamin C (50-100 mg) contents as well as medicinal value (Rai and Gupta, 1994).The total area under ber in India is 48,450 ha with the production of 0.66 million tons (NHB, 2015). In north Indian condition ber flowers in the month of August-September while in West Bengal flowering occurs mainly in September-November in different varieties which produces heavy flowers in the axillary cymes on both mature and current season's growths (Teaotia and Chauhan, 1963). High degree of immature fruits dropped during initial stage of fruit growth and development experiences all over India may be due to various factors like hormonal imbalance, abortion of embryo and inclement weather (Bal *et al.,* 1988; Singh and Randhawa, 2001), nutrition (Chauhan and Gupta, 1985), moisture stress (Ghosh and Tarai, 2007) and pathogen infestation (Reddy *et al.,* 1997) makes ber cultivation non-profitable.

'BAU Kul-1', an introduced cultivar from Bangladesh, released from Bangladesh Agricultural University – Germpalsm Centre, FTIP having large fruit size, round and slightly elongate in shape; skin color is brightly yellowish with smooth and shiny surface with acceptable taste and texture. This cultivar is well acclimatized and a steady performer in West Bengal condition both in respect of quality and quantity parameters but facing problem of high degree of fruit drop (Majumder, 2015).

Plant growth regulators and micro nutrients in minute quantities play an important role in enhancing growth and development of plants to influence yield and quality, affecting plant metabolism by bringing about a change in nutritional and hormonal status of the plant (Gadi and Bohra, 2005). 1-Naphthaleneacetic acid (NAA) is an important plant hormone reported to enhance the fruit set, growth, retention, yield and market price of some fruit species (Nawaz *et al.,* 2008) also delayed in fruit ripening as well as enhancing fruit formation through cell division and elongation (Dutta and Banik, 2007). Gibberellins are reported to

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increase fruit set, size, retention and yield as well as improve fruit physico-chemical characteristics and ripening (Rizk-Alla *et al.,* 2011). Micronutrients (B, Fe and Zn) also have a positive effect on ber fruit set, yield, fruit quality and storage-life (Samant *et al.,* 2008). In this context, the present study was undertaken to investigate the effect of plant growth regulators and micronutrients in different concentrations on yield, fruit physico-chemical attributes and economics of ber cv. 'BAU Kul-1' during 2013-2015.

MATERIALS AND METHODS

Experimental site: A field experiment was conducted during 2013-14 and 2014-15 at the Horticulture Research Station, Mondouri, Bidhan Chandra Krishi-Viswavidyalaya, West Bengal, India (22° 43′N, 88° 30′E and 9.75m above mean sea level) to evaluate the effect of different plant growth regulators and micronutrients in different concentrations on fruit setting, yield and economics of ber cv. 'BAU Kul-1' at fixed site. The climate of the region is humid sub-tropical with hot-humid summers and cool winters. The mean annual rainfall is 1,750 mm, out of which 80-90% is normally received from June to September. The experiment was conducted in a four year aged well managed ber orchard. Soil at the experiment site was sandy clay loam (sand 64.8%, silt 10.4%, and clay 24.8%) with a pH of 6.8 and contained organic carbon of 0.56%, available N of 131.58 kg/ha, available P of 20.5 kg/ha and available K of 170.63 kg/ha.

Experimental design and crop management: The experiments in both years were arranged in a randomized complete block design with three replications. The ber trees under investigation were planted at 5m × 5m spacing and subjected to eleven treatments combinations as, GA_3 @ 10 and 20 mg/l, NAA @ 10 and 20 mg/l, 2,4-D @ 5 and 10 mg/l, $ZnSO_4$ at 0.5 and 1%, H_3BO_3 @ 0.2 and 0.4% and control (water spray only). These chemicals were thoroughly sprayed twice along with the control trees (water spray) using *teepol* as surfactant. The first spray was given just after fruit set (2nd week of October) and second spray after 30 days from the 1st spray (2nd week of November) in both the year of experimentation using a manual knapsack sprayer having a delivery of about 5 l per plant of spray solution through a flat fan nozzle at a spray pressure of 140 kPa. All ber plants were given recommended doses of NPK fertilizer i.e.400:200:400 g N, P_2O_5 and K_2O per plant respectively in two splits, one at before flowering (1st week of June) and rest amount after fruit set of ber (2nd week of October) in both the years.

