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Evaluating the Effects of Bio-formulations and Boric Acid in Bael (Aegle marmelos) cv. NB-9 under Subtropical Conditions:

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Abstract

The present investigation entitled " Evaluating the Effects of Bio-formulations and Boric Acid in Bael (Aegle marmelos)cv.NB-9 under subtropical condition" was carried out during the year 2022-2024 at Main Experimental Station, Department of Fruit Science, College of Horticulture & Forestry, A.N.D.U.A.&T., Narendra Nagar (Kumarganj), Ayodhya, Uttar Pradesh, India. The treatments comprised the application of various Bio-formulations and Boric acid with eco-friendly materials to study the various chemical properties, cracking, fruit drop and effect of the above treatments on the quality of fruit. The experiment was laid down in randomized block design (RBD) with (12) treatments and (03) replications. The experiment consists of 12 treatments including control, T_1 (Control), T_2 (FYM 50 Kg), T_3 (FYM 100 Kg), T_4 (Boric acid 200g), T_5 (Boric acid 400g), T_6 (Biofertilizer 250g/plant [100g Azotobacter + 100g Biovita + 50g PSB]), T_7 (FYM 50Kg + Boric acid 200g), T_8 (FYM 50Kg + Boric acid 400g), T_9 (FYM 50Kg +Biofertilizer 250g/plant [100g Azotobacter + 100g Biovita + 50g PSB]), T_{10} (FYM 100Kg + Boric acid 200g), T_{11} (FYM 100Kg + Boric acid 400g) and T_{12} (FYM 100Kg +Biofertilizer 250g/plant [100g Azotobacter + 100g Biovita + 50g PSB]) was used for this study. The results revealed that the treatment T_7 outperformed the rest with maximum TSS (36.27°B), minimum acidity (0.33%), maximum ascorbic acid (24.51 mg/100g), total sugar (20.29%) was most effective in chemical properties of Bael fruits like Total Soluble Solids (TSS), Vitamin C (Ascorbic acid), Reducing sugar, non-reducing sugar, Total sugars, and less acidity in quality point of view. Thus, the treatment combination T_7 is therefore recommended for application to Bael trees in subtropical conditions to obtain high yields with better quality fruits.

Keywords: Azotobacter, Bael, Biofertilizer, Biovita, Bio-formulations, Boric acid, PSB, Subtropical conditions.

1. INTRODUCTION

Aegle marmelos (L.) Correa, commonly known as Bael, holds a significant position in the botanical world, particularly within the Rutaceae family. It commonly referred to as the Bengal quince, is a fruit-bearing tree native to the Eastern Ghats and Central India, this plant has garnered attention for its medicinal properties and nutritional value. Bael is cultivated extensively in tropical and subtropical regions, typically at an altitude of 1200 m [Singh et. al., (2014)] and even thrives in hot and dry climates with minimal maintenance requirements. Its historical roots trace back to ancient times, with records dating back to 800 B.C., indicating its cultivation in India. These trees can be found in several countries such as India, Sri Lanka, Thailand, Pakistan, Bangladesh, Myanmar, Vietnam, the Philippines, Cambodia, Malaysia, Java, Egypt, Surinam, Trinidad, and even Florida. According to historical reports [Nagar et. al., (2017)],

Revered for its resilience and ability to produce abundant fruit even in challenging soil conditions, Bael has become a cornerstone of traditional medicine, particularly in ayurvedic practices. indigenous to the Indian subcontinent and revered for both its religious significance and its myriad health benefits. In addition to these components, bael fruit contains amino acids, fatty acids, various organic acids, minerals, carbohydrates, vitamins, and fibres, making it a highly nutritious fruit with numerous health benefits [Bhardwaj (2014)]. It is also a valuable source for extracting pharmaceuticals and various other economically significant herbal compounds, according to WHO (2005). The cultivar NB-9 is particularly acclaimed for its superior fruit quality and adaptability to subtropical climates. However, fruit cracking and premature dropping are pervasive issues that significantly impair the yield and quality of bael fruits, posing substantial economic losses to cultivators and hindering the supply of this valuable produce. These phenomena are influenced by a myriad of factors including environmental stresses, nutritional imbalances, and physiological disorders, making their management a complex and critical challenge.

