International Journal of Biology Sciences

ISSN Print: 2664-9926
ISSN Online: 2664-9934
NAAS Rating (2025): 4.82
IJBS 2025; 7(10): 01-07
www.biologyjournal.net
Received: 20-07-2025
Accepted: 23-08-2025

RA Borikar
P.G. Student, Department of Plant Pathology and Agricultural Microbiology, College of Agriculture, Pune, Maharashtra, India

YS Balgude
Plant Pathologist AICRP on Arid Zone Fruits (Fig and Custard Apple), Jadhavwadi, Tal. Purandar, Dist. Pune, Maharashtra, India

PD Dalve
Horticulturist. AICRP on Arid Zone Fruits (Fig & Custard apple) Jadhavwadi Tal. Purandar Dist. Pune, Maharashtra, India

AC Jadhav
Jr. Mycologist AICRP on Mushroom College of Agriculture, Pune-05, Maharashtra, India

VM Sali
Junior Plant Pathologist, Regional Wheat Rust Research Station, Mahabaleshwar, Dist. Satara, Maharashtra, India

Corresponding Author:
RA Borikar
P.G. Student, Department of Plant Pathology and Agricultural Microbiology, College of Agriculture, Pune, Maharashtra, India

Effect of liquid consortium of *Azotobacter*, phosphate solubilizing bacteria and potassium mobilizing bacteria on growth and yield of custard apple (*Annona squamosa* L.) var. Phule Purandar

RA Borikar, YS Balgude, PD Dalve, AC Jadhav and VM Sali

DOI: https://www.doi.org/10.33545/26649926.2025.v7.i10a.490

Abstract
A field experiment was conducted during *Kharif* Bahar 2024 at the All India Coordinated Research Project on Arid Zone Fruits (Fig and Custard Apple), Jadhavwadi, Pune, with laboratory analyses conducted at the Division of Plant Pathology and Agricultural Microbiology and the Division of Soil Science and Agricultural Chemistry, College of Agriculture, Pune. to study the impact of a liquid consortium containing *Azotobacter*, Phosphate Solubilizing Bacteria (PSB), and Potassium Mobilizing Bacteria (KMB), integrated with varying levels of recommended fertilizer dose (RDF), on growth and yield of custard apple (*Annona squamosa* L.) var. Phule Purandar. The experiment was laid out in Randomized Block Design (RBD) with ten treatments and three replications. The results revealed that the combined application of RDF with the liquid consortium significantly enhanced vegetative growth, yield attributes, fruit quality, and soil microbial activity as compared to RDF or biofertilizer application alone. Notably, the treatment with 100% RDF + consortium at 20 ml per plant recorded the highest growth and yield, while 75% RDF + consortium produced comparable yield with improved benefit-cost ratio, highlighting its superiority as a sustainable and economically viable practice. This study establishes the efficacy of biofertilizer consortia in improving growth, productivity, and profitability of custard apple cultivation.

Keywords: *Azotobacter*, PSB, KMB, liquid consortium, growth and yield

Introduction

Custard apple (*Annona squamosa* L.) is a delectable and significant minor fruit crop well-suited to tropical and subtropical climates. Belonging to the Annonaceae family, this fruit is originally from the West Indies but has been cultivated across Central America to Southern Mexico since ancient times.

Biofertilizer is increasingly important due to its environmental safety, non-toxic nature, and potential to reduce soil and water pollution. It plays a key role in promoting organic and sustainable agriculture, offering small and marginal farmers an eco-friendly means to enhance crop yields (Moorthy and Malliga, 2012) [15]. The application of biofertilizer involves the inoculation of microorganisms that convert non-usable nutrient elements into a usable form through biological processes (Bandara *et al.*, 2019) [1]. *Azotobacter*, a type of microbial inoculant, exists in the soil and has the ability to convert nitrogen elements from an insoluble to a soluble form through a biological process. These *Azotobacter* organisms are utilized in live formulations of beneficial microorganisms, which can be applied to the roots, soil, or seeds to enhance the availability of nutrients. This is achieved through their biological activity, ultimately aiding in the restoration of the depleted micro flora and improving overall soil health (Hazarika and Ansari, 2007) [10].

Phosphorus (P) is a vital nutrient necessary for the healthy growth and proper functioning of plants. Its role in various aspects of plant growth and development is crucial, and any deficiencies in phosphorus can hinder plant growth and development. Although soil contains both organic and inorganic compounds of phosphorus, most of them are inactive and not readily available to plants. This poses a challenge for farmers who cannot afford phosphorus fertilizers to address phosphorus deficits.

Therefore, alternative methods are necessary to provide plants with phosphorus. One such method is the use of phosphate solubilizing microbes (PSMs), which are beneficial microorganisms capable of converting insoluble phosphorus compounds into a soluble form that plants can easily absorb and utilize.

