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Khushboo Tandon
Ph.D. Scholar, Department of Horticulture (Fruit Science), College of Agriculture, I.G.K.V., Raipur, Chhattisgarh, India

HK Panigrahi
Assistant Professor, Department of Horticulture (Fruit Science), College of Agriculture, I.G.K.V., Raipur, Chhattisgarh, India

Prabhakar Singh
Professor & Head, Department of Horticulture (Fruit Science), College of Agriculture, I.G.K.V., Raipur, Chhattisgarh, India

GL Sharma
Professor, Department of Horticulture (Fruit Science), College of Agriculture, I.G.K.V., Raipur, Chhattisgarh, India

Preeti Toppo
Ph.D. Scholar, Department of Horticulture (Fruit Science), College of Agriculture, I.G.K.V., Raipur, Chhattisgarh, India

Corresponding Author:
Khushboo Tandon
Ph.D. Scholar, Department of Horticulture (Fruit Science), College of Agriculture, I.G.K.V., Raipur, Chhattisgarh, India

Response of inorganic fertilizers and bio-inoculants on flowering and fruiting behaviour of sapota [*Manilkara acharas* (Mill.) Fosberg] cv. cricket ball under agro-climatic condition of Chhattisgarh plains

Khushboo Tandon, HK Panigrahi, Prabhakar Singh, GL Sharma and Preeti Toppo

Abstract
A study entitled "Response of inorganic fertilizers and bio-inoculants on flowering and fruiting behaviour of sapota [*Manilkara acharas* (Mill.) Fosberg] cv. Cricket Ball under climatic condition of Chhattisgarh Plains" was conducted at the experimental field of Horticulture Farm, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.). The experiment resulted that applying 100% RDF + Azospirillum + PSB + Azotobacter + VAM (T15) significantly increased flowering and fruiting parameters, including the maximum number of flowers produced per shoot (10.75), fruit set (%) (39.11%), number of fruits per shoot (4.21), final retention of fruits per shoot (%) (24.38%) and fruit drop (%) (75.62%). However, reduced number of days to 50% flowering (24.05 days) and days to fruit maturity (249.11 days) when compared to other treatments at all stages of observation. It is concluded that application of inorganic fertilizer with integration of bio-inoculants, markedly improved the flowering and fruiting of sapota cv. Cricket Ball.

Keywords: Sapota, inorganic fertilizers, bio-inoculants, flowering and fruiting parameters

Introduction
One of the significant tropical fruit crops is the sapota, *Manilkara acharas* (Mill.) Fosberg. It pertains to the family Sapotaceae. Sapotas are climacteric fruits that may be picked while they're still hard. Sapota bears heavy flush all over the year in Indian Sub-continent but all the flowers do not develop into fruits and all the fruits do not reach up to maturity. Sapota flower pollination relies heavily on wind. At every stage, from blossoming to fruit maturity, there is a significant quantity of flowers and fruit dropping. Surprisingly, only 50.0% of sapota flower buds open to become flowers, and of those, only 10.0% bear fruit (10% of fruit sets open to form fruit) it means the dropping of fruits instantly takes place after the fruit setting. The usage of chemical fertilisers, which are mostly used for fruit production, degrades the soil's properties and fertility and may cause heavy metals to accumulate in plant tissues, which has an impact on the fruit's nutritional value and palatability. Inorganic fertilisers are becoming so expensive that small and marginal farmers are unable to afford them. The bio-inoculants are living organisms that contribute, store and mobilize soil nutrients for plant growth. According to Kundu *et al.* (2011) [8], bio-inoculants based on renewable energy sources can lower the high investment needed for fertilizer use and are a cost-effective supplement to chemical fertilizers. Since many plants develop and fix nitrogen on organic acid salts like malic and aspartic acid, Azospirillum creates associative symbioses with them (Arun, 2007) [2]. This is especially true of plants that use the C4-dicarboxylic photosynthesis pathway (Hatch and Slack pathway). In order to some extent reduce seedling mortality, Azotobacter generates anti-fungal antibiotics that hinder the growth of a number of dangerous fungi in the root area. Additionally, gibberellins, indole acetic acid (IAA), and B group vitamins are among the physiologically active growth-promoting substances that Azotobacter is known to generate. A number of Azotobacter strains have also demonstrated anti-fungal activity against plant diseases such *Fusarium*, *Alternaria*, and *Helminthosporium*. In order to properly incorporate these helpful organisms into sustainable commercial cropping systems for fruit crops, many research is required to advance our understanding of how to use and employ them.

