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Effect of fertilizer sources and rate through drip fertigation on growth and yield of custard apple (*Annonas squamosa* L.) Cv. Balanagar

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Abstract
A study was conducted during 2019 to 2020 and 2020 to 2021 to find out the effect of fertilizer sources and rate through drip fertigation on growth and yield of custard apple (*Annonas squamosa* L.) *Cv*. Balanagar. The experiment was laid out in factorial randomized block design with eight treatment combinations which included four levels of fertigation (100, 75, 50% and surface application) and two sources of fertilizers, which included water soluble fertilizers and solid fertilizers with four replication. Nitrogen, phosphorus and potassium (NPK) content of solid and water soluble fertilizers were applied through fertigation as well as soil application to test various attributes of 5-years-old custard apple *cv*. Balanagar. The investigation indicated that 100% RDF (recommend dose of fertilizers) with water soluble fertilizers (F_1S_2) resulted in maximum plant height (3.25 m), canopy volume (19.90 m^3), stem girth (8.05cm), leaf area index (2.87), relative chlorophyll content (56.31 SPAD readings), percent of fruit set (44.71 %), fruit length (7.38 cm), fruit diameter (7.85 cm), average fruit weight (184.93 g), fruit volume (196.73 g), number of fruits per plant (84.55) and fruit yield (6.45 t ha^{-1}). However, surface application of 100% RDF with solid fertilizers (F_4S_1) resulted in minimum growth and yield attributes in custard apple.

Keywords: Custard apple, fertigation, source of fertilizers, growth, yield

Introduction
Custard apple (*Annona squamosa* L.) belongs to family Annonaceae and is one of the finest fruits gifted to India by tropical America. It is commonly found in India and is cultivated an area of 38,000 ha with production of 3,20,000 MT (Anonymous, 2018) [1]. Custard apple, popularly known as Sitaphal is grown mainly in the States of Andhra Pradesh, Assam, Tamil Nadu, Madhya Pradesh and grows wild in Deccan plateau and some parts of central India. Custard apple is generally classified as semi wild fruit by virtue of its spontaneous spread in forests, wastelands and other uncultivated places. It is hardy, tolerant to drought, salinity and saline irrigation water to certain extent. It grows very well even on a shallow soil. It also sheds off leaves during stress period to minimize the moisture loss from plant tissues through transpiration and thus a most appropriate fruit crop for rain fed region. Custard apple is known by varied names as Sitaphal, Sugar apple and Shariffa. It is considered as one of the delicious and nutritionally valuable fruits meant for table purpose. Fruits have an edible, soft, granular, juicy and sugary pulp with mild flavour and with slight acidity. Fruits are considered for their medicinal value besides their general use in ice cream, confectionery, certain milk products and in making preserves such as jam, jelly and other products. It is considered as beneficial for cardiac disease, diabetes, hyperthyroidism and cancer. It contains about 28-55% of edible portion consisting of 73.30% moisture, 1.60% protein, 0.30% fat, 0.70% mineral matter, 23.90% carbohydrates, 0.20% calcium, 0.40% phosphorus, 1.0% iron, 12.4-18.15% sugar and 0.26-0.65% acidity with caloric value of 105 KCal/100g.
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. Nutrition of fruit tree is an important part of orchard management practices.

Nutrients have certain specific role to play in the plant and their presence is must for a plant to complete its life cycle and to determine the fruitfulness and physico - chemical properties of the fruit.

The fertilizers are becoming costly input day by day. Hence, it is felt necessary to study the efficient use of this input. This can be achieved by adopting efficient use of drip system of irrigation.The application of fertilizers through irrigation system is called "fertigation". It has become a common practice in modern irrigated agriculture. Increased yields, improvement in quality of the produce, irrigation and fertilizer use efficiencies and protection of the soil environment are some of the main characteristics of this method, which made it very popular throughout the world.

Fertilizer must supply and maintain an optimum level of nutrients within the root zone. For this new irrigation and fertilization techniques are required. Combined irrigation and fertilization is ideal for this purpose, with irrigation water acting as a vehicle for the nutrients required by crops. One of the major factors to promote modern fertigation is the development of micro irrigation systems, which include drips, jets and micro-sprinklers. Fertigation technology involves application of fertilizers with drip irrigation system at a slow and controlled rate to the root zone.