Potassium is a major and essential macronutrient for normal plant growth and development. It can strengthen crop resistance to a wide range of biotic and abiotic stresses, including pests and diseases. However, the amount of potassium released by soils depends on changes in different soil parameters, topographical features, and biogeochemical characteristics (Basak and Biswas, 2009) [2]. Microorganisms possess the ability to mobilize mineral nutrients in soil, thereby making them available for efficient plant uptake. For example, one way to utilize feldspar, waste mica, or rock phosphate is by mobilizing their potassium through beneficial microorganisms. These microorganisms convert unavailable potassium into a form that plants can readily absorb through microbial activity (Chandra and Greep, 2006, Parmar and Sindhu, 2013; Sessitsch *et al.*, 2013) [4, 16, 22]. Designated this group of beneficial microorganisms as Potash Mobilizing Bacteria (KMB).

Using biofertilizers along with chemical fertilizers in custard apple farming ensures a synergistic effect boosting productivity, preserving soil health, and promoting sustainability. This integrated nutrient management approach is especially valuable in the long-term cultivation of perennial fruit crops like custard apple.

Materials and Methods

The details of the material used and methods adopted during the course of the present investigation are described in this chapter under different headings.

Experimental details

Season: *Kharif Bahar* 2024
Treatments: 10
Replication: Three
Design: RBD

Treatment Details

T_1	Recommended Dose of Fertilizers (RDF) (250: 125: 125 g NPK per plant)
T_2	100% RDF + Liquid consortium of *Azotobacter* PSB and KMB @ 10ml each per L water per plant
T_3	75% RDF + Liquid consortium of *Azotobacter* PSB and KMB @10 ml each per L water per plant
T_4	50% RDF + Liquid consortium of *Azotobacter* PSB and KMB @10 ml each per L water per plant
T_5	100% RDF + Liquid consortium of *Azotobacter* PSB and KMB @20 ml each per L water per plant
T_6	75% RDF + Liquid consortium of *Azotobacter* PSB and KMB @20 ml each per L water per plant
T_7	50% RDF + Liquid consortium of *Azotobacter* PSB and KMB @20 ml each per L water per plant
T_8	Liquid consortium of *Azotobacter* PSB and KMB @10 ml each per L water per plant
T_9	Liquid consortium of *Azotobacter* PSB and KMB @20 ml each per L water per plant
T_{10}	Absolute control

I. Growth parameters

A. Initial and incremental plant spread [N-S & E-W directions] (cm) after fruit harvest

Plant spread was measured in both North-South and East-West directions at two stages: at the beginning of the experiment (June 2024) and upon its completion (November 2024). Measurements were taken in centimetres using a measuring tape. The increase in plant spread (cm) in both the N-S and E-W directions was calculated using the following formula.

Incremental plant spread (cm) = Plant spread (cm) at the end of harvest - Plant spread (cm) at initial

B. Initial and incremental plant height (cm) after fruit harvest

Plant height (cm) was recorded at two stages during the experiment: prior to its commencement in June 2024, and after its completion in November 2024. The height was measured from the ground level to the topmost point of the plant using a measuring tape. Incremental plant height (cm) was calculated using the following formula.

Incremental plant height (cm) = Plant height (cm) at the end of harvest - Plant height (cm) at initial

C. Initial and incremental stem girth (cm) after fruit harvest

Stem girth (cm) was measured at two stages: at the beginning of the experiment (June 2024) and upon its completion (November 2024). Measurements were taken in centimeters using a measuring tape. The increase in stem girth in was calculated using the following formula.

Incremental stem girth (cm) = Stem girth (cm) at the end of harvest - Stem girth (cm) at initial

II. Yield parameters

A. Per cent fruit set (%)

The percentage of fruit set was calculated by dividing total number of fruit set by total number of flowers per tree multiplied by 100.

$$\text{Fruit set (\%)} = \frac{Total\ number\ of\ fruits\ set}{Total\ number\ of\ flowers\ per\ tree} \times 100$$

B. Per cent fruit retention (%)

In each fortnight, the fruits those were set, were tagged. Their retention was observed at the time of harvesting when the fruits attained appropriate maturity and percentage was worked out as follows.

$$\text{Fruit retention (\%)} = \frac{Total\ number\ of\ fruits\ carried\ to\ maturity}{Total\ number\ of\ fruits\ set} \times 100$$

C. Average Fruit length (cm)
Fruit length was measured at the time of harvest (maturity stage). For each treatment, five fruits were randomly selected, and their lengths were measured in centimetres using a Vernier Calliper. The average fruit length was then calculated and recorded in centimetres.

D. Average Fruit breadth (cm)
The fruit diameter of randomly selected fruits was measured at harvest (maturity stage). For each treatment, the diameter of five fruits was recorded in centimetres using a measuring tape. The average fruit diameter was then calculated and expressed in centimetres.

E. Average fruit weight (gm)
At the time of harvest (maturity stage), five marketable fruits were randomly selected from each treatment. Their weights were measured in grams using an electronic weighing balance, and the average fruit weight was calculated.

F. TSS (º Brix)
The total soluble solids (TSS) of custard apple fruit were measured using a hand refractometer. A drop of extracted custard apple pulp was placed on the refractometer prism, and the reading was recorded in degrees Brix. For each treatment, five readings were taken, and their average was calculated.

G. Pulp percentage
For calculating weight of pulp, sum of weight of rind and weight of seed was subtracted from weight of fruit. The weight of pulp was taken separately from each fruit. The percentage pulp is calculated by dividing actual weight of pulp by total weight of fruit multiplied by 100.