Materials and Methods

The research was carried out in Raipur (C.G.) during the academic years 2020–2021 and 2021–2022 at the Horticulture Farm Experimental Field of the College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya. A Randomized Block Design was used to organize the experiment, with sixteen different inorganic fertilizer and bio-inoculant treatment combinations are T_0 (Control-100% RDF), T_1 (60% RDF + Azospirillum), T_2 (60% RDF + PSB), T_3 (60% RDF + Azotobacter), T_4 (60% RDF + VAM), T_5 (60% RDF +Azospirillum + PSB + Azotobacter + VAM), T_6 (80% RDF + Azospirillum), T_7 (80% RDF + PSB), T_8 (80% RDF + Azotobacter), T_9 (80% RDF + VAM), T_{10} (80% RDF + Azospirillum + PSB + Azotobacter + VAM), T_{11} (100% RDF + Azospirillum), T_{12} (100% RDF + PSB), T_{13} (100% RDF + Azotobacter), T_{14} (100% RDF + VAM) and T_{15} (100% RDF +Azospirillum + PSB + Azotobacter + VAM), which were replicated three times. The inorganic fertilizer composition was administered seven days before the bio-inoculant operations, with the first half of the N, P, and K dosages supplied in June and the second half in November of each year. The shoots were marked with tags in order to record the observations for the following variables: Days to 50% blooming, Number of flowers produced per shoot, Fruit set (%), Number of fruits per shoot, Final retention of fruits per shoot (%), and Fruit drop (%). The Gomez and Gomez (1984) method of analysis was used for the data.

Days to 50% flowering

On the tagged shoots in all four directions, the overall numbers of flower buds were counted. The average number of days needed for 50% blooming was obtained by counting the blooms after anthesis and 50% flowering on each branch.

Number of flowers produced per shoot

For each treatment, the number of flowers generated on the tagged terminal shoots was counted, and the average number of flowers per shoot was then determined.

Fruit set (%)

After the stigmatic surface and other non-essential floral components, as well as a minor enlargement of the ovary, were dried, the fruit set was designated. The percentage of flower drop and fruit set were computed in accordance with the difference between the quantity of flowers produced and the number of fruit sets.

$$\text{Fruit set \%} = \frac{\text{No. of fruit set}}{\text{No. of flowers}} \times 100$$

Number of fruits per shoot

For each treatment and replication, the number of fruits per tagged shoot were counted.

Final retention of fruits per shoot (%)

The number of harvestable fruits on each tagged stalk was tallied and the average number of fruits that were kept was calculated. Number of fruits retained divided by total number of fruit sets multiplied by 100 was used to compute the percentage of fruit retention.

Fruit drop (%)

Fruit drop was defined as the difference between the number of fruits set and the number of fruits retained, and the ratio of fruit drop to fruit set was determined.

