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Studies on the response of bio-fertilizers on growth and productivity of custard apple (*Annona squamosa* L.)

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Abstract
The present study was aimed to assess the influence of integrated use of inorganic fertilizers (N,P,K) and bio fertilizers (Azotobacter, *Azospirillum, Phosphobacteria* and VAM) on plant growth, yield and quality of custard apple var. APK 1. An experiment was conducted during 2017 to 2020 at Regional Research Station, Tamil Nadu Agricultural University, Aruppukottai under the dry vertisols of Tamil Nadu, India. This experiment was carried out under ICAR- All India Coordinated Research Project on Arid Zone Fruits (ICAR-AICRP-AZF). This experiment was carried out under ICAR- All India Coordinated Research Project on Arid Zone Fruits (ICAR-AICRP-AZF). The finding showed that, the combined application of *Azotobacter*, *Azospirillum*, VAM, *Phosphobacteria* and 50% standard NPK recorded higher tree height of 5.1 m, tree girth of 55.4 cm and plant spread of 5.6 m and 5.2 m respectively towards east west and north south direction respectively. It also recorded higher yield of 14.9 kg/tree, fruit weight of 133.6 g /fruit and TSS of 19.0º Brix followed by application of *Azotobacter* + *Azospirillum* + *Phosphobacteria* with standard dose of NPK which recorded yield of 13.6 kg/tree, fruit weight (128.8 g) and 17.9º Brix compared to all other treatments including control. Based on this it could be concluded that the combined application of *Azotobacter*, *Azospirillum*, VAM, *Phosphobacteria* and 50% standard NPK on Custard apple var. APK 1 is suitable for dry vertisols tracts of Tamil Nadu to enhance the overall output for the farming community.

Keywords: Custard apple, bio fertilizers, NPK, integrated nutrient management, vertisol

Introduction
Custard apple (*Annona squamosa* L.) is a tropical and subtropical fruit tree belongs to Annonaceae family (Nakasone and Mariguele, 1998) [6]. It is popularly called as Sitaphal in India and Tamil Nadu, is commercially cultivated in dry treats of Maharashtra, Andhra Pradesh, Karnataka, Tamil Nadu, Bihar, Madhya Pradesh etc. The fruit prized a high demand due to its delicious taste and nutritive values (Priyanka Nandi *et al*., 2018) [8]. Fruits have also high demand in the industry for preparation of ice-cream and others due to richness in carbohydrates (Maurya and Singh, 2006; Nath *et al*.,2008) [5, 7]. The custard apple is considered as a crop of wasteland and can successfully be grown in sandy, rocky, gravel, heavy and even in saline soil (Vijay Singh Meena *et al*., 2022) [12]. The custard apple can successfully be grown in tropical, sub-tropical, arid and semi-arid region and best performed where there is less rainfall. It is established fact that successful cultivation of any crop mainly depends on suitable cultivar/s in an area or region and selection or recommendation of such cultivar/s require through scientific investigation.
Bio fertilizers are input containing microorganisms capable of mobilizing and solubilisation of nutritive elements through biological processes. These are less expensive, eco friendly and sustainable and do not require non-renewable source of energy during their production. They improve plant growth and fruit quality by producing plant hormones. They increase the fertility of the soil and make it more productive and it is a way of achieving sustainability. They are also useful as bio control agents since they control many plant pathogens and harmful microorganism. The beneficial effect of bio fertilizers are now well established in many fruit crops like mango (Ahmad *et al*., 2004) [1]. But, minimum information is available on effect of bio fertilizer on organic fruit production of guava particularly in the new alluvial zones of West Bengal. Research evidences are uncourageous towards the integrated use of organic + inorganic + bio fertilizers which may improve the soil productivity and crop yield with better quality (Singh *et al*., 2011) [9].

According to Subba Rao (1998) [11], bio fertilizers are otherwise called microbial inoculants, are the carrier based preparation containing beneficial microorganisms designed to improve the soil fertility and help the plant growth by their increased number and biological activity in the rhizosphere.