A significant goal of fertilizer studies is to develop cultural practices by which crop nutrient requirements are satisfied through maximum uptake of nutrients from a minimum quantity of applied fertilizers. In general, injection of fertilizers into irrigation water gives a better crop response than either band or broadcast application. Fertigation gives flexibility of fertilization, which enables the specific nutritional requirements of the crop, to be met at different stages of its growth.

The area under custard apple is increasing in India on commercial scale and no work has been done with respect to different levels of fertigation. Therefore, the present study was under taken to evaluate the fertigation system involving sources of fertilizers and various levels of fertilizers in comparison to farmers practice (soil application of RDF) on growth of trees, fruit set and yield of custard apple.

Materials and Methods

The experiments were conducted at the Horticulture Garden, Department of Horticulture, College of Agriculture, Raichur, Karnataka, during 2019-20 and 2020-21 on uniform 5 year old custard apple *cv*. Balanagar which were spaced at 4.5 × 4.5 m (494 plant ha^{-1}). The region belongs to Agro-Climatic Zone-II (North-Eastern dry zone) of Karnataka. Raichur is located at 16.21° N, 77.35° E longitude and an altitude of 407 meters above mean sea level. The experimental site was clay loamy with pH of 7.0-7.3. The soil was fertile, with organic content (0.45 %), low available nitrogen (212.8 kg/ha), medium available phosphorous (27.1 P_2O_5 kg/ha) and potassium (237.7 K_2O kg/ha). There were 4 levels of fertigation, namely fertigation at 100% RDF (F_1), fertigation at 75% RDF (F_2), fertigation at 50% RDF (F_3) and surface application at 100% RDF (F_4) with two source of fertilizers were used in the experiment were, solid fertilizer (S_1) and water soluble fertilizer (S_2) along with eight treatment combinations. The experiment was laid out in factorial randomized block design with four replications and two plants were kept in each treatment. The recommended fertilizer dose of 250: 125:125 g NPK $plant^{-1}$ $year^{-1}$ was adopted for fertigation as well as soil application. The fertigation system was installed in the experimental orchard. The drip unit consisted of 63 and 40 mm PVC pipes, valves, venturi, a sand filter which was connected in series. The main PVC line was 63 mm in diameter to which a sub-main of 40 mm diameter was fixed. Lateral drip inline (16 mm LLDPE) were drawn from the sub mains parallel to the plant rows. One lateral was placed for one row of plants with two drippers at a discharge rate of four litres per hour. The water source for the drip system was from bore well near the experimental site. Well decomposed farmyard manure was applied at the rate of ten kg per plant at the time of basin preparation. The fertigation was given to custard apple plants as per treatments. Solid fertilizers like urea, di ammonium phosphate and muriate of potash were applied in the form of liquid fertilizers by soaking it in water for overnight and water soluble fertilizers like 19:19:19 along with urea were applied in five split doses at twenty days intervals after pruning. The observation on the plant height (m) and stem girth (cm) were recorded using meter scale and vernier caliper. Canopy volume (m^3) was calculated by Castles formula, leaf area index was (LAI) was measured with an AccuPAR 80 ceptometer (Decagon Devices, Inc., Pullman, WA, USA) between 11:00 am to 3:00 pm. relative chlorophyll content was measured by using chlorophyll meter (SPAD plus 502). Percent of fruit set (%), fruit length (cm) and fruit diameter was taken with the help of vernier caliper. Average fruit weight was recorded with the help of an electronic balance. Fruit volume (m^3) was measured by water displacement method. Further, number of fruits per plant were taken by counting number of fruits as per treatment at each picking and the result was expressed as number of fruits per tree and fruits per ha were calculated by multiplying the fruit yield per plant to the number of plants per ha. The data obtained on various characters were subjected to Factorial RBD analysis and interpretation of the data was carried out in accordance to Panse and Sukhatme (1985) [7].