Result and Discussion

1. Days to 50% flowering

Application of various mixes of inorganic fertilizers and bio-inoculants had a considerable impact on the number of days needed for sapota to reach 50% blooming. The data presented in Table 1 clearly showed that during first year, second year and pooled data the minimum days to 50% flowering (24.50, 23.60 and 24.05 days) was recorded under the treatment (100% RDF +Azospirillum + PSB + Azotobacter + VAM) T_{15} which was found non-significant difference with the treatment (80% RDF + Azospirillum + PSB + Azotobacter + VAM) T_{10} having days to 50% flowering of (25.50, 24.07 and 24.78 days) and the maximum days to 50% flowering (31.07, 30.47 and 30.77 days) was registered under the treatment 60% RDF + PSB (T_2). Bio-fertilizers and inorganic fertilizers together promotes cytokinin synthesis in plants which encouraged in the translocation of this produced cytokinin as well as more readily available phosphorus through the xylem arteries in these axillary buds would have favoured the plant's early entry into the reproductive phase. The results closely agree with those published by Nayyer *et al.* (2014) [12] in the banana, Singh *et al.* (2015) [19-20] in the strawberry and Maskar *et al.* (2018) [11] in the sapota.

2. Number of flowers produced per shoot

The various combinations of inorganic fertilizers and bio-inoculants in sapota cv. Cricket Ball considerably influenced the number of flowers produced per branch. It is evident from Table 1, The treatment T_{15} (100% RDF + Azospirillum + PSB + Azotobacter + VAM) resulted in the highest number of flowers produced per shoot (10.33, 11.17, and 10.75) and the lowest number of flowers produced per shoot (7.00, 7.27, and 7.13) was recorded under the treatment T_2 (60% RDF + PSB) during the first and second years, as well as based on pooled data. According to Marathe & Bharambe (2007) [10], The improvement in nutrient availability caused by Azotobacter, FYM, and organic phosphorus through VAM may have elevated levels of several endogenous hormones in plant tissue, which may be responsible for encouraging blooming. This may be due to the addition of organic and inorganic fertilizers to the soil, which increased the efficiency of photosynthesis, resulting in the vigorous growth of plants and the eventual production of many blooms. (Vishwakarma *et al.*, 2017) [22] Because nitrogen fixers made more nitrogen available to plant roots and made it easier for nitrogen to go from roots to flowers through leaves, (Singh and Singh, 2006) [17]. The findings are consistent with the findings published by Pilania *et al*. (2010) [13] for guava, Gupta and Tripathi (2012) [7] for strawberry and Singh *et al.* (2015) [18] for guava.

3. Fruit set (%)

Inorganic fertilizer and bio-inoculant treatment combinations had a significant impact on the proportion of sapota fruits that were set, according to a study of the data in Table 2. The maximum fruit set percentages (38.43, 39.79, and 39.11%) were noted under the treatment T_{15} (100% RDF + Azospirillum + PSB + Azotobacter + VAM), and the minimum fruit set percentages (25.18, 25.39, and 25.29%) was noted under the treatment 60% RDF + PSB (T_2) during the first year, second year and based on pooled data. This may be due to the use of Azotobacter and PSB, which have both promoter and inhibitory effects on growth hormone. The percentage of berry set and the quantity of fruits per shoot were both boosted by the combined effects of applying bio-fertilizer, nitrogen, and GA_3 to strawberry plants. (Singh and Singh 2009) [18]. According to Dheware and Waghmare (2009) [5], the availability of nutrients through FYM, organic phosphorus through phoshobacteria, and IAA through azospirillum may have increased the levels of several endogenous hormones in plant tissue, which are in charge of enhancing flowering and fruit development. According to Addicot and Lynch (1955) [1], increased auxin production may be the reason for fruit set and decreased flower drop in response to nitrogen delivery.

4. Number of fruits per shoot

The treatment T15 (100% RDF + Azospirillum + PSB + Azotobacter + VAM) produced the highest number of fruits per shoot (3.97, 4.44, and 4.21), while the treatment T2 (60% RDF + PSB) produced the lowest number of fruits per shoot (1.76, 1.84, and 1.80) in the first, second and based on pooled mean years. The highest number of fruits per shoot may be a result of the combination of inorganic, organic and bio-inoculants, which promotes faster plant growth and higher levels of cytokinin production. It would have been advantageous for the plant to enter the reproductive phase early if cytokinin and phosphorus had accumulated in these axillary buds. This could have facilitated the movement of the cytokinin that was produced as well as an increase in the quantity of phosphorus that was easily accessible through the xylem arteries. It may also be the result of cytokinin accumulation in the flower that is generating fruit, which may have increased the number of fruits per stem. The current results are consistent with that which observed in Banana cv. Grand Naine and Baviskar et al. (2011) [3] reported in Sapota.