Measurements and observations: Fruit setting and yield indicators of ber were measured as fruit set %, fruit retention %, total no. of fruits/ tree, fruit weight (g), fruit yield (kg/tree and q/ ha). In order to calculate the percentage of fruit set, twenty branches for each tree of all treatments were selected at random; then tagged and their flowers were counted during the full bloom. Fruitlets were also counted and recorded at the right time of fruit setting in last week of October. Fruit set % was worked out using following formula (equation 1).

$$\text{Fruitset \%} = \frac{\text{No. of developed fruitlets}}{\text{Total no. of flowers at full bloom stage}} \times 100 \quad \text{...Eq (1)}$$

Twenty bearing shoots of uniform size and vigour were randomly selected at different directions on each tree and tagged just after fruit set to record fruit retention. Fruit retention % was worked out using following formula (equation 2).

$$\text{Fruit retention \%} = \frac{\text{No. of fruits retained upto harvest}}{\text{Total no. of fruits counted during the time of spraying}} \times 100 \quad \text{....Eq (2)}$$

Fruit weight was calculated by taking fifty matured fruits from tagged branches and taking total weight of them and after that average fruit weight was determined. The fruit yield was calculated by multiplying average fruit weight to number of fruits/plant and then converted the value in t/ha. Economic analysis of the treatments was calculated on the basis of total expenditure to total income or profit.

To record fruit physical parameters like fruit length (cm), fruit breadth (cm), fruit weight (g), seed weight (g) and pulp:seed ratio, 50 fruits per replication were randomly taken from previously tagged five uniform branches of individual tree. The fruit length and breadth were recorded with Vernier's callipers whereas; the fruit and stone weight was recorded by weighing 50 fruits on pan balance. Fruit bio-chemical qualities like total soluble solid (ºBrix), total acidity (%), T.S.S: acidity ratio, vitamin C (mg 100 g^{-1}), total sugar (%), reducing sugar (%), non-reducing sugar (%) were determined as per the guidelines of AOAC (2000).

Statistical analysis: Statistical assessment was performed by the analysis of variance (ANOVA) for randomized block design (RBD) based on the guidelines given by Gomez and Gomez (1984). For comparison of 'F' values and computation of critical difference (CD) at 5% level of significance, Fisher and Yates' table were consulted. The variances over years were firstly analyzed by homogeneity test by performing Barlett's chi-squre test and pooled analysis of observation are presented to discuss and to draw logical conclusions using SAS software. The Excel software (version 2007, Microsoft Inc., WA, USA), were used to draw graphs and figures.

RESULTS AND DISCUSSION

Fruit yield and yield components: Fruit set, fruit retention, number of fruits/plant and fruit weight is the most important yield contributing components for any fruit crops. Most of the yield components and yield of ber was significantly ($p \leq 0.05$) improved by the application of micronutrients and growth regulators over

Table 1. Effect of different growth regulators and micronutrients on fruit set, fruit retention and yield of ber cv. BAU Kul-1. (Pooled data of two years).

Treatments	Fruit set (%)	Fruit retention(%)	No. of fruits/ plant	Yield (kg/ plant)	Yield (t/ ha)	Percent increment of the yield over control
GA_3 @ 10 mg/l	47.97	39.09	469	27.39	10.95	68.63
GA_3 @ 20 mg/l	47.83	42.25	507	30.67	12.27	88.87
NAA @ 10 mg/l	48.56	38.19	458	25.11	10.04	54.61
NAA @ 20 mg/l	48.47	42.83	514	28.48	11.39	75.33
2,4-D @ 5 mg/l	48.56	35.84	430	22.75	9.09	40.05
2,4-D @ 10mg/l	48.80	36.92	443	22.64	9.05	39.37
ZnSO4 @ 0.5%	48.20	34.33	412	23.61	9.44	45.36
ZnSO4 @ 1%	48.75	36.33	436	25.24	10.09	55.41
H_3BO_3 @ 0.2%	47.75	39.75	477	26.57	10.62	63.57
H_3BO_3 @ 0.4%	47.70	40.08	481	27.32	10.92	68.22
Control	48.47	32.00	38	16.2	6.49	-
S. Em (±)	0.360	0.29	2.51	0.14	0.58	-
CD at 5%	NS[a]	0.86	7.47	0.43	1.18	-

[a]NS, Non-significant

Table 2. Effect of different growth regulators and micronutrients on fruit physical attributes of ber cv. BAU Kul-1. (Pooled data of two years).