The multifaceted significance of Bael extends beyond its medicinal properties. Its fruit, rich in phytochemicals and essential nutrients, offers a plethora of possibilities for functional food products and industrial applications. They possess significant potential for being transformed into various products, including preserves, powder, jam, wine, slab, and syrup [Singh et. al., (2014)]. In India, a variety of products are made from bael fruits, including bael sherbet, murabba, and syrups. In various countries like Indonesia and Thailand, people enjoy eating ripe bael fruits and using their sliced pieces in food. Syrups made from bael fruits are also used as ingredients in cakes [Baliga et. al., (2011)]. However, despite its widespread cultivation and cultural importance, challenges persist in Bael cultivation, ranging from fruit cracking to nutritional deficiencies in soils. Addressing these challenges requires innovative approaches, including the integration of bio-formulations and boron supplementation into cultivation practices. To achieve the best fruit quality and minimize physiological disorders, it is important to have a thorough understanding of nutrient management, as highlighted by Rangare et. al., (2022).

The cultivation practices, medicinal significance, nutritional composition, and challenges faced in the cultivation of Bael crops. By synthesizing existing research and highlighting emerging trends, this review seeks to contribute to a deeper understanding of the potential of Bael cultivation and its applications in various fields, from traditional medicine to agro-industrial sectors. In recent years, the utilization of bio-formulations and boric acid has emerged as a promising strategy to mitigate these issues. Bio-formulations, consisting of beneficial microbes and organic substances, offer a sustainable approach to enhancing plant health and stress tolerance by improving soil fertility, enhancing nutrient uptake, and inducing systemic resistance against stresses. Boric acid, on the other hand, plays a crucial role in the regulation of cell wall synthesis and the stabilization of cell membranes, which are pivotal in preventing fruit cracking and supporting the fruit's retention on the tree until proper ripening. This approach has the potential to improve growth, increase yield, and address problems like fruit cracking and premature fruit drop [Khan et. al., (2023)]. This alternative has been extensively promoted in recent years [Khan et. al., (2020); Pathak et. al., (2022); Ayilara et. al., (2023)]. Thus, the concept of bio-formulation refers to the creation of material that incorporates living and beneficial microbial strains, utilizing appropriate carrier materials for their effective application in agriculture, industry, bioremediation, and other fields [Balla et. al., (2022)]. Potential microbes with plant growth-promoting properties, such as nutrient solubilizers, nitrogen fixers, biocontrol agents, and bioremediation, are the essential components of a bio-formulated product or bioformulation [Pirttila et. al., (2021)].

The efficacy of these treatments under subtropical conditions, specifically evaluating their impacts on mitigating fruit cracking and premature dropping in the bael cultivar NB-9. Through a comprehensive analysis of experimental data and observations, the study seeks to contribute valuable insights into sustainable agricultural practices that can enhance the production quality and yield of bael, thereby supporting the livelihoods of farmers and the availability of this nutritionally rich fruit. By addressing these challenges through innovative and environmentally friendly approaches, this research endeavours to pave the way for a more resilient and productive bael cultivation system.