5. Final retention of fruits per shoot (%)

The treatment T_{15} (100% RDF + Azospirillum + PSB + Azotobacter + VAM) had the highest final retention of fruits per shoot (23.98, 24.78, and 24.38%), while the treatment T_2 (60% RDF + PSB) had the lowest (9.79, 9.88, and 9.84%) during the first and second year as well as based on pooled mean. The presence of auxins in the abscission zone may be the major cause of flower/fruit drop. The Azotobacter, PSB, and AM fungi increased the availability of N and P to plant roots as well as their transport from roots to flowers by developing a large additional radical mycelium that supports the plants in utilising mineral nutrients and water from the soil. The application of bio-inoculants is known to enhance the rate of synthesis of plant growth regulators (auxins, gibberellins, and cytokinin), resulting in an internal balance between promoters and inhibitors that favours the fruit-growing process. The current results are consistent with those reported by Mahendra *et al.* (2009) [9] in ber cv. Banarasi Karahka and Sharma *et al.* (2016) [9] in mango cv. Amrapali.

6. Fruit drop (%)

Data analysis demonstrated that the treatment T15 (100% RDF + Azospirillum + PSB + Azotobacter + VAM) had the lowest fruit drop percentages of 76.02, 75.22, and 75.62% over the first, second, and pooled years. During the same observation periods, the maximum fruit drop percentages of 90.21, 90.12, and 90.16% were declared with the treatment T2 (60% RDF + PSB). The increased fruit setting might be attributed to the major influence of Azotobacter, PSB, VAM fungus, and Azospirillum on fruit set and fruit drop. According to (Sharma *et al.*, 2016) [16], bio-inoculants boosted nutrient availability and improved plant solute absorption. This is due to the fact that farmyard manure and bacteria not only supply organic matter and macro and micronutrients to soil, but also improve its physical and chemical qualities, resulting in nutritional balance in both the soil and the plant. Thus, improved plant growth and development as a result of nutritional balance increases fruit set percentages while decreasing fruit loss. These findings are consistent with Mahendra *et al.* (2009) [9] in ber, Sharma *et al.* (2016) [16] in mango, and Shaimaa and Massoud (2017) [14] in Orange cv. Washington Navel orange.

Table 1: Impact of different combinations of inorganic fertilizers and bio-inoculants on days to 50% flowering, number of flowers produced per shoot and fruit set (%) in sapota cv. Cricket Ball

