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Studies on the Effect of Split Application of NPK Fertilizers on Yield and Quality of Papaya (*Carica papaya* L.) under Central Dry Zone of Karnataka

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ABSTRACT

The experiment was conducted from October, 2020 to July, 2021 at Eswargere village in the Chitradurga district of Karnataka, India to evaluate the impact of split applications of nitrogen, phosphorus, and potassium (NPK) fertilizers on the growth, yield, and quality of papaya. The study utilized a Randomized Complete Block Design (RCBD), incorporating seven distinct treatments. These treatments included varying rates of fertilizer application 75%, 100%, and 125% of the recommended dose of fertilizers (RDF) and different application frequencies, either bimonthly or monthly. This design aimed to determine the most effective fertilizer rates and timing to optimize papaya production and quality under local agronomic conditions. Among yield and yield attributes fruit length (23.54 cm), fruit diameter (14.36 cm), number of fruits plant^{-1} (30.85), fruit weight (1.46 kg), total fruit yield (138.83 t ha^{-1}) were recorded maximum in 125% RDF through split application. The maximum total soluble solids (13.45°Brix), reducing sugars (10.10%), non-reducing sugars (2.68%), total sugars (12.97%) and minimum acidity (0.014%) were also found in 125% RDF through split application. The results were on par with 100% RDF through split application treatment. So, the application of 100% RDF through split at different growth stages (150:125:100 N:P_2O_5:K_2O g plant^{-1}) in vegetative stage of 4 months, (50:100:150 N:P_2O_5:K_2O g plant^{-1}) in flowering to fruit set stage of 2 months, (50:25:250 N:P_2O_5:K_2O g plant^{-1}) in fruit development stage of 3 months at monthly interval proved to be promising for fetching higher yield and good quality of papaya fruits.

KEYWORDS: Papaya, fertilizer, fruit yield, TSS, total sugars

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1. INTRODUCTION

The papaya (*Carica papaya* L.), a hardy evergreen herbaceous fruit crop, belongs to the Caricaceae family and grows well in tropical and subtropical climates (Vincent et al., 2019, Saran et al., 2016, Fuentes and Santamaria, 2013). Its distinctive qualities, which include being gynodioecious and supporting both male and hermaphrodite plants, being easy to cultivate, offering quick returns on investment, and being tolerant of a wide range of soil and climate conditions, are largely responsible for its recent rise in popularity. But probably most importantly, papaya's appeal is derived from its delicious and adaptable fruits, which are praised for their healthfulness and diverse range of uses (Jiao et al., 2023, Ugbogu et al., 2023, Daagema et al., 2020, Saran and Choudhary, 2019). Papaya farming is integral to Indian agriculture, covering 1,50,000 hectares and yielding 60,63,000 metric tonnes annually as per Anonymous 2020–21. Andhra Pradesh leads production, followed by Gujarat and Karnataka. Despite its potential, challenges persist, notably in maximizing yield within time constraints. Success relies on a careful balance of factors, with nutrition playing a pivotal role. The availability and uptake of critical nutrients are closely related to the growth, yield, and general quality of papaya fruits. Papaya plants react strongly to both organic manures and inorganic fertilizers (Ali et al., 2023, Arora et al., 2021, Fallas-Corrales et al., 2020, Baiyeri and Ugese, 2017, Bakheit and Elsadig, 2015). The vital components required for strong vegetative growth, good blooming, and abundant fruit set are supplied by these nutrient sources (Sutter et al., 2017, Sharma et al., 2021). However insufficient nourishment can seriously impair the physiological functions of the plant, leading to stunted growth, poor fruit development, and ultimately, below-average yields. Understanding the complex interactions between nutrient assimilation, yield creation, and vegetative growth is essential to overcoming these obstacles (Muneer et al., 2024, Lu et al., 2023, Vos and Arancon, 2020). Through understanding the ways in which distinct nutrients impact different phases of papaya growth and development, farmers can adjust their fertilization strategies to better suit the crop's requirements (Lakshmi et al., 2020, Rahman et al., 2017, Dalal et al., 2017). Studies like the one that was done in 2017 by Bindu B. Podikunju B. highlight how crucial it is to comprehend the complex relationship between nutrient availability and papaya productivity. Together, these data can be used to create tailored nutrient management strategies that optimize yield potential while reducing resource inputs. Furthermore, papayas have different nutritional requirements at each of their five stages of growth: immature, flowering, growing, and ripening. Papaya's rapid growth trajectory, consistent fruiting habit, and prolific fruit production make it different from other fruit crops in terms of nutrient requirements. India's papaya exports are increasing, therefore increasing output and improving fruit quality is imperative. To meet these needs, a complete strategy that incorporates improvements in cultivation and post-harvest procedures coupled with optimized nutrition management suited to each growth phase is required (Tan et al., 2022, Atta et al., 2021, Azam et al., 2021, Aluko et al., 2021, Colpaert et al., 2021, Wu et al., 2019, Srivastava and Malhotra, 2017). Through the application of cutting-edge agricultural techniques and scientific knowledge, the papaya sector may chart a path toward long-term expansion and international competitiveness. A program was developed to look into the stage-by-stage nutrient requirements for papaya in the arid zone of Karnataka after gaps in studies on nutrient requirements were identified. These gaps included split applications at different growth phases in particular. Through the provision of practical insights to optimize nutrient management procedures and further increase the efficiency of papaya farming, this programme seeks to close significant knowledge gaps.