H. Number of seeds per fruit
Five marketable fruits were randomly selected from each treatment, and their seeds were manually removed. The seeds from each fruit were counted individually, and the average number of seeds per fruit was calculated and recorded.

I. Average Number of fruits per plant
The number of fruits per plant was recorded treatment-wise at each harvest. These values were then summed and expressed as the total number of fruits per plant.

J. Fruit yield (kg/plant and t/ha)
Fruits harvested from each treated plant were weighed in kilograms during all harvestings. The total weight was then summed and expressed as fruit yield per plant (kg/plant) and per hectare (t/ha).

Result and Discussion

I. Effect of *Azotobacter*, PSB and KMB isolates on growth parameters
The results obtained in respect of increase in plant height, canopy spread (N-S and E-W direction), and stem girth are presented in Table 1.

A. Plant height (cm)
The results revealed that among all the treatments, the significantly maximum incremental plant height (48.33 cm) was recorded with T_5 (100% RDF + Liquid consortium of *Azotobacter* + PSB + KMB @ 20 ml each per L water per plant) treatment. However, it was statistically at par with T_6 (46.50 cm), T_2 (46.00 cm) and T_1 (45.33 cm). Significantly, minimum incremental plant height (16.67 cm) was recorded in T_{10} (Absolute control) treatment.

B. Canopy spread (N-S) (cm)
The results indicated that among all the treatments, the significantly maximum incremental canopy spread (48.00 cm) was recorded with T_5 (100% RDF + Liquid consortium of *Azotobacter* + PSB + KMB @ 20 ml each per L water per plant). However, it was statistically at par with T_6 (44.67 cm), T_2 (43.67 cm), and T_3 (42.33 cm). Significantly the minimum canopy spread in N-S direction (20.33 cm) was recorded in T_{10} (Absolute control).

C. Canopy spread (E-W) (cm)
The results revealed that among all the treatments, the significantly maximum incremental canopy spread (46.00 cm) was recorded with T_5 (100% RDF + Liquid consortium of *Azotobacter* + PSB + KMB @ 20 ml each per L water per plant). However, it was statistically at par with T_6 (44.00 cm) and T_2 (42.00 cm). The treatment T_{10} i.e. absolute control recorded significantly minimum incremental canopy spread in E-W direction of 19.33 cm.

D. Stem girth (cm)
The effect of liquid consortia of *Azotobacter*, phosphate solubilizing bacteria and potash mobilizing bacteria on stem girth of custard apple did not show any increase in its length.
These findings regarding enhancement in plant height and canopy spread are in accordance with the results reported by Waghamare *et al.* (2019) [25] except stem girth, who observed increase in plant height (51.55cm), increase in tree spread (east-west spread 47.55cm and north-south spread 49.80 cm) in custard apple cv. Balanagar with the treatment 100%RDF + FYM + *Azotobacter* + PSB and Rajadurai *et al.* (2022) [20] who reported positive influence of combined application of *Azotobacter*, *Azospirillum*, VAM, Phosphobacteria and 50% standard NPK on the vegetative growth of custard apple var. APK-1. Patil *et al.* (2022) [19] and Gondaliya *et al.* (2023) [8] also found that the integration of RDF with biofertilizers and organic sources like vermicompost and neem cake significantly improved the growth parameters.

II. Effect of *Azotobacter* PSB and KMB isolates on quality and yield
The data regarding fruit set (%), fruit retention (%), fruit length (cm), fruit breadth (cm), tss (°brix), no. of seeds, seed weight (g), pulp percentage (%), fruit weight (g), number of fruits per plant and yield (kg/plant and t/ha), fruit weight (gm), no. of fruits/plant, fruit yield per tree (kg/tree) and fruit yield per ha (t/ha), is presented in Table 2, 3 and 4.

A. Fruit set (%)
The result clearly indicated significantly that an application of liquid consortium of *Azotobacter*, PSB, and KMB and inorganic fertilizer influenced the fruit set (%). Among all the treatments, significantly the highest fruit set (22.12%) was recorded with T_5 (100% RDF + Liquid consortium of *Azotobacter* + PSB + KMB @ 20 ml each per L water per

plant). It was followed by T_6 (22.07%) and T_2 (21.62%). However, the minimum fruit set (18.41%) was recorded in T_{10} (Absolute control).

B. Fruit retention (%)

The result revealed that, among all the treatments, the T_5 i.e. application of 100% RDF + Liquid consortium of *Azotobacter* + PSB + KMB @ 20 ml each per L water per plant of custard apple recorded the significant maximum fruit retention (66.86%). It was followed by treatment T_6 (66.26%) Significantly, the minimum fruit retention (59.31%) was recorded with T_{10} (Absolute control).

C. Fruit length (cm)

The results indicated that, the application of different treatments had a significant influence on fruit length. Among all the treatments, the significantly maximum average fruit length (7.63 cm) was recorded with T_5 (100% RDF + Liquid consortium of *Azotobacter* + PSB + KMB @ 20 ml each per L water per plant). However, it was statistically at par with T_6 (7.60 cm). Significantly, the minimum average fruit length (5.90 cm) was recorded with T_{10} (Absolute control).