Materials and Methods

The experiment was conducted during 2017 to 2020 at Regional Research Station (RRS), Tamil Nadu Agricultural University, Aruppukottai, Virudhunagar District under dry vertisols conditions. This research station is located at Aruppukottai, Virudhunagar District of Tamil Nadu. The altitude is 102 m above mean sea-level with a Latitude of $9^0$33' North and Longitude of $78^0$05' East. The centre is coming under semi-arid climatic conditions. The annual average rainfall is 770mm. The soil type is vertisols (Black clay loam soil underlying canker nodules). Soil depth ranged between 0.6 to 1.2 m and received maximum rainfall during North – East Monsoon (Fig. 1). Fifty trees with uniform in size and vigour were given cultural practices as per package of practices recommended by Tamil Nadu Agricultural University were selected for the present study. During the course of studies, recommended cultural practices were followed in the experimental materials. The experiment was laid out in Randomized Block Design (RBD) having eleven treatments with three replications. Treatments consisted of T0 (Control), T1 (*Azotobacter* (AZB)– 250g/tree), T2 (*Azospirillum* (AZS) – 250g/tree), T3 (VAM - 250g/tree), T4 (*Phosphobacteria* – 250g/tree), T5 (Standard dose of NPK-250:125:250g/tree), T6 (AZB+AZS), T7 (AZB+AZS+VAM), T8 (50% N of standard dose+ AZB+AZS+P+K), T9 (50% N of standard dose + AZB+AZS+VAM), T10 (AZB+AZS+*Phosphobacteria* + standard dose of NPK) and T11 (AZB + AZS + VAM + *Phosphobacteria* +50% of standard NPK). Before application of bio fertilizers and inorganic fertilizers, the amount to be applied was calculated. They were applied by mixing with FYM and were directly applied near the root zone of plant. Observations were recorded on tree height (m), stem girth (cm), plant spread (m), fruit weight (g), pulp weight (g), TSS (^{o}Brix) yield (Kg/tree) and yield (t/ha) total amount of fruits produced per plants were weighed and then calculated on per hectare basis in tons.

Results and Discussion

(i) Vegetative Parameters

In the present investigation, it is reported that the tree height, stem girth, plant spread (E-W) and plant spread (N-S) were increased significantly with the use of bio fertilizers or in combinations. The maximum plant height (5.1m), plant spread-EW (5.6m), plant spread-NS (5.2m) and stem girth (55.4cm) were recorded in the application of *Azotobacter*, *Azospirillum*, VAM, *Phosphobacteria* and 50% standard NPK (T11), this was followed by AZB + AZS + *Phosphobacteria* + standard dose of NPK (T10) and the minimum tree height (3.6m), stem girth (42.7cm), tree spread – EW (3.4m) and tree spread-NS (3.3m) were recorded with the application of T0 (control). The increase in tree height might be due to the production of more chlorophyll content with inoculation of nitrogen and phosphorus fixers. The reason of increase in growth characters is constituent of the protein which is essential for formation of protoplasm thus affecting the cell division and cell elongation and there by more vegetative growth (Dutta *et al*., 2009) [2]. The other reason for increased vegetative growth may be the production of plant growth regulators by bacteria in rhizosphere, which are absorbed by the roots. Better development of root system and the possibly synthesis of plant growth hormones like IAA, GA and cytokines and direct influence of bio fertilizers might have caused increase in plant growth parameters (Gupta and Tripathi, 2012) [3]. The results of present study accordance were observed the vegetative growth of custard apple was improved by the application of different fertilizers, microbial culture and bio fertilizers. The increasing of canopy volume might be due to the better nutritional environment, application of organic matter improve the soil health by improving physicochemical and biological activities of soil (Kumar *et al*., 2017) [4] (Table 1)