Treatments	Fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Seed weight (g)	Pulp:seed ratio	Fruit specific gravity
GA_3 @ 10 mg/l	58.4	5.3	4.9	4.3	12.6	1.101
GA_3 @ 20 mg/l	60.5	5.8	5.1	4.1	13.9	1.104
NAA @ 10 mg/l	54.8	5.4	4.9	4.1	12.3	1.096
NAA @ 20 mg/l	55.4	5.5	5.0	4.2	12.3	1.097
2,4-D @ 5 mg/l	52.9	5.3	4.8	4.2	11.5	1.102
2,4-D @ 10mg/l	51.1	5.6	5.0	4.0	11.9	1.092
$ZnSO_4$ @ 0.5%	57.3	5.1	4.7	4.1	13.0	1.102
$ZnSO_4$ @ 1%	57.9	5.0	4.6	3.9	13.7	1.092
H_3BO_3 @ 0.2%	55.7	5.1	4.5	4.1	12.6	1.096
H_3BO_3 @ 0.4%	56.8	5.4	4.7	4.2	12.6	1.100
Control	42.3	4.1	3.9	4.8	7.9	1.085
S. Em (±)	0.51	0.06	0.05	0.06	0.15	0.004
CD. at 5%	1.52	0.19	0.15	0.18	0.44	NS

control. Though there was no significant variation in fruit set percentages in both of the experimental years initially, but fruit retention, number of fruits/plant and fruit yield significantly increased by application of micronutrients and growth regulators (Table 1). Maximum fruit retention (42.83%) and number of fruits/ plant (514) was recorded with NAA 20 mg/l which was statistically at par ($p \leq 0.05$) with GA_3 at 20 mg/l. This finding is partially in agreement with Bal and Randhawa (2007), where they recorded minimum fruit drop with higher fruit set percent with NAA 20-30 mg/ l. Singh and Randhawa (2001) and Ghosh *et al.* (2009) also recorded highest fruit set in ber with NAA at 20 mg/l and 25mg/l, respectively. The increase in fruit retention by application of NAA might be attributed to reduce fruit drop by the on-going physiological and biochemical process of inhibition of abscission (Tomaszewska and Tomaszewska, 1970). Chaudhury *et al.* (2006) also reported that auxin like plant hormones (i.e. NAA) are known to stimulate cell division, cell elongation, photosynthesis, RNA synthesis and membrane permeability resulting higher water and nutrient uptake that finally reduced fruit drop resulted higher fruit retention. Application of GA_3 at 20 mg/l recorded significantly ($p \leq 0.05$) highest yield (12.27 t/ ha) which was statistically at par ($P \leq 0.05$) with NAA at 20 mg/l. Higher fruit yield (kg/tree and t/ha) with application of GA_3 and NAA may be due to influential role in reduction of fruit drop and increasing fruit retention percentage with production of greater sized fruit. A strong positive correlation between fruit retention ($R^2 = 0.843$) with fruit yield (t/ha) (Fig. 1) con-

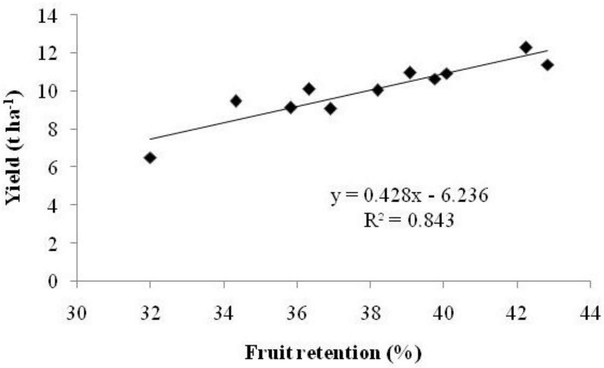

Fig. 1. *Relationship between ber cv. BAU Kul-1 yield (t/ha) to fruit retention %.*

Table 3. Effect of different growth regulators and micronutrients on fruit biochemical attributes of ber cv. BAU Kul-1.(Pooled data of two years).