D. Fruit breadth (cm)

The results revealed that, the application of different treatments significantly influenced the fruit breadth. Among all the treatments, the significantly maximum average fruit girth (7.57 cm) was recorded with T_5 (100% RDF + Liquid consortium of *Azotobacter* + PSB + KMB @ 20 ml each per L water per plant). It was statistically at par with T_6 (7.43 cm). However, the minimum average fruit girth (5.90 cm) was recorded with T_{10} (Absolute control).

These findings regarding enhancement in fruit set and fruit retention were reported by Mahendra *et al.* (2009) [14] who observed that application of *Azotobacter* + PSB in combination with inorganic fertilizers significantly improved fruit set (57.55%) and fruit retention in ber in FYM + NPK @ 100% + *Azotobacter* + PSB and Godage *et al.* (2013) who noticed maximum fruit set in guava in 75% N+ 75% P2O5 + 100% K2O + *Azotobacter* 5 ml/tree + PSB 5 ml/tree. Waghamare *et al.* (2019) [25] also found that the combined use of inorganics and biofertilizers positively influenced the fruit set% in treatment 100% RDF + FYM + *Azotobacter* + PSB. The increase in fruit length and fruit breadth under integrated application of RDF with microbial consortium were reported by Gondaliya *et al.* (2023) [8] and Patel *et al.* (2024) [18] in custard apple.

E. TSS (ºBrix)

The results indicated that different treatments had an observable but statistically non-significant effect on TSS content. Among all the treatments, the maximum TSS (26.43°Brix) was recorded with T_5 (100% RDF + Liquid consortium of *Azotobacter* + PSB + KMB @ 20 ml each per L water per plant). It was followed by T_6 (26.27°Brix). However, the minimum TSS (24.11°Brix) was recorded with T_{10} (Absolute control). These results are in agreement with the findings of Rajadurai *et al.* (2022) [20], Gondaliya *et al.* (2023) [8] and Patel *et al.* (2024) [18].

Table 1: Effect of liquid consortium of *Azotobacter*, PSB and KMB on plant growth parameters of custard apple (*Annona squamosa L.*) cv. Phule Purandar.

SN	Treatments	Initial (At bahar)				Final (at harvest)				Incremental (Final- Initial)			
		Plant height (m)	Canopy spread (N-S) (m)	Canopy spread (E- W) (m)	Stem girth (cm)	Plant height (m)	Canopy spread (N-S) (m)	Canopy spread (E- W) (m)	Stem girth (cm)	Plant height (cm)	Canopy spread (N-S) (cm)	Canopy spread (E- W) (cm)	Stem girth (cm)
1	RDF (250: 125:125 g NPK per plant)	2.84	3.57	3.40	29.00	3.30	3.98	3.80	29.00	45.33	41.33	40.00	0.00
2	100% RDF + Liquid cons. *Azotobactor*, + PSB + KMB @ 10 ml each per plant	2.87	3.01	2.98	31.67	3.33	3.44	3.40	31.67	46.00	43.67	42.00	0.00
3	75% RDF + Liquid cons. of *Azotobactor*,+ PSB + KMB @ 10 ml each per plant	2.73	3.06	3.21	27.83	3.12	3.48	3.61	27.83	38.83	42.33	40.33	0.00
4	50% RDF + Liquid cons. of *Azotobactor*,+ PSB + KMB @ 10 ml each per plant	2.76	2.60	2.90	28.67	3.09	2.99	3.26	28.67	32.17	38.67	36.00	0.00
5	100% RDF + Liquid cons. of *Azotobactor*,+ PSB + KMB @ 20 ml each per plant	2.71	3.10	3.05	30.83	3.19	3.58	3.51	30.83	48.33	48.00	46.00	0.00
6	75% RDF + Liquid cons. of *Azotobactor*,+ PSB + KMB @ 20 ml each per plant	2.88	3.37	3.27	32.75	3.35	3.81	3.71	32.75	46.50	44.67	44.00	0.00
7	50% RDF + Liquid cons. of *Azotobactor*,+ PSB + KMB @ 20 ml each per plant	2.81	3.22	3.45	31.08	3.11	3.62	3.83	31.08	30.00	40.33	37.67	0.00
8	Liquid cons. of *Azotobactor*,+ PSB + KMB @ 10 ml each per plant	2.85	2.97	2.98	30.00	3.02	3.26	3.26	30.00	16.67	29.33	28.00	0.00
9	Liquid cons. of *Azotobactor*,+ PSB + KMB @ 20 ml each per plant	2.87	3.10	3.00	28.50	3.06	3.44	3.32	28.50	19.17	34.33	32.33	0.00
10	Absolute control	2.72	3.00	2.95	26.33	2.82	3.20	3.14	26.33	9.50	20.33	19.33	0.00
	SE(m)±	0.12	0.32	0.30	1.89	0.12	0.32	0.30	1.89	2.33	1.96	1.86	--
	CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	6.97	5.88	5.56	--
	CV (%)	7.53	17.79	16.55	11.06	6.65	16.12	14.90	11.06	12.13	8.88	8.80	--

Table 2: Effect of liquid consortium of *Azotobacter*, PSB and KMB on fruit set, fruit retention, fruit length and fruit breadth (Yield parameters) of custard apple (*Annona squamosa L.*) cv. Phule Purandar.

