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Effect of inorganic and biofertilizers on fruit set, yield and quality of custard apple (*Annona squamosa* L.) cv. Balanagar

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Abstract
The field study was carried out at Custard apple Research Station, Ambejogai, Dist. Beed. The experiment was laid out in Randomized Block Design (RBD) with fourteen treatments and three replications. The data on fruit set, yield, and quality was recorded individually. Reproductive growth parameters viz., maximum number of flowers per meter cube (21.00 flowers), number of fruits per meter cube (16.00 fruits), maximum fruit set % (76.21%) recorded in treatment T_2 (100% RDF + FYM + *Azotobacter* + PSB) followed by T_3 (100 % RDF + FYM + *Azotobacter*). Yield parameters viz., maximum number of fruits per plant (68.00 fruits), yield per tree (13.46 kg), marketable yield (12.41kg) and yield per hectare (8.41t/ha.) were recorded higher in treatment T_2 (100% RDF + FYM + *Azotobacter* + PSB) followed by treatment T_4 (100 % RDF + *Azotobacter* + PSB) and maximum fruit weight (221.13 g) recorded in T_4 (100% RDF +*Azotobacter* + PSB) while the lowest values for these observations were recorded under control treatment (T_{14}).As regards to the fruit quality, the biochemical attributes viz., total soluble solids (23.80%), reducing sugar (14.11 %), non- reducing sugar (3.46%), total sugars (17.57%), ascorbic acid (37.22 mg per 100 g of pulp), minimum acidity (0.32%) observed in treatment T_2 (100% RDF + FYM + *Azotobacter* + PSB) followed by treatment T_3 (100% RDF +FYM + *Azotobacter*).

Keywords: Azotobactor, inorganic fruit set, Yield, PSB, VAM

1. Introduction

Custard apple (*Annona squamosa* L.), It belongs to family Annonaceae and comprises of 40 genera and 120 species of which only five of them produce edible fruits, it is the most ancient dry land fruit crop in India. They are originated from tropical region of America and widely distributed throughout the tropics and subtropics. The origin of different species of annona is reported to be at different regions. *Annona squamosa* L. is originated in Central America from there; it was distributed to Mexico and Tropical America (Popenoe, 1974) [10]. The fruits are medium in size (250-300 g), globular, green skin, conspicuous reticulation on fruit surface, non-acidic, having good quality and sweet pulp. Edible portion or pulp of fruit is creamy, granular with good blend of sweetness and acidity which vary with the species. Fruit pulp contains proteins, fatty acids, fibre, carbohydrates, minerals and vitamins (Lizana and Reginato, 1990) [7]. The pleasant flavour and mild aroma have universal liking. The fruit contains vitamin C and minerals such as calcium, phosphorus and potassium.

Nutritional composition of custard apple (per 100 g of Pulp)

S. No.	Constituents	Values
1.	Carbohydrates	20-25.2 g
2.	Protein	1.17-2.47 g
3.	Fat	0.5-0.6 g
4.	Crude fibre	0.9-6.6 g
5.	Calcium	17.6-27 mg
6.	Phosphorus	14.7-32.1 mg
7.	Iron	0.42-1.14 mg
8.	Thiamine	0.075-0.018 mg
9.	Riboflavin	0.086-0.175 mg
10.	Niacin	0.528-1.190 mg
11.	Ascorbic acid	15.0-44.4 mg

(Navaneethakrishnan and Nattar, 2011) [9]. Custard apple has slightly granular, creamy, yellow or white, sweet pulp with good flavour and low acidity, thus it is considering the sweetest fruit of the other annonas (FAO, 1990) [4]. Fruit contains sugar 16-20 per cent and lipids 0.35 per cent of edible part of fruit (Leal, 1990) [6].

It has many health and nutritional benefits. It is a rich source of dietary fibre, which helps in digestion. It contains magnesium, which plays a vital role in relaxing muscles and protecting heart against diseases. Flesh of the fruit is used for the preparation of milk shakes and ice-cream. It can be made a delicious sauce for cake and puddings by blending the seeded flesh with mashed banana and with a little cream. The seeds of the fruits have insecticidal and abortifacient properties. Similarly, seed oil is suitable for soap making and seed cake can be used as manure (Naidu and Saetor, 1954) [8]. Custard apple has many alkaloids, such as aporohine, romerine, norocoydine, squamonine corydine, norisocroriydine, glaucine and anononaine in different parts of the plant (Kowlska and Putt, 1990) [5].