2. MATERIALS AND METHODS

The experiment was carried out during October, 2020 to July, 2021 in the farmers field at Eswargere village, Hiriyur taluk of Chitradurga district. The experimental site comes under Central Dry Zone (Zone-IV) of Karnataka, India and is situated at 13° 57' North latitude and 70° 37' East longitude at an elevation of 606.1 m above the Mean Sea. A representative soil sample was collected from experiment field and analysed soil properties. The experimental soil is classified as loamy, characterized by a balanced texture that typically promotes good aeration and drainage. It has a pH of 7.10, which is neutral and ideal for most crops. The electrical conductivity (EC) is 0.38 dS/m, indicating a low level of salinity that is favorable for plant growth. The soil's nutrient profile shows a substantial availability of nitrogen at 295.16 kg ha^{-1}, which supports robust plant development. Phosphorus is available at 29.10 kg ha^{-1}, providing essential nutrients for root development and energy transfer. Additionally, the soil contains 207 kg/ha of potassium, crucial for various physiological functions in plants. Overall, these properties suggest that the soil has a healthy nutrient balance and is well-suited for agricultural use. Planting was taken up with 45 days old seedlings in a spacing of 1.8×1.8 m^2 in October, 2020. The experiment was carried out with seven treatments and four replications in Randomized Complete Block Design. Treatments were as follows: T_1–100% recommend dose of fertilizers (RDF) (250:250:500 g of NPK plant^{-1}), T_2–125% RDF (312.5:312.5:625 g of NPK plant^{-1}), T_3–75% RDF (187:187:375 g of NPK plant^{-1}), T_4–100% RDF through split application, T_5–125% RDF through split application, T_6–75% RDF through split application, T_7–Absolute control (No fertilizer application). In treatments T_1, T_2, and T_3, the recommended dose of fertilizers was applied bimonthly according to their respective treatment schedules. In contrast, Treatments T_4, T_5, and T_6 involved applying the recommended dose of fertilizers at monthly intervals based on a specific schedule. No fertilizers were applied in Treatment T_7. For the split application of the recommended dosage of NPK fertilizers across different growth stages, specific nutrient distribution is employed for treatments T_4, T_5, and T_6. During the vegetative stage, which lasts for 4 months, 60% of the nitrogen (N), 50% of the phosphorus (P_2O_5), and 20% of the potassium (K_2O) are applied. As the plants transition to the flowering and fruit set stage, spanning 2 months, the nutrient application shifts to 20% nitrogen, 40% phosphorus, and 30% potassium. In the final fruit development stage, which continues for 3 months, the distribution adjusts to 20% nitrogen, 10% phosphorus, and 50% potassium. This staged approach ensures that plants receive appropriate nutrient levels tailored to their specific growth needs at each developmental phase.