SN	Treatments	Fruit Set (%)	Fruit Retention (%)	Fruit length (cm)	Fruit girth (cm)
1	RDF (250: 125:125 g NPK per plant)	21.11	64.30	7.20	7.13
2	100% RDF + Liquid cons. *Azotobacter*, + PSB + KMB @ 10 ml each per L water per plant	21.62	65.21	7.37	7.23
3	75% RDF + Liquid cons. of *Azotobacter*,+ PSB + KMB @ 10 ml each per L water per plant	21.53	65.00	7.20	7.17
4	50% RDF + Liquid cons. of *Azotobacter*,+ PSB + KMB @ 10 ml each per L water per plant	20.77	62.54	6.90	6.87
5	100% RDF + Liquid cons. of *Azotobactor*,+ PSB + KMB @ 20 ml each per L water per plant	22.12	66.86	7.63	7.57
6	75% RDF + Liquid cons. of *Azotobactor*,+ PSB + KMB @ 20 ml each per L water per plant	22.07	66.26	7.60	7.43
7	50% RDF + Liquid cons. of *Azotobactor*,+ PSB + KMB @ 20 ml each per L water per plant	20.94	63.24	7.03	6.97
8	Liquid cons. of *Azotobactor*,+ PSB + KMB @ 10 ml each per L water per plant	20.60	61.22	6.67	6.40
9	Liquid cons. of *Azotobactor*,+ PSB + KMB @ 20 ml each per L water per plant	20.68	61.97	6.80	6.50
10	Absolute control	18.41	59.31	5.93	5.90
	SE(m)±	0.01	0.12	0.07	0.06
	CD (0.05)	0.02	0.37	0.22	0.17

F. Average No. of seeds per fruit and seed weight per fruit

The results revealed that, among all the treatments, the significant minimum number of seeds per fruit (40.40) and minimum seed weight (15.40 g) was recorded with T_5 (100% RDF + Liquid consortium of *Azotobacter* + PSB + KMB @ 20 ml each per L water per plant). However, regarding average number of seed per fruit, it was statistically at par with T_6 (41.35), T_3 (44.93), T_2 (45.20), T_1 (49.07). But in case of average seed weight, treatment T_5 was followed by T_6 wherein 15.70 g seed weight fruit was measured. The maximum average seed number (56.00) and seed weight (18.00 g) was observed in T_{10} (Absolute control) (17.77 g). These findings regarding a smaller number of seeds per fruit and minimum seed weight per fruit in treatment T_5 and T_6 are in agreement with the reports of Singh (2020) [23]. Parsana *et al.*, (2023) [17] also recorded minimum number of seed (25.55), less weight of seed (13.42 g) of custard apple in 100% RDN + 10 kg FYM + *Azotobacter* 15 ml + PSB 15 ml + Micronutrient grade-IV (0.5%) + GA3 25 ppm (F2).

G. Pulp (%)

The results revealed that, among all the treatments, the significantly highest pulp percentage (46.02%) was recorded in T_5 (100% RDF + Liquid consortium of *Azotobacter* + PSB + KMB @ 20 ml each per L water per plant). However, it was statistically at par with, T_2, T_6, T_3, T_7, T_4 and T_1 which recorded 45.21, 45.08, 44.93, 41.46, 40.96 and 40.50 per cent pulp, respectively. However, the lowest pulp percentage (33.85%) was recorded with absolute control (T_{10}). These findings are in line with those reported by Baviskar *et al.* (2011) [3], Godge *et al.* (2013), Parsana *et al.*, (2023) [17] and Patel *et al.* (2024) [18].

Table 3: Effect of liquid consortium of *Azotobacter*, PSB and KMB on TSS, No of seeds, Seed wt (g) and Pulp percentage (Yield parameters) of custard apple (*Annona squamosa L.*) cv. Phule Purandar.

S.N	Treatments	TSS ^{0} Brix	No of seeds	Seed wt (g)	Pulp (%)
1	RDF (250: 125:125 g NPK per plant)	25.09	49.07	16.80	40.50
2	100% RDF + Liquid cons. *Azotobacter*, + PSB + KMB @ 10 ml each per L water per plant	26.04	45.20	15.87	45.08
3	75% RDF + Liquid cons. of *Azotobactor*,+ PSB + KMB @ 10 ml each per L water per plant	26.05	44.93	16.00	44.13
4	50% RDF + Liquid cons. of *Azotobactor*,+ PSB + KMB @ 10 ml each per L water per plant	25.48	53.00	16.93	40.96
5	100% RDF + Liquid cons. of *Azotobactor*,+ PSB + KMB @ 20 ml each per L water per plant	26.43	40.40	15.40	46.02
6	75% RDF + Liquid cons. of *Azotobactor*,+ PSB + KMB @ 20 ml each per L water per plant	26.27	41.35	15.70	45.21
7	50% RDF + Liquid cons. of *Azotobactor*,+ PSB + KMB @ 20 ml each per L water per plant	25.57	50.53	16.83	41.46
8	Liquid cons. of *Azotobactor*,+ PSB + KMB @ 10 ml each per L water per plant	25.66	54.67	17.77	35.46
9	Liquid cons. of *Azotobactor*,+ PSB + KMB @ 20 ml each per L water per plant	25.73	54.07	17.10	36.26
10	Absolute control	24.11	56.00	18.00	33.85
	SE(m)±	-	3.27	-	2.53
	CD (0.05)	-	9.80	-	7.56
	CV (%)	NS	11.59	NS	10.70