2. MATERIALS AND METHODS

The present investigation was carried out at the Main Experiment Station, Horticulture, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya (U.P.) during the years 2022-2024. The experiment was laid out in randomized block design with 12 Treatment, namely: T_1 (Control), T_2 (FYM 50 Kg), T_3 (FYM 100 Kg), T_4 (Boric acid 200g), T_5 (Boric acid 400g), T_6 (Biofertilizer 250g/plant [100g Azotobacter + 100g Biovita + 50g PSB]), T_7 (FYM 50Kg + Boric acid 200g), T_8 (FYM 50Kg + Boric acid 400g), T_9 (FYM 50Kg +Biofertilizer 250g/plant [100g Azotobacter + 100g Biovita + 50g PSB]), T_{10} (FYM 100Kg + Boric acid 200g), T_{11} (FYM 100Kg + Boric acid 400g) and T_{12} (FYM 100Kg +Biofertilizer 250g/plant [100g Azotobacter + 100g Biovita + 50g PSB]). The experiment was replicated three times. The Ayodhya district's climate is classified as semi-arid, with three distinct seasons: rainy or wet, winter, and summer or hot. The rainy season begins the last week of June and lasts until September or even into October, with 1200 mm of rain on average. The soil was identified as sandy loam with an average pH of 7.71 and an average proportion of fine sand (64.77%), silt (22.76%), and clay (14.95%). Sixteen-year-old plants were used in the experiment. The prescribed schedule for the Bael plantation was followed for the usual cultural operations, plant protection measures, and basal application of manures and fertilizers. Data was collected on chemical parameters like TSS (°B), acidity (%), Ascorbic acid (mg/100g), reducing sugars (%), non-reducing sugar (%), total sugars (%) and riboflavin (mg/100g). The data obtained during experimentation were statistically analysed as per the method given by Panse and Sukhatme (1985).

3. RESULT AND DISCUSSION

3.1 Effect of Bio-formulations and Boric acid on chemical attributes of fruits of Bael

3.2.1 TSS (°Brix)

TSS, as presented in Table 2 and Graph 2 that the treatment T_7 [FYM 50Kg + Boric acid 200g] recorded the maximum TSS (°Brix) [35.45 (2022-23), 37.09 (2023-24) and 36.27 (Pooled)] °Brix over all other treatments during both the years of study as well as pooled analysis. The 2nd best treatment combination was found to be treatment T_8 [FYM 50Kg + Boric acid 400g] with [35.02 (2022-23), 36.64 (2023-24) and 35.83 (Pooled)] °Brix TSS. During the year 2022-23, it was found that the effect of treatment T_8 [FYM 50Kg + Boric acid 400g] was found at par with treatment T_7 [FYM 50Kg + Boric acid 200g]. The lowest TSS (°Brix) i.e., [30.11 (2022-23), 31.50 (2023-24) and 30.81 (Pooled)] °Brix was recorded in T_1 [Control] during both the years of study as well as pooled analysis.

3.2.2 Acidity (%)

As presented in Table 2 and Graph 2 the minimum acidity value recorded for T_7 [FYM 50Kg + Boric acid 200g] that is minimum acidity (%) [0.32 (2022-23), 0.33 (2023-24) and 0.33 (Pooled)] % over all other treatments during both the years of study as well as pooled analysis. The 2nd best treatment combination was found to be treatment T_8 [FYM 50Kg + Boric acid 400g] with [0.33 (2022-23), 0.35 (2023-24) and 0.34 (Pooled)] % acidity. However, during both the years of study as well as pooled data, the effect of treatment T_8 [FYM 50Kg + Boric acid 400g] was found at par with the treatment T_7 [FYM 50Kg + Boric acid 200g]. The highest acidity (%) i.e., [0.55 (2022-23), 0.58 (2023-24) and 0.56 (Pooled)] % was recorded in T_1 [Control] during both the years of study as well as pooled analysis.

3.2.3 Ascorbic acid (mg/100g)

It is evident from the data presented in Table 2 and Graph 2 that the treatment T_7 [FYM 50Kg + Boric acid 200g] recorded the maximum ascorbic acid (mg/100g) i.e., [24.24 (2022-23), 24.79 (2023-24) and 24.51 (Pooled)] mg/100g over all other treatments during both the years of study as well as pooled analysis. The 2nd best treatment combination was found to be treatment T_8 [FYM 50Kg + Boric acid 400g] with [23.50 (2022-23), 24.03 (2023-24) and 23.76 (Pooled)] mg/100g ascorbic acid. However, during both the years of study as well as pooled data, the effect of treatment T_8 [FYM 50Kg + Boric acid 400g] was found at par with the treatment T_7 [FYM 50Kg + Boric acid 200g]. The lowest ascorbic acid (mg/100g) i.e., [13.40 (2022-23), 13.70 (2023-24) and 13.55 (Pooled)] mg/100g was recorded in T_1 [Control] during both the years of study as well as pooled analysis.