Results and Discussion

Vegetative growth

Treatment wise biometric observations of the plant were recorded and after analysis of data these are given in table 1. Pooled data over two years indicates that biometric parameters were significantly influenced by different fertigation level and source of fertilizers treatments. Application of fertilizers through fertigation of 100% RDF with water soluble fertilizers (F_1S_2) was found effective in increasing the plant height (3.25 m), canopy volume (24.42 m^3), leaf area index (2.87) and relative chlorophyll content (56.31) which was statistically at par with fertigation of 75% RDF with water soluble fertilizers (F_2S_2), which registered a plant height of 3.17 cm, canopy volume 18.93 m^3, leaf area index 2.73 and relative chlorophyll content (53.59). However, lower plant height (2.66 m), canopy volume (16.59 m^3), leaf area index (2.39) and relative chlorophyll content (46.96) recorded under surface application of 100% RDF with solid fertilizers (F_4S_1). Among various fertigation levels, higher doses of fertilizers showed better vegetative growth in the plant. This might be due to application of higher dose of fertilizers which attributed to better nutritional environment in the root zone as well as in plant system. Nitrogen, phosphorus and potassium are most indispensable of all mineral nutrients for growth and development of the plant as these are the basis

of fundamental constituents of all living matter. The results obtained in this experiment was similar to the results obtained by Chauhan and chandel (2008) [3] found that vegetative growth was correlated positively with the amount of nitrogen applied. Similar results were also documented by Shirgure *et al*. (2016) [11] in Nagpur mandarin. The significantly lower values of growth contributing characters were obtained for plant height in conventional method of irrigation and fertilizer application. This fact is supported by the works of Kumar and Pandey (2008) [6] and Basant singh *et al.* (2018) [2] in pomegranate. The increase in height through fertigation could be best explained with the regular supply of plant nutrients and water which increased the availability of N, P and K in crop root zone ultimately leading to the enhanced uptake of these nutrients.

The source of fertilizers is also an important factor as it is directly linked with the readily available nutrients to the crop. A major success of fertigation was reported from the usage of water soluble fertilizers. Kavino *et al.* (2004) [5] opined that the plants fertigated with water soluble fertilizers exhibited a strong influence on plant morphology in terms of pseudo stem, plant height, girth, number of leaves, leaf area and leaf area index. Application of water soluble fertilizers resulted in higher bunch weight in banana cultivar Robusta.

Table 1: Effect of fertilizer sources and rate through drip fertigation on growth parameters of custard apple Cv. Balanagar

Treatment	Plant height (m)			Canopy volume (m^3)			Leaf area index			Relative chlorophyll content (SPAD)		
	2019-20	2020-21	Mean	2019-20	2020-21	Mean	2019-20	2020-21	Mean	2019-20	2020-21	Mean
F_1S_1- Fertigation of 100 % RDF with solid fertilizers	2.95	3.11	3.03	14.71	22.24	18.47	2.47	2.77	2.62	50.63	52.13	51.38
F_1S_2- Fertigation of 100% RDF with water soluble fertilizers	3.10	3.41	3.25	15.37	24.42	19.90	2.70	3.04	2.87	55.59	57.04	56.31
F_2S_1- Fertigation of 75 % RDF with solid fertilizers	2.85	3.09	2.97	13.94	22.15	18.04	2.45	2.76	2.60	50.41	51.74	51.07
F_2S_2-Fertigation of 75 % RDF with water soluble fertilizers	3.10	3.24	3.17	14.63	23.24	18.93	2.57	2.89	2.73	52.90	54.28	53.59
F_3S_1-Fertigation of 50 % RDF with solid fertilizers	2.83	2.98	2.90	13.42	21.32	17.37	2.36	2.65	2.51	48.52	49.79	49.15
F_3S_2-Fertigation of 50 % RDF with water soluble fertilizers	2.74	2.96	2.85	13.35	21.20	17.27	2.35	2.64	2.49	48.26	49.52	48.89
F_4S_1-Surface application 100 % RDF with solid fertilizers	2.48	2.84	2.66	12.82	20.37	16.59	2.77	2.53	2.39	46.36	47.57	46.96
F_4S_2-Surface application 100 % RDF with water soluble fertilizers	2.81	2.87	2.84	12.93	20.54	16.73	3.04	2.56	2.41	46.75	47.98	47.36
SEm±	0.07	0.06	0.06	0.42	0.41	0.34	0.05	0.05	0.05	0.94	0.99	0.95
CD @ 5 %	0.20	0.17	0.18	1.24	1.21	0.99	0.14	0.15	0.14	2.76	2.91	2.8