H. Fruit weight (gm)

The results revealed that, among all the treatments, the significantly maximum average fruit weight (247.00 g) was recorded with 100% RDF + Liquid consortium of *Azotobacter* + PSB + KMB @ 20 ml each per L water per plant (T_5). However, it was statistically at par with treatment T_6, T_2 and T_3 where average fruit weight recorded was 240.87 g, 231.93 and 229.93 g, reactively. However, the significant minimum fruit weight (191.18 g) was recorded with absolute control (T_{10}). Similar results were obtained by Waghamare *et al.* (2019) [25], Rajadurai *et al.* (2022) [20] Gondaliya *et al.* (2023) [8], Patel *et al.* (2024) [18] and Patil *et al.* (2024) [19] while conducting integrated nutrient management experiment with *Azotobacter* + PSB + KMB in custard apple.

I. No. of fruits/plant

The results revealed that the number of fruits per plant was significantly influenced by different treatments. The treatment T_6 i.e. 75% RDF + Liquid consortium of *Azotobacter* + PSB + KMB @ 20 ml @ 20 ml each per L water per plant yielded the significantly highest (115.00) among all the treatments. However, it was followed with T_5, T_2, T_3 and T_1wherein average number of fruits per plants observed were 113.00, 108.67, 104.67 and 96.00, respectively. Significantly, the minimum number of average fruits per plant (53.33) was recorded in absolute control

(T_{10}). Similar results were obtained by Waghamare *et al.* (2019) [25], Rajadurai *et al.* (2022) [20] Gondaliya *et al.* (2023) [8], Patel *et al.* (2024) [18] and Patil *et al.* (2024) [19] while conducting integrated nutrient management experiment with *Azotobacter* + PSB + KMB in custard apple.

J. Fruit yield per tree (kg/tree) and Fruit yield per ha (t/ha)

The results indicated that fruit yield per tree (kg/tree) and fruit yield per hectare (t/ha) were significantly influenced by different treatments. among all the treatments, the significantly highest fruit yield (27.90 kg/tree) and yield per hectare (6.98 t/ha) was recorded with treatment of 100% RDF + Liquid consortium of *Azotobacter* + PSB + KMB @ 20 ml each per L water per plant (T_5). However, it was statistically at par with T_6 and T_2 wherein 27.69 kg/tree and 25.20 kg/tree yield per tree and 6.92 t/ha and 6.30 t/ha yield per ha recorded, respectively. Absolute control recorded the lowest fruit yield per tree (10.19 kg/tree) and yield per ha (2.55 t/ha). Similar results were obtained by Waghamare *et al.* (2019) [25], Rajadurai *et al.* (2022) [20] Gondaliya *et al.* (2023), Patel *et al.* (2024) [18] and Patil *et al.* (2024) [19] while conducting integrated nutrient management experiment with *Azotobacter* + PSB + KMB in custard apple.

Table 4: Effect of liquid consortium of *Azotobacter*, PSB and KMB on fruit Wt (g), No. of fruit per tree, fruit yield per tree and fruit yield per ha (Yield parameters) of custard apple (*Annona squamosa L.*) cv. Phule Purandar.

S.N	Treatments	Av. Fruit Wt (g)	Av. No of Fruits / plant	Fruit yield (kg/tree)	Fruit yield (t/ha)
1	RDF (250: 125:125 g NPK per plant)	223.10	96.00	21.67	5.42
2	100% RDF + Liquid cons. *Azotobactor*, + PSB + KMB @ 10 ml each per L water per plant	231.93	108.67	25.20	6.30
3	75% RDF + Liquid cons. of *Azotobactor*,+ PSB + KMB @ 10 ml each per L water per plant	229.93	104.67	24.07	6.02
4	50% RDF + Liquid cons. of *Azotobactor*,+ PSB + KMB @ 10 ml each per L water per plant	212.60	87.67	18.64	4.66
5	100% RDF + Liquid cons. of *Azotobactor*,+ PSB + KMB @ 20 ml each per L water per plant	247.00	113.00	27.90	6.98
6	75% RDF + Liquid cons. of *Azotobactor*,+ PSB + KMB @ 20 ml each per L water per plant	240.87	115.00	27.69	6.92
7	50% RDF + Liquid cons. of *Azotobactor*,+ PSB + KMB @ 20 ml each per L water per plant	217.47	90.33	19.64	4.91
8	Liquid cons. of *Azotobactor*,+ PSB + KMB @ 10 ml each per L water per plant	202.03	70.67	14.17	3.54
9	Liquid cons. of *Azotobactor*,+ PSB + KMB @ 20 ml each per L water per plant	205.67	71.00	14.55	3.64
10	Absolute control	191.18	53.33	10.19	2.55
	SE(m)±	5.42	8.22	1.89	0.47
	CD (0.05)	16.24	24.61	5.67	1.42
	CV (%)	4.27	15.64	16.10	16.13

3. Economics of use of liquid consortium of *Azotobacter*, PSB and KMB in custard apple production.

The data regarding economics of the custard apple cultivation influenced due to use of liquid consortium of *Azotobacter*, PSB and KMB along with fertilizers are summarized in Table 5.