3.2.4 Riboflavin (mg/100g)

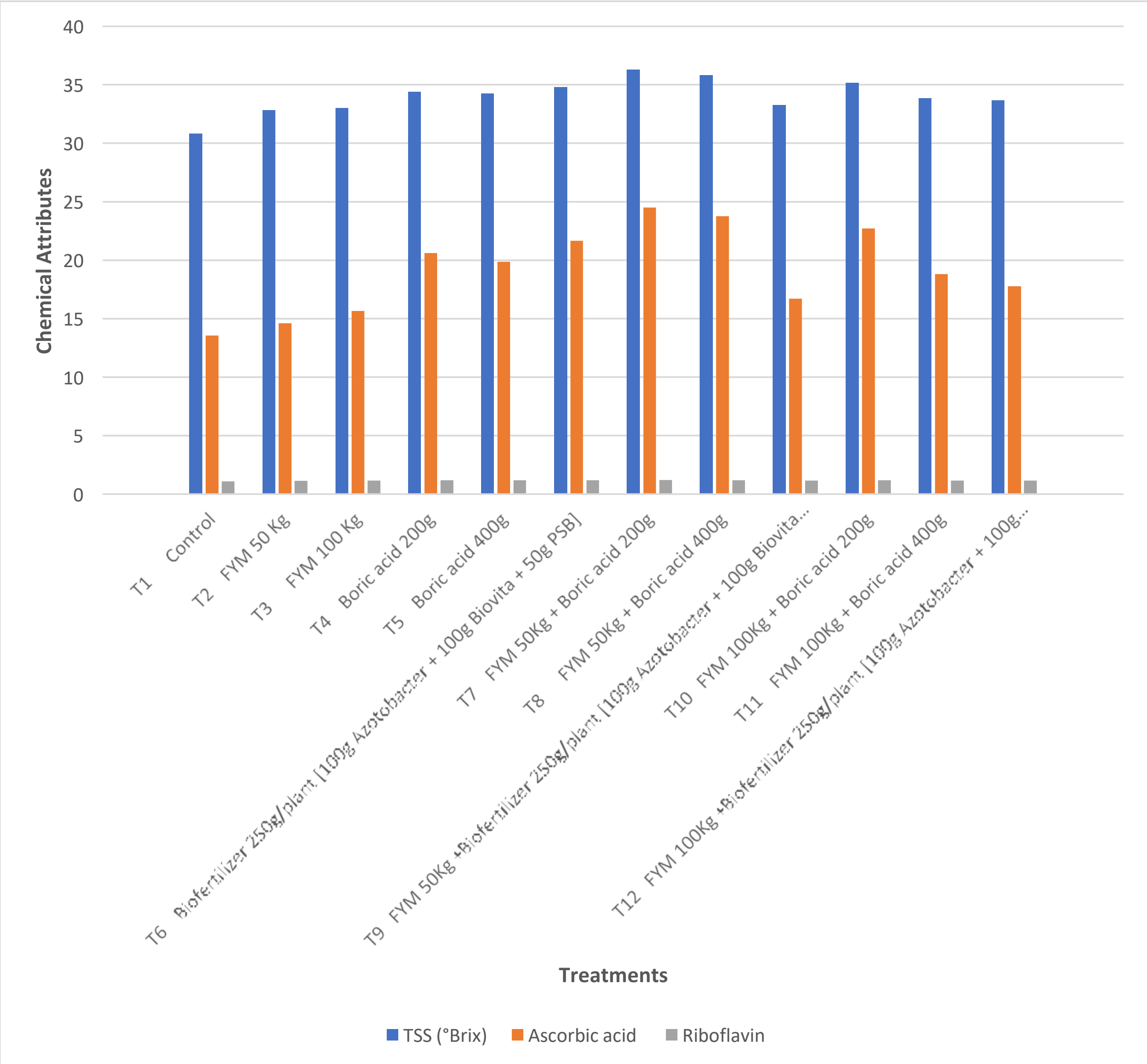
The data significantly presented in Table 2 and Graph 2 revealed that the treatment T_7 [FYM 50Kg + Boric acid 200g] recorded the maximum riboflavin (mg/100g) [1.18 (2022-23), 1.20 (2023-24) and 1.19 (Pooled)] mg/100g over all other treatments during both the years of study as well as pooled analysis. The 2nd best treatment combination was found to be treatment T_8 [FYM 50Kg + Boric acid 400g] with [1.18 (2022-23), 1.18 (2023-24) and 1.18 (Pooled)] mg/100g riboflavin. However, during both the years of study as well as pooled data, the effect of treatment T_8 [FYM 50Kg + Boric acid 400g] and T_{10} [FYM 100Kg + Boric acid 200g] were found at par with T_7. However, according to both the years data, effect of treatment T_5 [Boric acid 400g] whereas according to the year 2022-23 data, effect of treatments T_4 [Boric acid 200g] and T_6 [Biofertilizer 250g/plant (100g Azotobacter + 100g Biovita + 50g PSB)] were found at par with the treatment T_7 [FYM 50Kg + Boric acid 200g]. The lowest riboflavin (mg/100g) i.e., [1.08 (2022-23), 1.08 (2023-24) and 1.08 (Pooled)] mg/100g was recorded in T_1 [Control] during both the years of study as well as pooled analysis.