Use of biofertilizers results in reducing the inorganic fertilizer application and at the same time increasing the crop yield besides maintaining soil fertility is well recognised. In other words, biofertilizers based on renewable energy sources and are eco-friendly compared to commercial fertilizers (Verma and Bhattacharyya, 1994) [11]. An assessment of nutrient efficiency revealed that nitrogen deficiency is universal and will be continued. Nitrogen has many functions in plant life. Being as a part of protein, nitrogen is an important constituent of protoplasm. It is also responsible for the biosynthesis of enzymes, nucleoproteins, amino acids, amines, amino sugars, polypeptides, chlorophylls and encourages cell division. Phosphorus is a component of ADP, ATP, DNA and various RNA. It plays a role in photosynthesis, respiration, energy storage and transfer, cell division, cell enlargement and several other processes in the living plant. It promotes early root formation and growth. It also improves the quality of fruits. Potassium is the third important nutrient, essential for protein synthesis, in fruit formation. Potassium has a great impact on crop quality.

The custard apple gives better response to fertilizer application in respect to yield and quality of fruits. But, the low productivity of custard apple may be due to less adoption of improved crop management technology in respect of planting system, nutrition, plant protection and irrigation etc. Among several other factors affecting the productivity of fruit trees, as custard apple trees removes large amount of nutrients from soil, balance fertilization seems to be an important factor governing the productivity of custard apple trees. Large scale use of chemical fertilizers causes problem of ground water and environmental pollution through leaching, volatilization and denitrification. The disproportionate of chemical fertilizers has widened soil imbalance in terms of NPK ratio. The occurrence of multinutrient deficiencies and overall decline in productive capacity of soil has been widely reported due to non-judicious fertilizer use (Chhonkar, 2008) [3]. Custard apple is very hardy to soil and agro-climatic conditions and gives good response to manuring in terms of increasing fruit production and quality of fruits. Fertilizer experiment conducted in India showed that custard apple has given good response to balance use of inorganic fertilizers along with organic manures and biofertilizers. It is reported that, application of organic and chemical fertilizers not only increases the yield but also improved the fruit quality in custard apple (Anon., 2008) [1, 2]. It has been also reported that the application of biofertilizers is more effective than organic manures in enhancing fruit quality parameters, also the inoculation of *Azotobacter* and PSB along with inorganic fertilizers proved effective in increasing quality parameters like TSS, total sugars etc. (Anon., 2008) [1, 2].

2. Material 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:

Table 1: Details of the treatments

S. No.	Treat. no.	Treatment details
1.	T_1	100 % RDF (250 g N, 125g P_2O_5 and 125g K_2O tree^{-1})
2.	T_2	100 % RDF + FYM + *Azotobacter* + PSB
3.	T_3	100% RDF + FYM + *Azotobacter*
4.	T_4	100 % RDF + *Azotobacter* + PSB
5.	T_5	100 % RDF + FYM + PSB
6.	T_6	75% RDF + FYM + *Azotobacter* + PSB
7.	T_7	75% RDF + FYM + *Azotobacter*
8.	T_8	75% RDF + *Azotobacter* + PSB
9.	T_9	75% RDF + FYM + PSB
10.	T_{10}	50 % RDF + FYM + *Azotobacter* + PSB
11.	T_{11}	50% RDF + FYM + *Azotobacter*
12.	T_{12}	50 % RDF + *Azotobacter* + PSB
13.	T_{13}	50 % RDF + FYM + PSB
14.	T_{14}	Control (Absolute)

FYM @ 20 Kg tree^{-1}

Azotobacter and PSB @ 80 g each tree^{-1}

Table 2: Chemical composition of organic manures and fertilizers

Organic Manures / Fertilizers	Nutrient contents		
	N (%)	**P_2O_5 (%)**	**K_2O (%)**
Urea	46	-	-
Single Super Phosphate	-	16	-
Muriate of Potash	-	-	60
Farm Yard Manure	0.75	0.20	0.50

3. Results and discussion

3.1 Fruit set

The data regarding number of flowers per meter cube, number of fruits per meter cube, per cent fruit set, are presented in Table 3.