Yield attributing parameters

Yield and yield component are the most important economic traits, which are highly influenced by fertigation treatments. The observations on percent of fruit set, fruit length, fruit diameter and fruit volume were recorded for two years and presented in table 2. Fertigation of 100% RDF with water soluble fertilizers (F_1S_2) had significantly resulted in the highest percent of fruit set (44.71 %), fruit length (7.38 cm), fruit diameter (7.85 cm) and fruit volume (196.73 cm^3) which was statistically at par with fertigation of 75% RDF with water soluble fertilizers (F_2S_2), which recorded a percent of fruit set of 42.55 %, fruit length 7.03 cm, fruit diameter 7.48 cm and fruit volume of 188.29 cm^3. However, lesser values were recorded for percent of fruit set (37.29 %), fruit length (6.16 cm), fruit diameter (6.55 cm) and fruit volume (165.02 cm^3) under surface application of 100% RDF with solid fertilizers (F_4S_1). The yield attributing characters were significantly influenced by either application of 100 % and 75 % recommended dose of water soluble fertilizers through fertigation over the conventional method of soil application of 100% RDF. This might be due to the continuous supply of optimum dose of water-soluble fertilizers in available form through fertigation at critical stages of plant growth. This might have resulted in higher uptake and better translocation of assimilates from source to sink, which in turn increased the yield attributes. More nutrient and moisture per plant, which is beneficial in improving all the morphological characters of fruits. Thus, photo assimilate production is higher, which allows the plants to express their potential by forming more racemes and in turns the yield. Similar results of increased fruit volume with increased nutrient application were reported Vijayakumar. (2001) [12] in mango, Haneef *et al*. (2014) [4] in pomegranate Shirgure and Shrivastav (2016) [11] in mandarin.

Similarly the observations on average fruit weight, number of fruits per plant and yield per ha were recorded for two years and presented in table 3. Significantly maximum average fruit weight (184.93 g) number of fruit per plant (84.55) and fruit yield (6.45 t ha^{-1}) was observed in fertigation at 100% RDF with water soluble fertilizers (F_1S_2) which was on par with fertigation of 75% RDF with water soluble fertilizers (F_2S_2) which recorded average fruit weight (177.53g) fruits per plant (80.46) and fruits per ha (6.14 t ha^{-1}) while, minimum average fruit weight (155.59 g) number of fruit per plant (70.52) and fruit yield (5.38 t ha^{-1}) was recorded in the surface application at 100% RDF with solid fertilizers. The treatment consisting of 100 per cent RDF as water soluble fertilizers through fertigation registered significantly highest yield ha^{-1} compare to conventional method of soil application of 100% RDF. This may be due to increased photosynthetic rate promoted by higher availability of nutrients, leading to enhanced formation of protoplasm, cell division and cell enlargement complementing vigorous growth. This, in turn, increased reproductive traits like number of fruits, weight of fruits and fruit yield per tree which was highest under 100 per cent RDF as WSF through fertigation treatment. These results are in line with those of Reddy *et al.* (2002) [9] and Raghupathi *et al.*

(2002) [8], who observed that significant increase in crop yield of banana with increased fertigation levels of N P K. Higher yields obtained under fertigation was also reported by Haneef *et al*. (2014) [4] in pomegranate, Shirgure *et al.* (2016) [11] in mandarin and Sandeep kumar *et al*. (2020) [10] in citrus who observed significant increase in crop yield with increasing fertigation levels.

In conclusion, it may be stated that growth and yield of custard apple can be significantly enhanced with fertigation of 100% RDF with water soluble fertilizers followed by fertigation of 75 % RDF with water soluble fertilizers. Thus, it was inferred that application of 100% recommended dose of water soluble fertilizers through fertigation could be the best option for getting high growth and yield of custard apple.