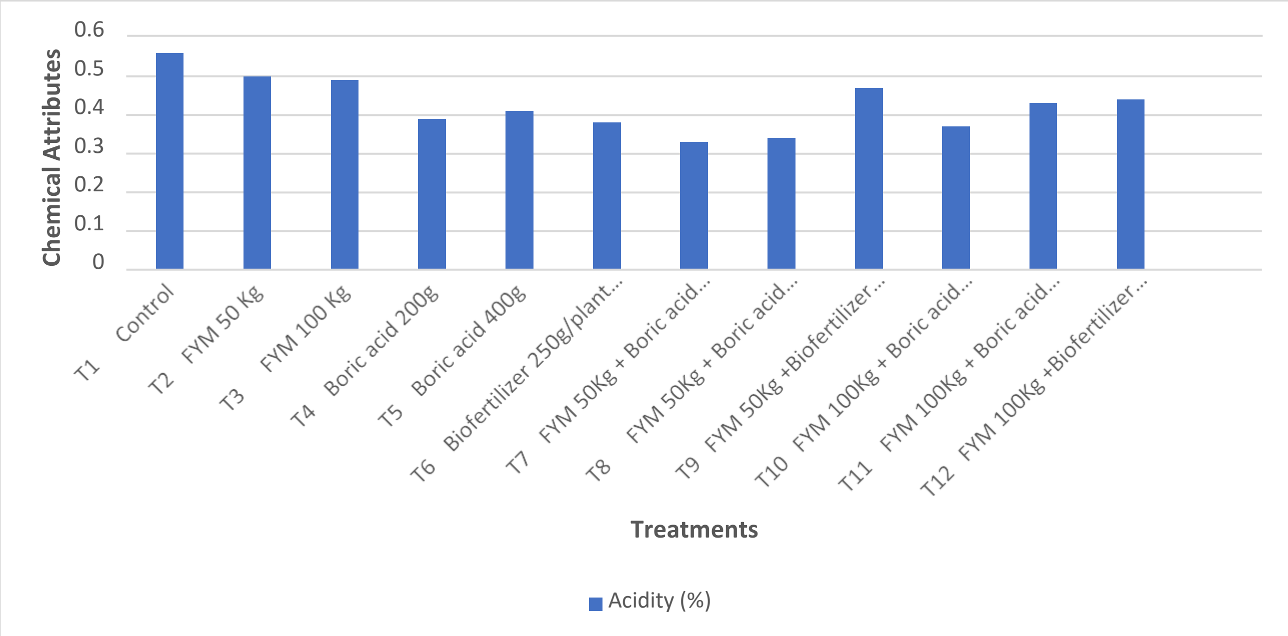
Table 1: Chemical Attributes of Fruits of Bael