A. Total monetary returns

Use of liquid consortium of *Azotobacter*, PSB and KMB along with fertilizers in different combinations gave total returns ranging from Rs. 1,27,273.42 to 2,44,104.00 as against Rs 89,141.79, in control. Highest total monetary returns (Rs. 2,44,104 ha-1) were obtained in T_5 treatment (100% RDF + Liquid cons. of *Azotobactor*,+ PSB + KMB @ 20 ml each per L water per plant). However, it was followed by T_6 treatment with Rs. 2,42,329.41 ha^{-1}.

B. Net income

The highest net income of Rs. 1,10,330.39 ha-1 were obtained in T_6 treatment (75% RDF + Liquid cons. of *Azotobactor*,+ PSB + KMB @ 20 ml each per L water per plant). However, it was followed by T_5 treatment with net monetary returns of Rs. 1,09,547.36.

Table 5: Economics of use of liquid consortium of *Azotobacter*, PSB and KMB along with fertilizers in custard apple production.

SN	Treatments	Yield (q/ha)	Gross Monitory Returns (Rs/ha)	Cost of Cultivation (Rs/ha)	Net Monitory Returns (Rs/ha)	B:C Ratio
1	RDF (250: 125:125 g NPK per plant)	54.18	189628.83	129468.64	60160.19	1.46
2	100% RDF + Liquid cons. *Azotobactor*, + PSB + KMB @ 10 ml each per L water per plant	63.01	220522.17	132012.64	88509.52	1.67
3	75% RDF + Liquid cons. of *Azotobactor*,+ PSB + KMB @ 10 ml each per L water per plant	60.18	210639.33	129454.82	81184.52	1.63
4	50% RDF + Liquid cons. of *Azotobactor*,+ PSB + KMB @ 10 ml each per L water per plant	46.60	163113.13	126896.99	36216.13	1.29
5	100% RDF + Liquid cons. of *Azotobactor*,+ PSB + KMB @ 20 ml each per L water per plant	69.74	244104.00	134556.64	109547.36	1.81
6	75% RDF + Liquid cons. of *Azotobactor*,+ PSB + KMB @ 20 ml each per L water per plant	69.24	242329.21	131998.82	110330.39	1.84
7	50% RDF + Liquid cons. of *Azotobactor*,+ PSB + KMB @ 20 ml each per L water per plant	49.10	171861.67	129440.99	42420.67	1.33
8	Liquid cons. of *Azotobactor*,+ PSB + KMB @ 10 ml each per L water per plant	35.41	123950.46	121781.34	2169.12	1.02
9	Liquid cons. of *Azotobactor*,+ PSB + KMB @ 20 ml each per L water per plant	36.36	127273.42	124325.34	2948.08	1.02
10	Absolute control	25.47	89141.79	119237.34	-30095.55	0.75

Selling rate of custard apple @Rs. 3500 per quintal

C. Benefit cost ratio (B:C): The highest benefit cost ratio of 1.83 was calculated in treatment with T_6 treatment (75% RDF + Liquid cons. of *Azotobactor*, + PSB + KMB @ 20 ml each per L water per plant). Then, the next treatments in order of superiority were T_5 treatment (1.81).

Conclusion

Treatment 100% RDF + liquid consortium of *Azotobacter*, PSB, and KMB @ 20 ml each per L water per plant (T_5) significantly improved plant growth, yield and gross returns. However, treatment using 75% RDF + liquid consortium of *Azotobacter*, PSB, and KMB @ 20 ml each per L water per plant (T_6) achieved yields comparable to T_5 but offered superior net profit and benefit-cost ratio due to reduced input cost. Integrating biofertilizers with 75% RDF (T_6) is a sustainable and economically viable practice for custard apple cultivation, combining high productivity, profitability, and long-term soil health benefits.