3.1.1 Number of flowers per meter cube

The results revealed that, the number of flowers per meter cube was significantly affected by different treatments. The maximum number of flowers per meter cube (21.00 flowers) was recorded in the treatment of 100% RDF + FYM + *Azotobacter* + PSB (T_2) which was at statistically par with T_3 (19.00), T_6 (18.00), T_4 (17.00) and T_7, T_{10} and T_{11} (16.00). The minimum number of flowers per meter cube (8.00) was recorded in control (T_{14}).

Table 3: Effect of inorganic and biofertilizers on reproductive growth parameters.

Treat. no.	Treatments	Number of flowers/m^3	Number of fruits/m^3	Fruit set (%)
T_1	100 % RDF (250 g N, 125 g P_20_5 and 125 g K_20 tree^{-1})	11.00	7.00	63.64
T_2	100 % RDF + FYM + *Azotobacter* + PSB	21.00	16.00	76.21
T_3	100% RDF + FYM + *Azotobacter*	19.00	14.00	73.69
T_4	100 % RDF + *Azotobacter* + PSB	17.00	12.00	70.59
T_5	100 % RDF + FYM + PSB	14.00	9.00	64.29
T_6	75% RDF + FYM + *Azotobacter* + PSB	18.00	13.00	72.22
T_7	75% RDF + FYM + *Azotobacter*	16.00	11.00	68.76
T_8	75% RDF + *Azotobacter* + PSB	15.00	9.00	60.00
T_9	75% RDF + FYM + PSB	13.00	8.00	61.53
T_{10}	50 % RDF + FYM + *Azotobacter* + PSB	16.00	11.00	68.75
T_{11}	50% RDF + FYM + *Azotobacter*	16.00	10.00	62.50
T_{12}	50 % RDF + *Azotobacter* + PSB	12.00	8.00	66.67
T_{13}	50 % RDF + FYM + PSB	10.00	6.00	60.00
T_{14}	Control	8.00	4.00	50.00
S.E.$\pm$		0.71	0.47	3.79
C.D at 5%		2.06	1.36	11.01

3.1.2 Number of fruits per meter cube

The results revealed that, the number of fruits per meter cube was also significantly affected by different treatments. The maximum number of fruits per meter cube (16.00 fruits) was recorded in the treatment of 100% RDF + FYM + *Azotobacter* + PSB (T_2) which was statistically at par with T_3 (14.00), T_6 (13.00) and T_4 (12.00) superior over rest of the treatments. The minimum number of fruits per meter cube (4.00) was observed in control (T_{14}).

3.1.3 Per cent fruit set

The per cent fruit set was also significantly influenced due to various treatments. The maximum per cent fruit set (76.21%) was recorded in the treatment of 100% RDF + FYM + *Azotobacter* + PSB (T_2) which was statistically at par with T_3 (73.69%), T_6 (72.22%), T_4 (70.59), T_7 (68.76%), T_5 (64.29%) and T_{10} (62.21%). The minimum per cent fruit set (50.00%) was observed in control treatment (T_{14}).

3.2 Yield parameters

The data pertaining to weight of fruit, number of fruits/tree, yield/tree (kg), marketable yield/tree (kg) and yield/hectare (ton) are presented in Table 4.

3.2.1 Weight of fruit (g)

The results regarding weight of fruit indicated that the weight of the fruit was significantly affected by various treatments. The treatment of 100% RDF + *Azotobacter* + PSB (T_4) produced the heaviest fruit (221.13 g) and it was significantly superior over rest of the treatments. The lowest fruit weight (182.53 g) was recorded in control (T_{14}).

3.2.2 Number of fruits per tree

The results revealed that, the number of fruits per tree was significantly influenced by various treatments. The maximum number of fruits per tree (68.00 fruits) was produced by the treatment of 100% RDF + FYM + *Azotobacter* + PSB (T_2) which was statistically at par with T_6 (62.00), T_3 (59.00), T_4 (56.00), T_5 (54.00), T_8 (52.00), T_9 (51.00), T_7 and T_{10} (50.00) and T_{12} (48.00). The minimum number of fruits per tree (45.00) was recorded in control (T_{14}).