2.1. *Imposition of treatments*

Experimental plants were supplied with FYM at 10 kg plant^{-1} at the time of planting and fertilizers were applied as per the treatment requirements. Recommended dose of fertilizers 250:250:500 N:P_2O_5:K_2O gram plant^{-1} was adopted to carry out the experiment. Fertilizer doses were applied during the months of Oct–June. The recommended dose of N, P and K required for different treatments were supplied in the form of Urea–CH_4N_2O (46-0-0), Di-ammonium phosphate–$NH_4H_2PO_4$ (18-46-0) and Muriate of potash–KCL (0-0-60). For treatment T_4, T_5 and T_6 the recommended dose of fertilizers was split and applied at different stages viz., vegetative stage (four equal splits), flowering to fruit set stage (two equal splits) and fruit development stage (three equal splits).

2.2. *Observations recorded*

The yield and yield attributes such as fruit length, fruit diameter, fruit weight was measured in each replication of randomly taken five fruits at 80% maturity. The fruit yield per plant was noted down each treatment and each picking computed and expressed in yield per plant and hectare. The quality parameters such as TSS, reducing sugars, total sugars and acidity as were analyzed at 80% maturity. The TSS of fruits was measured by using a hand refractometer. The total sugars were estimated by the anthrone reagent method, reducing sugars were determined by the Dinitro-Salicylic acid (DNSA) method (Miller, 1972), The non-reducing sugar was determined by subtracting the per cent reducing sugar from the per cent total sugar and multiplying the same with 0.95 (Somogyi, 1952) and the acidity content of fruits was analyzed by the method given by Ranganna (1986). The data on different parameters viz., yield, quality parameters analysis results content was tabulated and subjected to statistical analysis using the analysis of variance (ANOVA) for Randomized Complete Block Design (RCBD) by Fisher and Yates (1963). Whenever 'F' test was found significant for comparing the means of two treatments, the critical difference (C.D. at 5%) was worked.

3. RESULTS AND DISCUSSION

3.1. *Yield parameters*

Results indicated that split application of NPK fertilizers significantly affected the yield and yield attributes viz., fruit length, diameter, number of fruits per plant, fruit weight, fruit yield (Table 1). Amongst the treatments highest fruit length (23.54 cm), diameter (14.36 cm), number of fruits plant^{-1} (30.85), fruit weight (1.46 kg), total fruit yield (138.83 t ha^{-1}) were recorded in the split application of 125%

Table 1: Effect of split application of NPK fertilizers on yield and yield attributes of papaya

Treatments	Fruit length (cm)	Fruit diameter (cm)	No. of fruits plant^{-1}	Fruit weight (kg)	Total fruit yield (t ha^{-1})
T_1-100% RDF (250:250:500 N:P_2O_5:K_2O g plant^{-1})	19.27	10.53	25.15	1.22	94.40
T_2-125% RDF	20.30	11.63	26.67	1.33	109.74
T_3-75% RDF	18.03	10.03	23.11	1.12	79.70
T_4-100% RDF through split application	23.01	13.20	29.66	1.41	128.53
T_5-125% RDF through split application	23.54	14.36	30.85	1.46	138.83
T_6-75% RDF through split application	19.73	11.20	25.77	1.22	97.18
T_7-Absolute control	14.71	8.60	17.82	0.65	35.49
SEm±	0.75	0.44	0.85	0.04	4.36
CD (p=0.05)	2.22	1.32	2.54	0.11	12.94

RDF and the lowest fruit length (14.71 cm), diameter (8.60), number of fruits plant^{-1} (17.82), fruit weight (0.65 kg), total fruit yield (35.49 t ha^{-1}) was observed in absolute control (without any fertilizer) treatment. The yield was 3.91 times more in split application of 125% RDF when compared to absolute control (No fertilizer application) treatment.

Maximum value of yield and yield attributes were obtained from papaya when plant treated with 125% and also 100% RDF through split application. Application of NPK fertilizers through split was increased the yield up to 1.26 times, when plans treated with 125% RDF through split application when compared with bimonthly application. The mobility of photosynthates from source to sink i.e., higher translocation was possible perhaps due to better sink capacity as indicated by the higher number of fruits per plant. Similarly, improvement in fruit number, fruit weight with split application of NPK resulting higher carbohydrate accumulation in plant at early stages of growth as a resulted better nutrient supply, which causes an increased in fruit size and there by increased the average fruit weight in terms of length and diameter of fruit (Mahboob et al., 2023, Colpaert et al., 2021).

The application of fertilizers NPK in form of Urea, DAP and MOP these are slow releasing and also through applying in split it causes constant availability of nutrients to the plants. So, it enhances the root activity and source sink relationship thus, it improves the fruit number and also weight of the fruits (Singh et al., 2012, Azam et al., 2021).