Treatments	Days to 50% flowering			Number of flowers produced per shoot			Fruit Set (%)		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
T_0 - Control (100% RDF)	28.53^{bcd}	27.70^{def}	28.12^{cdef}	8.77^{b}	9.10^{d}	8.93^{d}	33.41^{de}	33.70^{d}	33.56^{de}
T_1 - 60% RDF + Azospirillum	30.67^{a}	29.80^{ab}	30.23^{ab}	7.20^{ef}	7.40^{e}	7.30^{f}	25.22^{i}	25.43^{g}	25.33^{gh}
T_2 - 60% RDF + PSB	31.07^{a}	30.47^{a}	30.77^{a}	7.00^{f}	7.27^{e}	7.13^{f}	25.18^{i}	25.39^{g}	25.29^{h}
T_3 - 60% RDF + Azotobacter	29.53^{b}	29.00^{bc}	29.27^{bc}	7.80^{de}	7.93^{e}	7.87^{ef}	26.33^{hi}	26.84^{fg}	26.58^{gh}
T_4 - 60% RDF + VAM	29.40^{b}	28.80^{bcd}	29.10^{bcd}	7.97^{cd}	8.07^{e}	8.02^{e}	26.95^{gh}	27.23^{f}	27.09^{g}
T_5 - 60% RDF + (Azospirillum + PSB + Azotobacter + VAM)	28.87^{bc}	27.93^{cde}	28.40^{cde}	8.57^{bc}	9.03^{d}	8.80^{d}	27.63^{g}	27.73^{f}	27.68^{g}
T_6 - 80% RDF + Azospirillum	28.40^{bcd}	27.47^{efg}	27.93^{defg}	9.90^{a}	10.03^{c}	9.97^{bc}	32.25^{ef}	33.14^{de}	32.70^{ef}
T_7 - 80% RDF + PSB	28.07^{cde}	27.33^{efg}	27.70^{efgh}	9.83^{a}	9.97^{c}	9.90^{c}	31.81^{f}	32.28^{e}	32.05^{f}
T_8 - 80% RDF + Azotobacter	27.93^{cde}	26.87^{efgh}	27.40^{efgh}	9.93^{a}	10.00^{c}	9.97^{bc}	33.83^{d}	34.27^{cd}	34.05^{d}
T_9 - 80% RDF + VAM	27.67^{de}	26.53^{fghi}	27.10^{fghi}	10.00^{a}	10.17^{c}	10.08^{abc}	34.02^{d}	35.22^{c}	34.62^{d}
T_{10} - 80% RDF + (Azospirillum + PSB + Azotobacter + VAM)	25.50^{gh}	24.07^{kl}	24.78^{kl}	10.30^{a}	11.07^{ab}	10.68^{ab}	37.75^{ab}	38.12^{b}	37.94^{ab}
T_{11} - 100% RDF + Azospirillum	27.37^{def}	26.33^{ghi}	26.85^{ghi}	10.13^{a}	10.23^{c}	10.18^{abc}	35.34^{c}	36.76^{b}	36.05^{c}
T_{12} - 100% RDF + PSB	27.13^{ef}	26.00^{hij}	26.57^{hij}	10.10^{a}	10.20^{c}	10.15^{abc}	35.61^{c}	36.98^{b}	36.30^{c}
T_{13} - 100% RDF + Azotobacter	26.47^{fg}	25.40^{ij}	25.93^{ijk}	10.23^{a}	10.33^{c}	10.28^{abc}	36.83^{b}	37.18^{b}	37.01^{bc}
T_{14} - 100% RDF + VAM	26.00^{g}	25.00^{jk}	25.50^{jk}	10.27^{a}	10.40^{bc}	10.33^{abc}	36.95^{b}	37.29^{b}	37.12^{bc}
T_{15} - 100% RDF + (Azospirillum + PSB + Azotobacter + VAM)	24.50^{h}	23.60^{l}	24.05^{l}	10.33^{a}	11.17^{a}	10.75^{a}	38.43^{a}	39.79^{a}	39.11^{a}

SE(m)±	0.40	0.49	0.45	0.14	0.17	0.15	0.49	0.55	0.52
C.D. at 5%	1.17	1.40	1.26	0.41	0.48	0.44	1.41	1.60	1.48

Table 2: Impact of different combinations of inorganic fertilizers and bio-inoculants on Fruit Set (%) and Number of fruits per shoot in sapota cv. Cricket Ball