(ii) Yield parameters

Significant variation in number of fruits weight (g), pulp weight (g), yield per tree and yield per hectare were recorded in trees subjected to inorganic fertilizers and biofertilizers combination, where increased fruit weight (133.6g), pulp weight (77.8g), yield per tree (14.9 kg), yield per hectare (4.10 t/.ha.) and TSS (19.0 Brix^o) were recorded in the tree treated with T11 (*Azotobacter*, *Azospirillum*, VAM, *Phosphobacteria* and 50% standard NPK) however reduced number of fruit weight (81.6g), pulp weight (58.3g), yield per tree (9.1 kg), yield per hectare (2.50 t/.ha.) and TSS (15.1Brix^o) were recorded in the tree treated T0 (Control).The increase in yield might be due to increased fruit set per plant, increased berry size and weight and may also be due to the fact that nitrogen fixers and phosphorous solubilizes not only increased the availability of nitrogen and phosphorous to the plants but also increased their translocation from root to flower through plant foliage (Singh and Singh, 2009) [10] (Fig.2 and Table 2).

Table 1: Effect of bio fertilizers and on tree ht. (M), Stem girth (cm) and Plant spread (cm) of custard apple

Tr. No.	Treatments	Tree height (m)	Stem Girth (cm)	Plant Spread (m)	
				EW	NS
T0	Control	3.6	42.7	3.4	3.3
T1	*Azotobacter* (AZB)	3.9	48.5	4.0	3.6
T2	*Azospirillum* (AZS)	4.4	49.1	4.2	3.8
T3	VAM	4.6	48.2	4.3	3.2
T4	*Phosphobacteria*	3.7	47.2	4.6	4.2
T5	Standard dose of NPK	4.4	50.7	4.7	4.5
T6	AZB+AZS	3.9	51.3	4.7	4.3
T7	AZB+AZS+VAM	4.1	47.9	4.9	4.1
T8	50% N of standard dose + AZB + AZS + P + K	4.4	48.7	4.9	4.7
T9	50% N of standard dose + AZB + AZS + VAM	4.2	49.1	4.7	4.5

T10	AZB + AZS + *Phosphobacteria* + standard dose of NPK	4.4	52.1	5.1	4.8
T11	AZB + AZS + VAM + *Phosphobacteria* + 50% of standard NPK	5.1	55.4	5.6	5.2
S.Ed		0.1453	1.1499	0.1703	0.1784
CD (0.05%)		0.2929	2.3174	0.3432	0.3596

Table 2: Effect of inorganic and Bio-fertilizers on yield and quality parameters of custard apple.

Tr. No.	Treatments	Fruit weight (g)	Pulp weight (g)	Yield (Kg/tree)	Yield (t/ha.)	TSS (ºBrix)
T0	T_0 Control	81.6	58.3	9.1	2.50	15.1
T1	T_1Azotobacter (AZB)	91.1	63.6	9.9	2.72	16.5
T2	T_2Azospirillum (AZS)	93.5	65.7	10.8	2.97	17.4
T3	T_3 VAM	103.1	70.5	9.9	2.72	17.5
T4	T_4 'P' solubilization culture	98.4	63.4	9.6	2.64	16.7
T5	T_5 Standard dose of NPK 250:125:250g/tree	119.2	72.3	11.8	3.25	16.0
T6	T_6 AZB +AZS	109.8	67.4	12.5	3.44	17.3
T7	T_7 AZB+AZS+VAM	106.5	68.8	10.4	2.86	16.4
T8	T_8 50% N + AZB + AZS+P+K	113.6	74.8	9.9	2.72	15.9
T9	T_9 50% + AZB + AZS + VAM	117.8	75.2	10.8	2.97	17.3
T10	T_{10} AZB+AZS+VAM + Phosphobacteria + Standard dose of NPK	128.8	73.2	13.6	3.74	17.9
T11	T_{11} AZB + AZS + VAM + 'P' Solubilization culture + 50% NPK	133.6	77.8	14.9	4.10	19.0
S.Ed		7.3854	2.7390	0.8393	0.241	0.5175
	CD (0.05%)	15.0259	5.5727	1.7075	0.483	1.0528