3.2.3 Yield (kg tree^{-1})

It is clear from the data that, the yield per tree was significantly affected by various treatments of inorganic and biofertilizers. The highest yield (13.46 kg) was recorded in the treatment of 100% RDF + FYM + *Azotobacter* + PSB (T_2) which was statistically at par with T_4 (12.28 kg) and T_6 (12.11 kg). The lowest yield (4.20 kg) was recorded in control (T_{14}).

3.2.4 Marketable yield (kg tree^{-1})

It is clear from the data that, the marketable yield per tree was significantly affected by various treatments of inorganic and bio fertilizers. The highest marketable yield (12.41kg) was recorded in the treatment of 100% RDF + FYM + *Azotobacter* + PSB (T_2) which was statistically at par with T_4 (10.78 kg) and T_6 (10.43 kg). The lowest yield (2.21 kg) was recorded in control (T_{14}).

Table 4: Effect of inorganic and biofertilizers on yield parameters.

Treat. no.	Treatments	Weight of fruit (g)	Number of fruits per tree	Yield per tree (kg)	Yield per hectare (tonnes)	Marketable yield/tree (kg)
T_1	100 % RDF (250 g N, 125g P_20_5 and 125 g K_20 tree^{-1})	190.15	48.00	5.10	3.19	3.14
T_2	100 % RDF + FYM + *Azotobacter* + PSB	218.59	68.00	13.46	8.41	12.41
T_3	100% RDF + FYM + *Azotobacter*	212.31	59.00	11.91	7.44	10.18
T_4	100 % RDF + *Azotobacter* + PSB	221.13	56.00	12.28	7.67	10.78
T_5	100 % RDF + FYM + PSB	201.26	54.00	9.10	5.69	7.21
T_6	75% RDF + FYM + *Azotobacter* + PSB	218.00	62.00	12.11	7.57	10.43
T_7	75% RDF + FYM + *Azotobacter*	207.19	50.00	11.19	7.00	9.34
T_8	75% RDF + *Azotobacter* + PSB	202.89	52.00	7.45	4.66	5.54
T_9	75% RDF + FYM + PSB	195.53	51.00	6.19	3.87	4.28
T_{10}	50 % RDF + FYM + *Azotobacter* + PSB	208.89	50.00	11.45	7.16	9.67
T_{11}	50% RDF + FYM + *Azotobacter*	200.12	47.00	7.20	4.50	5.26
T_{12}	50 % RDF + *Azotobacter* + PSB	193.22	48.00	5.30	3.31	3.34
T_{13}	50 % RDF + FYM + PSB	187.19	46.00	5.10	2.74	2.43
T_{14}	Control	182.53	45.00	4.20	2.62	2.21
S.E.$\pm$		9.61	2.57	0.44	0.38	0.35
C.D at 5%		27.93	7.47	1.27	1.09	1.01

3.2.5 Yield (tones ha^{-1})
The results clearly showed that, the yield ha^{-1} was significantly affected by different treatments of inorganic and biofertilizers. The highest yield ha^{-1} (8.41 t) was recorded in the treatment of 100% RDF + FYM + *Azotobacter* + PSB (T_2) which was statistically at par with T_4 (7.67 t), T_6 (7.57 t), T_3 (7.44 t) and T_7 (7.00 t). The lowest yield ha^{-1} (2.62 t) was observed in control (T_{14}).

3.3 Quality parameters
The data pertaining to Total Soluble Solids, Reducing sugar, Non-reducing sugar, Total sugar, Ascorbic acid and Acidity percentage are presented in Table 5.

3.3.1 Total Soluble Solids (%)
The maximum TSS (23.80%) was observed in the treatment of 100% RDF + FYM + *Azotobacter* + PSB (T_2) which are statistically at par with T_3 (23.50%), T_6 (23.20%), T_4 (22.50%), T_{10} (22.30%) and T_7 (22.10%). The minimum TSS (17.40%) was observed in control (T_{14}).