References

1. Bandara M, Sutharsan S, Srikrishnah S. Effect of inorganic biofertilizer on growth and yield of *Allium cepa* L. Published online 2019.
2. Basak BB, Biswas DR. Influence of potassium solubilizing microorganism (*Bacillus mucilaginosus*) and waste mica on potassium uptake dynamics by sudan grass (*Sorghum vulgare* Pers.) grown under two Alfisols. Plant and Soil. 2009;317:235-255.
3. Baviskar BS, Gawande SD, Bhandakkar VD. Effect of integrated nutrient management on yield and quality of sapota (*Manilkara zapota* L.) at Akola. Journal of Soils and Crops. 2011;21(2):343-347.
4. Chandra K, Greep S. Potash mobilizing bacteria (*Frateuria aurentia*). Regional Director, RCOF, Govt of India, Bangalore; 2006. p. 74.
5. Gadekar TK. Effect of *Azotobacter*, P solubilizing and K mobilising bacteria on growth and yield of Aloe vera (*Aloe barbadensis* Miller). [M.Sc. thesis]. Rahuri (M.S.): Mahatma Phule Krishi Vidyapeeth; 2024. p. 1-79.
6. Game BC, Ilhe BM, Pawar VS, Khandagale PP. Effect of *Azotobacter*, phosphate solubilising bacteria and potash mobilising bacteria inoculants on productivity of wheat (*Triticum aestivum* L.). International Journal of Current Microbiology and Applied Sciences. 2020;9(3):2800-2807. doi:10.20546/ijcmas.2020.903.322
7. Godage MV, Patel BM, Patel DA. Influence of biofertilizers and chemical fertilizers on growth, flowering and fruit characters of guava (*Psidium guajava* L.) cv. Allahabad Safeda. Journal of Horticultural Sciences. 2013;8(1):45-49.
8. Gondaliya RR, Polara ND, Patel YJ, Makhmale S, Patel SR. Impact of integrated nutrient management on the growth and yield of sugar apple (*Annona squamosa* L.) cv. Sindhan. The Pharma Innovation Journal. 2023;12(7):3151-3154.
9. Gopalan C, Ramashastri BV, Balasubramanian SC. Nutritive value of Indian foods. Hyderabad: National Institute of Nutrition, Indian Council of Medical Research; 1987. p. 1-204.
10. Hazarika BN, Ansari S. Biofertilizers in fruit crops - A review. Agricultural Reviews. 2007;28(1):69-74.
11. Jangid R, Masu MM, Bhattacharjee P, Patel BD, Kumar P. Effect of different sources of nitrogen on growth and yield attributes of custard apple (*Annona squamosa* L.) cv. Sindhan. The Pharma Innovation Journal. 2022;11(5):1477-1481.
12. Kore SA. Effect of *Azotobacter*, PSB and KMB consortium on the growth and yield of tuberose (*Polianthes tuberosa* L.). [M.Sc. thesis]. Rahuri (M.S.): Mahatma Phule Krishi Vidyapeeth; 2020. p. 1-97.
13. Kundu S, Mishra J. Effect of biofertilizers and inorganic fertilizers on mango cv. Himsagar. Journal of Crop and Weed. 2018;14(3):100-105.
14. Mahendra M, Singh HK, Singh JK. Studies on integrated nutrient management on vegetative growth, fruiting behaviour and soil fertilizer status of ber (*Zizyphus mauritiana* Lamk.) orchard cv. Banarasi Karaka. The Asian Journal of Horticulture. 2009;4(1):230-232.
15. Moorthy SK, Malliga P. Plant characteristics, growth and leaf gel yield of *Aloe barbadensis* Miller as affected by cyanopith biofertilizer in pot culture. International Journal of Civil and Structural Engineering. 2012;2(3):884-892.
16. Parmar P, Sindhu SS. Potassium solubilization by rhizosphere bacteria: influence of nutritional and environmental conditions. Journal of Microbiological Research. 2013;3(1):25-31.
17. Parsana JS, Varu DK, Parmar VM, Patel S, Kanzaria DR, Mishra S. Influence of pruning and integrated nutrient management on custard apple (*Annona squamosa* L.). Agricultural Mechanization in Asia. 2023;54(4):12865-12874.
18. Patel BR, Patel YH, Leua HN, Wankhade VR, Patel SB, Nandre BM. Effect of organic inputs on yield and quality of custard apple (*Annona squamosa* L.). International Journal of Research in Agronomy. 2024;SP-7(9):1101-1103.
19. Patil A, Haldar A, Gawali K, Kamde M, Bobade SP. Studies on integrated nutrient management for growth and yield of custard apple with special reference to economics. International Journal of Advanced Biochemistry Research. 2024;8(8):525-529.
20. Rajadurai KR, Rajkumar J, Rajababu C. Studies on the response of biofertilizers on growth and productivity of custard apple (*Annona squamosa* L.). The Pharma Innovation Journal. 2022;11(6):1866-1869.
21. Sarkate PA. Studies on salt tolerant tripartite inoculation of *Azotobacter*, phosphate solubilizing and potash mobilizing bacteria and its effect on growth and yield of brinjal (*Solanum melongena* L.). [M.Sc. thesis]. Rahuri (M.S.): Mahatma Phule Krishi Vidyapeeth; 2024. p. 1-84.
22. Sessitsch A, Kuffner M, Kidd P, Vangronsveld J, Wenzel WW, Fallmann K, *et al.* The role of plant-associated bacteria in the mobilization and phytoextraction of trace elements in contaminated soils. Soil Biology and Biochemistry. 2013;60:182-194.
23. Singh Y. Effect of *Azospirillum* and vermicompost on growth, yield and fruit quality of custard apple cvs. Balanagar and Raydurg. [PhD thesis]. Kota (Rajasthan): Agriculture University; 2020. p. 1-465.
24. Waghmare DB, Bhosle AM, Syed SJ. Effect of inorganic and biofertilizers on vegetative growth and reproductive growth parameters of custard apple (*Annona squamosa* L.) cv. Balanagar. International Journal of Chemical Studies. 2018;6(4):1358-1361.
25. Waghmare SA, Kashid AM. Reverse phase-high performance liquid chromatography method development and validation for estimation of efavirenz by quality by design approach. J Drug Deliv Ther. 2019;9(1-s):319-330.