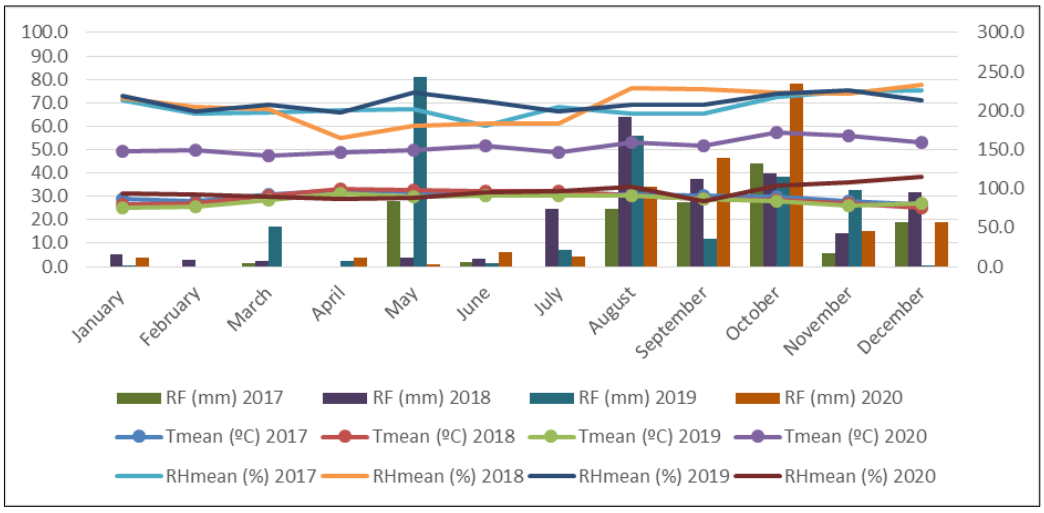

Fig 1: Weather data recorded during 2017-2020 at Regional Research Station, Aruppukottai, Tamil Nadu, India

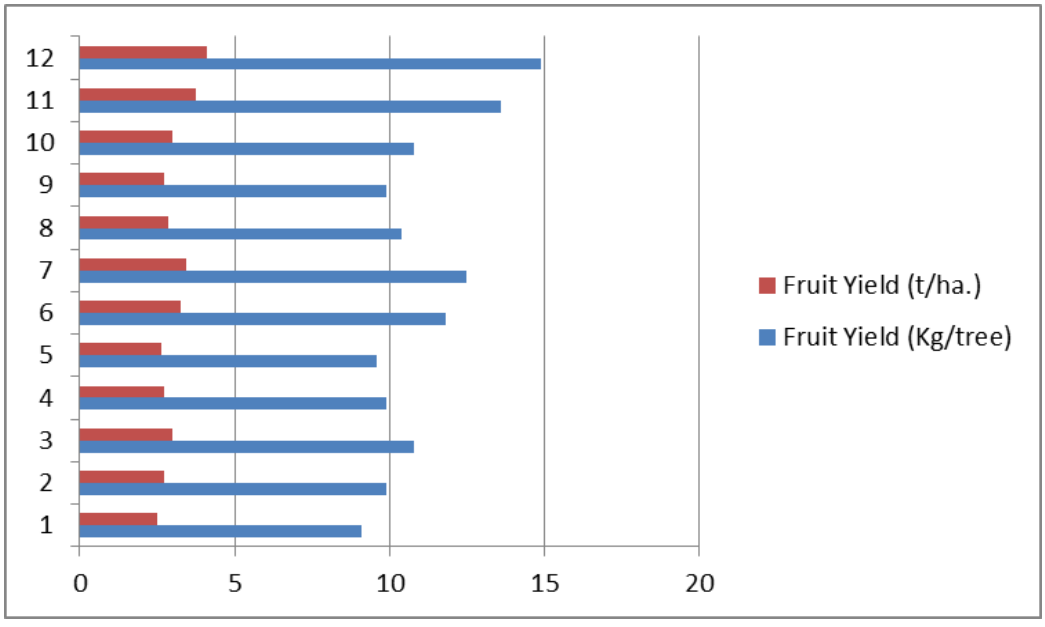

Fig 2: Effect of bio fertilizers on fruit yield / tree (kg/tree) and Fruit yield / ha. (t/tree)

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