Treatments	TSS (°Brix)			Acidity (%)			Ascorbic acid (mg/100g)			Riboflavin (mg/100g)		
	1st Year	2nd Year	Pooled	1st Year	2nd Year	Pooled	1st Year	2nd Year	Pooled	1st Year	2nd Year	Pooled
T_1 Control	30.11	31.50	30.81	0.55	0.58	0.56	13.40	13.70	13.55	1.08	1.08	1.08
T_2 FYM 50 Kg	32.08	33.56	32.82	0.49	0.51	0.50	14.44	14.77	14.60	1.14	1.14	1.14
T_3 FYM 100 Kg	32.28	33.77	33.03	0.48	0.50	0.49	15.48	15.83	15.65	1.14	1.15	1.15
T_4 Boric acid 200g	33.62	35.17	34.40	0.38	0.40	0.39	20.38	20.84	20.61	1.16	1.17	1.17

T_5 Boric acid 400g	33.46	35.01	34.23	0.40	0.42	0.41	19.64	20.08	19.86	1.16	1.18	1.17
T_6 Biofertilizer 250g/plant [100g Azotobacter + 100g Biovita + 50g PSB]	34.00	35.57	34.79	0.37	0.39	0.38	21.42	21.90	21.66	1.16	1.17	1.17
T_7 FYM 50Kg + Boric acid 200g	35.45	37.09	36.27	0.32	0.33	0.33	24.24	24.79	24.51	1.18	1.20	1.19
T_8 FYM 50Kg + Boric acid 400g	35.02	36.64	35.83	0.33	0.35	0.34	23.50	24.03	23.76	1.18	1.18	1.18
T_9 FYM 50Kg +Biofertilizer 250g/plant [100g Azotobacter + 100g Biovita + 50g PSB]	32.50	34.00	33.25	0.46	0.48	0.47	16.52	16.89	16.71	1.14	1.15	1.15
T_{10} FYM 100Kg + Boric acid 200g	34.38	35.97	35.17	0.36	0.38	0.37	22.46	22.97	22.71	1.17	1.18	1.18
T_{11} FYM 100Kg + Boric acid 400g	33.08	34.61	33.84	0.42	0.44	0.43	18.60	19.02	18.81	1.15	1.17	1.16
T_{12} FYM 100Kg +Biofertilizer 250g/plant [100g Azotobacter + 100g Biovita + 50g PSB]	32.91	34.43	33.67	0.43	0.45	0.44	17.56	17.96	17.76	1.15	1.16	1.16
SEm ±	0.10	0.11	0.08	0.01	0.01	0.01	0.28	0.30	0.21	0.28	0.30	0.21
CD at 5%	0.30	0.34	0.22	0.02	0.02	0.01	0.83	0.88	0.59	0.83	0.88	0.59

Graph 1: Chemical Attributes of Fruits of Bael





3.2.5 Reducing sugars (%)

Results of Table 3 and Graph 3 have shown significant value for the treatment T_7 [FYM 50Kg + Boric acid 200g] recorded the maximum reducing sugars (%) i.e., [4.78 (2022-23), 4.95 (2023-24) and 4.87 (Pooled)] % over all other treatments during both the years of study as well as pooled analysis. The 2nd best treatment combination was found to be treatment T_8 [FYM 50Kg + Boric acid 400g] with [4.76 (2022-23), 4.93 (2023-24) and 4.85 (Pooled)] % reducing sugar. However, during both the years of study as well as pooled data, the effect of treatment T_8 [FYM 50Kg + Boric acid 400g] and T_{10} [FYM 100Kg + Boric acid 200g] was found at par with the treatment T_7 [FYM 50Kg + Boric acid 200g]. The lowest reducing sugars (%) i.e., [4.07 (2022-23), 4.22 (2023-24) and 4.14 (Pooled)] % was recorded in T_1 [Control] during both the years of study as well as pooled analysis.