The higher nutrient content and metabolic levels enhanced the fruit parameters, ultimately leading to higher yield. The results are also in close conformity with the findings of Singh and Varu (2013) in papaya and Brar et al. (2015) in guava. Similar findings are also conformity with findings of Chaudhri et al. (2001) and Ravishankar et al. (2008) in papaya.

In split application of NPK increased potassium rates along with moderate levels of nitrogen and phosphorous during fruit development stage is known to regulate the transpiration and water conductance in plant cells, thereby increasing the photosynthetic activity, which in turn cause greater synthesis, translocation and accumulation of carbohydrates producing larger size fruits (Yadav et al., 2011, Sarker et al., 2012 and Sing et al., 2012).

3.2. *Quality parameters and benefit cost ratio*

Total soluble solids (TSS), total sugars, reducing sugars, non-reducing sugars were significantly distinct among the treatments (Table 2). The application of 125% RDF through split application showed highest total soluble solids (13.45°Brix), reducing sugars (10.10%), non-reducing sugars (2.68%), total sugars (12.97%) and the same treatment showed minimum acidity (0.014%). The lowest TSS (8.15°B), total sugars (7.17%), reducing sugars (6.01%) non-reducing sugars (1.10%) and maximum acidity (0.036%) was recorded in absolute control (No fertilizer application).

The research concludes that in the treatment of split application of NPK results in increased fruit quality significantly in terms of TSS, reducing sugars, non-reducing sugars and total sugars. When the level of potassium is high, the TSS content of the fruit increases, and when the nitrogen level is high, the process reverses. Fruit sugar content increased as potassium levels increased, while sugar content decreased as potassium levels decreased. Fruit acidity was reduced by higher potassium doses, whereas nitrogen levels increased as well as the creation of invertase and starch breaking enzymes. Increased sugars and TSS may be owing to increased respiration demand and appropriate nutritional supply at different growth period of crop (Dhillon et al., 2011, Santos et al., 2015 and Balamohan et al., 2015).

The role of K in carbohydrate synthesis, starch breakdown and translocation, protein synthesis, and neutralisation of

Table 2: Effect of split application of NPK fertilizers on quality parameters and benefit cost ratio of papaya

Treatments	TSS (°Brix)	Reducing sugars (%)	Non-reducing sugars (%)	Total sugars (%)	Acidity (%)	B:C Ratio
T_1-100% RDF (250:250:500 N:P_2O_5:K_2O g plant^{-1})	12.15	8.39	1.74	10.22	0.026	2.25
T_2-125% RDF	12.72	8.92	1.92	10.94	0.021	2.41
T_3-75% RDF	11.40	7.91	1.39	9.37	0.028	2.08
T_4-100% RDF through split application	13.23	9.86	2.63	12.59	0.016	3.00
T_5-125% RDF through split application	13.45	10.10	2.68	12.97	0.014	2.99
T_6-75% RDF through split application	12.55	8.70	1.84	10.64	0.024	2.48
T_7-Absolute control	8.15	6.01	1.10	7.17	0.036	1.31
SEm±	0.12	0.10	0.13	0.16	0.001	0.009
CD (p=0.05)	0.37	0.30	0.39	0.48	0.003	0.028

physiologically essential organic acids was responsible for the quality improvement (Kumar et al., 2022, Das and Dutta, 2022, Ganeshamurthy et al., 2023).

Potassium is known to enhance sugar translocation in plants, thus providing it to the papaya fruit enhanced sugar content and TSS. Another essential fruit quality feature is acidity, which should be kept to a minimum throughout ripening. With an increase in K supply, the acidity content decreased significantly. These results are conformity with findings of Dutta et al. (2016) in mango, Yener and Atluntas (2021) in sweet cherry.

The B:C ratio is a crucial indicator of economic viability. The highest Bratio was achieved with T_4 (100% RDF through split application) at 3.00, followed closely by T_5 (125% RDF through split application) at 2.99. These results indicate that split applications of fertilizers not only improve the quality of papaya but also enhance economic returns, likely due to increased fruit quality and market value. In contrast, T_1 (100% RDF) yielded a B:C ratio of 2.25, while T_3 (75% RDF) had the lowest B:C ratio of 2.08. The absolute control (T_7) showed the least favorable outcomes, with a B:C ratio of 1.31, reinforcing the importance of nutrient management for profitable papaya cultivation.