Treatment	TSS (^{0}Brix)	Total Sugar (%)	Reducing Sugar (%)	Acidity (%)	Ascorbic acid (mg/100 g)	TSS: Acid
GA_3 @ 10 mg/l	11.2	8.12	4.97	0.134	57.29	83.62
GA_3 @ 20 mg/l	11.5	8.21	5.01	0.122	64.68	94.07
NAA @ 10 mg/l	10.6	7.83	4.32	0.154	51.74	68.61
NAA @ 20 mg/l	10.4	7.95	4.40	0.141	60.98	73.51
2,4-D @ 5 mg/l	10.6	6.55	4.06	0.192	50.82	55.03
2,4-D @ 10mg/l	10.8	7.0	4.15	0.204	53.59	53.11
$ZnSO_4$ @ 0.5%	10.8	7.74	4. 31	0.173	49.90	62.75
$ZnSO_4$ @ 1%	10.7	7.67	4.21	0.186	48.05	57.45
H_3BO_3 @ 0.2%	11.6	8.26	5.03	0.128	55.44	90.39
H_3BO_3 @ 0.4%	11.7	8.33	5.21	0.109	59.13	107.36
Control	9.4	6.32	3.66	0.288	40.66	32.64
S. Em (±)	0.08	0.01	0.01	0.001	0.38	0.91
CD. at 5%	0.26	0.04	0.03	0.003	1.13	2.71

Table 4. Effect of different growth regulators and micronutrients on benefit cost ratio of the cultivation of ber cv. BAU Kul-1. (Mean data of two years)

Treatment	Yield t/ha	Total cost of production (US$/ha/year)	Gross revenue (US$/ha/year)	Net benefit (US$/ha/year)[a]	Benefit : Cost ratio
GA_3 @ 10 mg/l	10.956	1925	7303	5378	2.79
GA_3 @ 20 mg/l	12.271	1960	8180	6220	3.17
NAA @ 10 mg/l	10.045	1892	6697	4805	2.54
NAA @ 20 mg/l	11.391	1893	7595	5702	3.01
2,4-D @ 5 mg/l	9.099	1891	6067	4176	2.21
2,4-D @ 10mg/l	9.055	1892	6037	4145	2.19
$ZnSO_4$ @ 0.5%	9.444	1958	6297	4338	2.22
$ZnSO_4$ @ 1%	10.097	2027	6732	4705	2.32
H_3BO_3 @ 0.2%	10.627	1918	7085	5167	2.69
H_3BO_3 @ 0.4%	10.929	1947	7285	5338	2.74
Control	6.497	1890	4330	2440	1.29

[a]Net benefit = Gross revenue – Total cost of production; 1 US$ = ₹ 60.00; Market price for ber (BAU Kul-1) US$ 666.66 per tone

firmed that it is one of important yield contributing parameter of ber.

Physical and biochemical quality attributes of fruit: The physical characteristics of fruit are an expression of a plant's vegetative activity which were also significantly influenced by various plant growth regulators and micronutrients (Table 2). Application of GA_3 at 20 mg/l recorded significantly highest fruit weight (60.5 g) over the other treatments closely followed by GA_3 at 10 mg/l and $ZnSO_4$ at 1.0% foliar spray. Fruit length and breadth was recorded maximum (5.8 cm and 5.1 cm, respectively) in GA_3 at 20 mg/l treated trees and it was followed by 2,4-D @ 10 mg/l and minimum in case of control. The same treatment of GA_3 @ 20 mg/l produced fruits with highest pulp: seed ratio (13.9) and specific gravity (1.104) whereas lowest seed weight was recorded from the trees treated with $ZnSO_4$ at 1.0%.