3.2.6 Non-reducing sugars (%)

As presented in Table 3 and Graph 3 that the treatment T_7 [FYM 50Kg + Boric acid 200g] recorded the maximum non-reducing sugar (%) i.e., [15.15 (2022-23), 15.70 (2023-24) and 15.42 (Pooled)] % over all other treatments during both the years of study as well as pooled analysis. The 2nd best treatment combination was found to be treatment T_8 [FYM 50Kg + Boric acid 400g] with [15.09 (2022-23), 15.64 (2023-24) and 15.36 (Pooled)] % non-reducing sugar. However, during both the years of study as well as pooled data, the effect of treatment T_8 [FYM 50Kg + Boric acid 400g] was found at par with the treatment T_7 [FYM 50Kg + Boric acid 200g] whereas according to both the years of study, treatment T_{10} [FYM 100Kg + Boric acid 200g] was found at par with the treatment T_7 [FYM 50Kg + Boric acid 200g]. The lowest non-reducing sugar (%) i.e., [11.98 (2022-23), 12.41 (2023-24) and 12.20 (Pooled)] % was recorded in T_1 [Control] during both the years of study as well as pooled analysis.

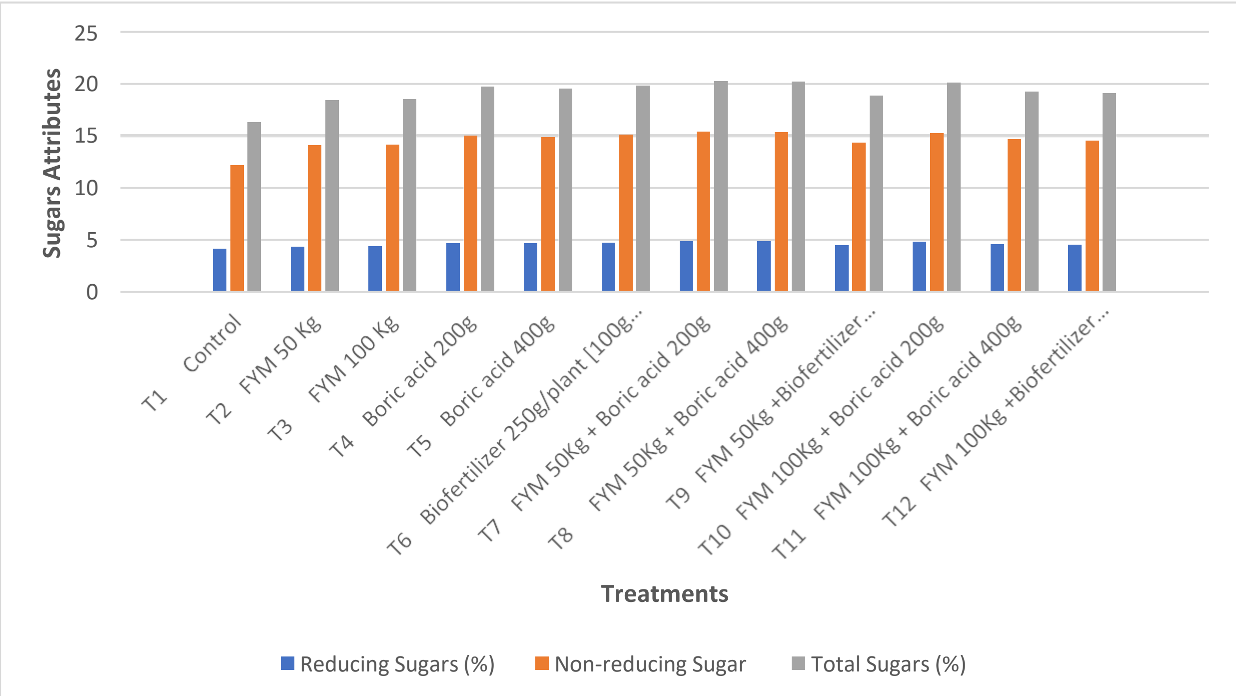
3.2.7 Total sugars (%)

In Table 3 and Graph 3, the highest value found in the treatment T_7 [FYM 50Kg + Boric acid 200g] recorded the maximum total sugar (%) [19.93 (2022-23), 20.65 (2023-24) and 20.29 (Pooled)] % over all other treatments during both the years of study as well as pooled analysis. The 2nd best treatment combination was found to be treatment T_8 [FYM 50Kg + Boric acid 400g] with [19.85 (2022-23), 20.57 (2023-24) and 20.21 (Pooled)] % total sugar. During both the years of study as well as pooled data, it was found that the effect of treatment T_8 [FYM 50Kg + Boric acid 400g] and T_{10} [FYM 100Kg + Boric acid 200g] were found at par with the treatment T_7 [FYM 50Kg + Boric acid 200g]. The lowest total sugars (%) i.e., [16.05 (2022-23), 16.63 (2023-24) and 16.34 (Pooled)] % was recorded in T_1 [Control] during both the years of study as well as pooled analysis.