Treatments	Number of fruits per shoot			Final retention (%)			Fruit Drop (%)		
	2020-21	**2021-22**	**Pooled**	**2020-21**	**2021-22**	**Pooled**	**2020-21**	**2021-22**	**Pooled**
T_0 - Control (100% RDF)	2.93^{e}	3.07^{e}	3.00^{f}	12.09^{h}	12.15^{i}	12.12^{h}	87.91^{b}	87.85^{b}	87.88^{b}
T_1 - 60% RDF + Azospirillum	1.82^{g}	1.88^{g}	1.85^{h}	9.91^{i}	9.99^{j}	9.95^{i}	90.09^{a}	90.01^{a}	90.05^{a}
T_2 - 60% RDF + PSB	1.76^{g}	1.84^{g}	1.80^{h}	9.79^{i}	9.88^{j}	9.84^{i}	90.21^{a}	90.12^{a}	90.16^{a}
T_3 - 60% RDF + Azotobacter	2.05^{fg}	2.13^{fg}	2.09^{gh}	10.08^{i}	10.19^{j}	10.14^{i}	89.92^{a}	89.81^{a}	89.86^{a}
T_4 - 60% RDF + VAM	2.15^{fg}	2.19^{fg}	2.17^{gh}	10.20^{i}	10.29^{j}	10.25^{i}	89.80^{a}	89.71^{a}	89.75^{a}
T_5 - 60% RDF + (Azospirillum + PSB + Azotobacter + VAM)	2.37^{f}	2.50^{f}	2.44^{g}	11.55^{h}	11.77^{i}	11.66^{h}	88.45^{b}	88.23^{b}	88.34^{b}
T_6 - 80% RDF + Azospirillum	3.19^{de}	3.32^{de}	3.26^{def}	15.82^{f}	15.92^{g}	15.87^{f}	84.18^{d}	84.08^{d}	84.13^{d}
T_7 - 80% RDF + PSB	3.13^{de}	3.22^{e}	3.17^{ef}	14.46^{g}	14.62^{h}	14.54^{g}	85.54^{c}	85.38^{c}	85.46^{c}
T_8 - 80% RDF + Azotobacter	3.36^{cde}	3.43^{cde}	3.39^{cdef}	17.00^{e}	17.54^{f}	17.27^{e}	83.00^{e}	82.46^{e}	82.73^{e}
T_9 - 80% RDF + VAM	3.40^{bcde}	3.58^{cde}	3.49^{cde}	17.26^{e}	17.83^{f}	17.54^{e}	82.74^{e}	82.17^{e}	82.46^{e}
T_{10} - 80% RDF + (Azospirillum + PSB + Azotobacter + VAM)	3.89^{ab}	4.22^{ab}	4.06^{ab}	22.37^{b}	23.34^{b}	22.86^{b}	77.63^{h}	76.66^{i}	77.14^{h}
T_{11} - 100% RDF + Azospirillum	3.58^{abcd}	3.76^{bcd}	3.67^{bcd}	19.61^{cd}	20.62^{de}	20.11^{cd}	80.39^{fg}	79.38^{fg}	79.89^{fg}
T_{12} - 100% RDF + PSB	3.60^{abcd}	3.77^{bcd}	3.68^{bcd}	19.06^{d}	20.06^{e}	19.56^{d}	80.94^{f}	79.94^{f}	80.44^{f}
T_{13} - 100% RDF + Azotobacter	3.77^{abc}	3.84^{bcd}	3.81^{abc}	20.47^{c}	21.39^{cd}	20.93^{c}	79.53^{g}	78.61^{gh}	79.07^{g}
T_{14} - 100% RDF + VAM	3.79^{abc}	3.88^{bc}	3.83^{abc}	21.64^{b}	22.25^{c}	21.95^{b}	78.36^{h}	77.75^{h}	78.05^{h}
T_{15} - 100% RDF +(Azospirillum + PSB + Azotobacter + VAM)	3.97^{a}	4.44^{a}	4.21^{a}	23.98^{a}	24.78^{a}	24.38^{a}	76.02^{i}	75.22^{j}	75.62^{i}
SE(m)±	0.07	0.08	0.07	0.37	0.35	0.36	0.37	0.35	0.36
C.D. at 5%	0.20	0.24	0.21	1.06	1.01	1.02	1.06	1.01	1.02

Conclusions

The results show that applying inorganic fertilizer with the addition of bio-inoculants improves flowering, fruit set, number of fruits per shoot, fruit retention, and minimizes fruit loss in sapota cv. Cricket Ball.

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