Table 2: Effect of fertilizer sources and rate through drip fertigation on yield parameters of custard apple Cv. Balanagar

Treatment	Percent of fruit set (%)			Fruit length (cm)			Fruit diameter (cm)			Fruit volume (cm^3)		
	2019-20	2020-21	Mean	2019-20	2020-21	Mean	2019-20	2020-21	Mean	2019-20	2020-21	Mean
F_1S_1- Fertigation of 100 % RDF with solid fertilizers	40.37	41.09	40.73	6.60	6.85	6.73	7.05	7.25	7.15	172.45	188.00	180.22
F_1S_2- Fertigation of 100% RDF with water soluble fertilizers	44.32	45.11	44.71	7.25	7.52	7.38	7.74	7.96	7.85	189.32	205.75	196.73
F_2S_1- Fertigation of 75 % RDF with solid fertilizers	40.19	40.91	40.55	6.58	6.82	6.70	7.02	7.22	7.12	171.71	187.20	179.46
F_2S_2-Fertigation of 75 % RDF with water soluble fertilizers	42.17	42.92	42.55	6.90	7.17	7.03	7.38	7.58	7.48	180.16	196.41	188.29
F_3S_1-Fertigation of 50 % RDF with solid fertilizers	38.69	39.37	39.03	6.33	6.56	6.45	6.75	6.95	6.85	165.26	180.17	172.72
F_3S_2-Fertigation of 50 % RDF with water soluble fertilizers	38.48	39.16	38.82	6.29	6.53	6.41	6.72	6.91	6.81	164.37	179.20	171.79
F_4S_1-Surface application 100 % RDF with solid fertilizers	36.96	37.62	37.29	6.05	6.27	6.16	6.45	6.64	6.55	157.90	172.14	165.02
F_4S_2-Surface application 100 % RDF with water soluble fertilizers	37.27	37.94	37.61	6.10	6.32	6.21	6.51	6.70	6.60	159.24	173.60	166.42
SEm±	0.75	0.76	0.76	0.12	0.13	0.12	0.13	0.13	0.13	3.20	3.39	3.18
CD @ 5 %	2.20	2.24	2.22	0.36	0.37	0.37	0.38	0.40	0.39	9.41	9.96	9.34

Table 3: Effect of fertilizer sources and rate through drip fertigation on average fruit weight, no fruits per plant and fruit yield of custard apple Cv. Balanagar

Treatment	Average fruit weight (g)			No. fruits per plant			Yield (t ha^{-1})		
	2019-20	2020-21	Mean	2019-20	2020-21	Mean	2019-20	2020-21	Mean
F_1S_1- Fertigation of 100 % RDF with solid fertilizers	154.52	154.52	167.97	72.74	81.29	77.01	4.94	6.81	5.88
F_1S_2- Fertigation of 100% RDF with water soluble fertilizers	170.12	170.12	184.93	79.86	89.24	84.55	5.42	7.48	6.45
F_2S_1- Fertigation of 75 % RDF with solid fertilizers	156.30	156.30	169.90	72.43	82.51	76.69	4.92	6.78	5.85
F_2S_2-Fertigation of 75 % RDF with water soluble fertilizers	163.31	163.31	177.53	76.00	86.51	80.46	5.16	7.12	6.14
F_3S_1-Fertigation of 50 % RDF with solid fertilizers	149.81	149.81	162.85	69.71	80.21	73.81	4.73	6.53	5.63
F_3S_2-Fertigation of 50 % RDF with water soluble fertilizers	149.0	149.0	161.97	69.34	78.19	73.41	4.71	6.49	5.60
F_4S_1-Surface application 100 % RDF with solid fertilizers	143.13	143.13	155.59	66.61	74.43	70.52	4.52	6.24	5.38
F_4S_2-Surface application 100 % RDF with water soluble fertilizers	143.76	143.76	156.27	67.17	75.06	71.12	4.56	6.29	5.43
SEm±	2.87	2.87	3.12	1.35	1.58	1.43	0.09	0.13	0.11
CD @ 5 %	8.43	8.43	9.17	3.97	4.64	4.20	0.27	0.37	0.32

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