Table 2: Sugars Attributes of Fruits of Bael

Indian Journal of Science and Technolog	Reducing Sugars (%)			Non-reducing Sugar (%)			Total Sugars (%)		
	1st Year	2nd Year	Pooled	1st Year	2nd Year	Pooled	1st Year	2nd Year	Pooled
T_1 Control	4.07	4.22	4.14	11.98	12.41	12.20	16.05	16.63	16.34
T_2 FYM 50 Kg	4.27	4.42	4.35	13.83	14.33	14.08	18.10	18.76	18.43
T_3 FYM 100 Kg	4.30	4.46	4.38	13.92	14.42	14.17	18.22	18.88	18.55
T_4 Boric acid 200g	4.63	4.80	4.71	14.74	15.27	15.01	19.37	20.07	19.72
T_5 Boric acid 400g	4.60	4.77	4.68	14.63	15.16	14.89	19.23	19.93	19.58
T_6 Biofertilizer 250g/plant [100g Azotobacter + 100g Biovita + 50g PSB]	4.66	4.83	4.74	14.84	15.38	15.11	19.50	20.21	19.85
T_7 FYM 50Kg + Boric acid 200g	4.78	4.95	4.87	15.15	15.70	15.42	19.93	20.65	20.29
T_8 FYM 50Kg + Boric acid 400g	4.76	4.93	4.85	15.09	15.64	15.36	19.85	20.57	20.21
T_9 FYM 50Kg +Biofertilizer 250g/plant [100g Azotobacter + 100g Biovita + 50g PSB]	4.40	4.56	4.48	14.11	14.62	14.37	18.51	19.18	18.85
T_{10} FYM 100Kg + Boric acid 200g	4.75	4.92	4.84	15.03	15.57	15.30	19.78	20.50	20.14
T_{11} FYM 100Kg + Boric acid 400g	4.50	4.66	4.58	14.42	14.94	14.68	18.92	19.60	19.26
T_{12} FYM 100Kg +Biofertilizer 250g/plant [100g Azotobacter + 100g Biovita + 50g PSB]	4.48	4.64	4.56	14.30	14.82	14.56	18.78	19.46	19.12
SEm ±	0.02	0.02	0.02	0.05	0.06	0.04	0.07	0.08	0.05
CD at 5%	0.05	0.07	0.04	0.14	0.18	0.11	0.19	0.25	0.15

Table 2: Sugars Attributes of Fruits of Bael



4. CONCLUSION

From the ongoing summary of the present investigation, it can be inferred that fruit quality parameters viz. chemical parameters like TSS (°B), acidity (%), Ascorbic acid (mg/100g), reducing sugars (%), non-reducing sugar (%), total sugars (%) and riboflavin (mg/100g) were recorded maximum in chemical attributes like TSS, Ascorbic acid, reducing sugars, non-reducing sugar, total sugars and riboflavin besides fruit drop, fruit cracking and acidity in the fruit was drastically reduced. It can be concluded that all the treatments show good effects on increasing fruit quality and minimizing fruit drop and fruit cracking as compared to the control but T_7 (FYM 50Kg + Boric acid 200g) was found more pronounced among all the treatments and can be used in increasing the quality and reducing fruit drop and fruit cracking of Bael.

5. FUTURE SCOPE

Bio-formulation is a system that helps to restore and sustain crop productivity and also assists in checking emerging micronutrient deficiencies. With this view, there is a dire need to minimize the use of chemical fertilizers with the use of integrated nutrient management and organic way for better growth and yield of fruits.

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7. COMPETING INTERESTS

The authors have declared that no competing interests exist.

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