Higher fruit weight due to application of GA_3 might be due to greater photosynthesis and plant metabolism that enable higher cell growth, cell expansion which in turn producing bigger fruit size with respect to maximum fruit length and breadth in compared to other treatments. Gibberellic acid promotes fruit growth by increasing plasticity of the cell wall followed by the hydrolysis of starch into sugars which reduces the cell water potential, resulting in the entry of water into the cell and causing elongation (Richard, 2006). A positive correlation between auxin content and fruit growth has been reported from different fruit crops. Besides triggering auxin biosynthesis, gibberellins are also implicated in preferential flow of metabolites from vegetative parts to developing fruits. The increase in fruit weight in GA_3, NAA and 2,4-D treated trees also depicted their role in cell enlargement and division, increase in intercellular spaces in the mesocarpic cells and higher translocation of photosynthates and mineral nutrients from vegetative parts towards the developing fruits that are extremely active metabolic sink (Krishnamoorthy, 1993). There were non-significant differences in specific gravity of ber under different treatments which might be due to proportionate increase in the weight and volume of fruits in trees sprayed with different PGRs. An increase in fruit weight and size (length and diameter) of fruits on account of zinc sulphate and boric acid application could be attributed to involvement in the cell division, cell elongation, moisture content of the fruits (Josan, 1991) and hormone metabolism which promotes synthesis of auxin necessary for hastening growth processes. Similar reports of increased fruit physical parameters in ber with exogenous foliar application of GA_3, NAA and $ZnSO_4$ have been presented by Arora and Singh (2014), Bal *et al.*(1988) and Samant *et al.* (2008), respectively.

Data on fruit biochemical attributes presented in Table 3 showed that all the treatments of growth regulators and micro nutrients affected significantly in improving fruit quality over the control. Among the treatments H_3BO_3 at 0.4% recorded the highest TSS (11.7° Brix), total sugar (8.33%), reducing sugar (5.21%) and TSS: Acid (107.36) ratio with lowest fruit acidity (0.10 %) followed by H_3BO_3 at 0.2% and GA_3 at 20 mg/l. Highest vitamin-C content of fruit was recorded with GA_3 at 20 mg/l (64.68 mg / 100 g) followed by NAA at 20 mg/l and H_3BO_3 at 0.4%.

Increase in TSS content with boron may be due to the fact that boron helps in transformations of polysaccharides and pectin into soluble compounds and translocation of sugars from leaves to the developing fruits through cellular membranes by formation of an ionisable sugar borate complex. The plant growth regulators used in this study (GA_3 , NAA and 2, 4-D) are known to increase membrane permeability in plant cells which might facilitate accelerated breakdown of organic acids stored in cell vacuoles with consequent increase in TSS content. Boron enhances nitrogen uptake and thus facilitates the process of photosynthesis, which ultimately led to the accumulation of carbohydrate and helped in increasing the sugar contents of the fruits (Movchan and Soboroikova, 1972). Gibberellins actively participate in the hydrolysis of sucrose and starch. They promote the activity of enzyme *invertase* which catalyzes the hydrolysis of sucrose, thereby yielding glucose and fructose. The downwards trend in the levels of organic acids was also possibly due to dilution effect with the increase in volume of fruits in micronutrient treatment. Higher TSS /acid ratio may be due to an increase in total sugars and decrease in acid contents. As ascorbic acid is synthesized from sugars, particularly L-glucose, any increase in sugar content by GA_3, NAA and 2, 4-D in fruits would be conducive to the higher synthesis of ascorbic acid in fruits (Krishnamoorthy, 1993). Micronutrients like boron and zinc stimulates the functioning of number of enzymes in the physiological processes which probably caused an increase in ascorbic acid contents of the fruits. These results are in accordance with the findings of Gill and Bal (2013) with GA_3 and NAA, Bankar and Prasad 1990 with GA_3 in ber; Iqbal *et al.* (2009) with NAA in guava and Singh and Singh (2015) with GA_3, NAA and Thiourea in aonla.

Economic assessment: Ber cultivation without growth regulator and micronutrient treatments (water spray only) had lower cost of production than the plants with growth regulator and micronutrient treatments, because in the former case no cost was involved in chemical application and resulted less yield (Table 4). However, all growth regulator and micronutrient treatments gave higher gross and net returns than control (water spray only). Ber with GA_3 20 mg/l gave the highest net returns (US$ 6220) as well as the highest benefit: cost ratio (3.17). Higher net returns with growth regulator and micronutrient treatments than the water spray (control) indicated the need for effective nutrient management for higher yield and economic return from ber.

Conclusion

Application of growth regulator and micronutrient significantly improved fruit retention, yield and fruit physico-chemical attributes as well as economic return. So, it can be concluded that twice spraying of GA_3 @ 20 mg/l and H_3BO_3 at 0.4% to the ber cv. BAU Kul-1 at monthly interval from fruit set not only resulted more yield of quality fruits to the farmers but also higher economic return in West Bengal condition.

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