3.3.2 Reducing sugar (%)
The maximum reducing sugar (14.11%) was observed in the treatment of 100% RDF + FYM + *Azotobacter* + PSB (T_2) which was statistically at par with T_3 (13.92%), T_6 (13.75%), T_4 (13.46%), T_{10} (13.10%), T_7 (12.87%), T_5 (12.60%), T_8 (12.56%) and T_{11} (12.22%). The minimum reducing sugar content (9.40%) was recorded in control (T_{14}).

Table 5: Effect of inorganic and biofertilizers on chemical composition of custard apple fruit.

Treat. no.	Treatments	Total Soluble Solids (%)	Ascorbic acid (mg/100g fruit pulp)	Reducing sugar (%)	Non- reducing sugar (%)	Total sugars (%)	Acidity (%)
T_1	100 % RDF (250 g N, 125 g P_20_5 and 125 g K_20 tree^{-1})	19.30	15.80	11.20	2.20	13.40	0.48
T_2	100 % RDF + FYM + *Azotobacter* + PSB	23.80	37.22	14.11	3.46	17.57	0.32
T_3	100% RDF + FYM + *Azotobacter*	23.50	31.10	13.92	3.29	17.21	0.35
T_4	100 % RDF + *Azotobacter* + PSB	22.50	22.16	13.46	3.10	16.56	0.37
T_5	100 % RDF + FYM + PSB	21.80	19.61	12.60	2.85	15.41	0.42
T_6	75% RDF + FYM + *Azotobacter* + PSB	23.20	28.41	13.75	3.21	16.96	0.34
T_7	75% RDF + FYM + *Azotobacter*	22.10	19.21	12.87	3.15	16.02	0.40
T_8	75% RDF + *Azotobacter* + PSB	21.60	17.86	12.56	2.73	15.29	0.43
T_9	75% RDF + FYM + PSB	21.10	17.42	11.95	2.52	14.74	0.48
T_{10}	50 % RDF + FYM + *Azotobacter* + PSB	22.30	20.49	13.10	3.00	16.10	0.39
T_{11}	50% RDF + FYM + *Azotobacter*	20.90	16.70	12.22	2.41	14.63	0.41
T_{12}	50 % RDF + *Azotobacter* + PSB	19.80	16.14	11.72	2.28	14.00	0.48
T_{13}	50 % RDF + FYM + PSB	18.34	15.66	10.29	2.14	12.43	0.49
T_{14}	Control	17.40	15.11	9.40	2.10	11.50	0.51
S.E.$\pm$		1.03	1.06	0.59	0.24	0.75	0.02
C.D at 5%		2.98	3.07	1.71	0.70	2.18	0.06

3.3.3 Non-reducing sugar (%)
The maximum non-reducing sugar (3.46%) was observed in the treatment of 100% RDF + FYM + *Azotobacter* + PSB (T_2) which was statistically at par with T_3 (3.29%), T_6 (3.21%), T_7 (3.15%), T_4 (3.10%) and T_3 (3.00%). The minimum reducing sugar content (2.10%) was recorded in control (T_{14}).

3.3.4 Total sugar (%)
The maximum total sugar (17.57%) was observed in the treatment of 100% RDF + FYM + *Azotobacter* + PSB (T_2) which was statistically at par with T_3 (17.21%), T_6 (16.96%), T_4 (16.56%), T_{10} (16.10%) and T_5 (15.41%). The minimum total sugar (11.50%) was observed in control (T_{14}).

3.3.5 Ascorbic acid (mg/100g pulp)
The maximum ascorbic acid content (37.22 mg/100g pulp) was observed in the treatment of 100% RDF + FYM + *Azotobacter* + PSB (T_2) which was statistically at par with T_3 (31.10 mg/100g pulp), T_6 (28.41 mg/100g pulp), T_4 (22.16 mg/100g pulp), T_{10} (20.49 mg/100g pulp) and T_5

(19.61mg/100g pulp). The minimum ascorbic acid content (15.11mg/100g pulp) was recorded in control (T_{14}).

3.3.6 Acidity (%)
Minimum acidity (0.32%) was observed in the treatment of 100% RDF + FYM + *Azotobacter* + PSB (T_2) which was statistically at par with T_6 (0.34%), T_3 (0.35%), T_4 (0.37) and T_{10} (0.39%). The highest acidity (0.51%) was observed in control (T_{14}).

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