3.3. Leaf nutrient content

Among the various treatments, a higher NPK content was observed in the split application of 125% and 100% NPK fertilizers treatment, as indicated in Table 3. Specifically, concerning nitrogen content in the leaves, a greater amount of nitrogen was observed during the vegetative stage. This can be attributed to the application of a higher quantity of nitrogen in the split application, emphasizing nitrogen over other nutrients during the vegetative stage. Additionally, during the growth period, nitrogen plays a pivotal role in cell division and other metabolic processes. As a result, plants tend to uptake more nitrogen during the vegetative stage compared to other nutrients, explaining the higher nitrogen content in the leaves. These findings are consistent with the research conducted by Bisht et al. (2010) on papaya, Negi (2018) on pomegranate, and El-Gioushy and Baiea (2015) as well as Zhang et al. (2020) on kiwi, all of which demonstrated that split application of nitrogen enhances nutrient uptake, particularly nitrogen, during the vegetative stage.

As we are aware, phosphorus demand is higher during the flowering stage. Consequently, we applied a greater quantity of phosphorus during the flowering stage compared to other nutrients, and the outcomes exhibited a similar trend. The uptake of phosphorus was observed to be highest during the flowering stage compared to other stages. This phenomenon may be attributed to the fact that the uptake of phosphorus occurs later in the growth cycle when compared to nitrogen (N) and potassium (K) fertilizers. Consequently, a higher amount of phosphorus was recorded in the leaves during the flowering stage as opposed to the initial stage. The phosphorous content in the leaf exhibited a positive correlation with increased levels of phosphorous application. This correlation is consistent with the findings of Singh and Varu (2013) in papaya and Negi (2018) in pomegranate, supporting the notion that higher phosphorous application results in increased phosphorous content. Potash is a crucial element highly demanded during the fruiting stage, as it contributes to enhancing the quality, shape, and size of the fruit. The plant's increased uptake of potash during the fruit development stage is reflected in higher potash content in the leaf at the harvesting stage. These results align with the research of Jadhav et al. (2016) in papaya, Kumar et al. (2012) in banana, Sheikh and Rao (2005), and Negi (2018) in pomegranate, reinforcing the association between higher potash application and increased potash content in the leaf.

Table 3: Effect of split application of NPK fertilizers on leaf nutrient content of papaya at different growth stages

Treatments	Vegetative stage	Flowering stage	Harvesting stage	Vegetative stage	Flowering stage	Harvesting stage	Vegetative stage	Flowering stage	Harvesting stage
T_1-100% RDF (250:250:500 $N:P_2O_5:K_2O$ g plant^{-1})	1.44	1.37	1.32	0.30	0.32	0.26	2.21	2.28	2.32
T_2-125% RDF	1.52	1.48	1.41	0.34	0.37	0.31	2.34	2.38	2.41
T_3-75% RDF	1.41	1.34	1.30	0.28	0.31	0.24	2.15	2.20	2.27
T_4-100% RDF through split application	1.59	1.55	1.49	0.37	0.41	0.34	2.49	2.56	2.59
T_5-125% RDF through split application	1.63	1.59	1.53	0.41	0.43	0.39	2.58	2.61	2.65
T_6-75% RDF through split application	1.46	1.40	1.34	0.31	0.34	0.29	2.26	2.31	2.35
T_7-Absolute control	1.22	1.15	1.06	0.19	0.23	0.17	1.86	2.03	2.08
SEm±	0.02	0.01	0.02	0.02	0.02	0.03	0.08	0.07	0.07
CD (p=0.05)	0.07	0.04	0.07	0.05	0.05	0.08	0.23	0.21	0.22

4. CONCLUSION

The application of 125% Recommended Dose of Fertilizer (RDF) through split applications yielded the highest quality and yield parameters, though these results were comparable to those obtained with 100% RDF, also applied via split applications. So, it can be concluded that 100 per cent RDF through split application at different growth stages i.e., 150:125:100 N: P_2O_5: K_2O g plant^{-1} in vegetative stage, 50:100:150 N: P_2O_5: K_2O g plant^{-1} in flowering to fruit set stage, 50:25:250 N:$_2O_5$:K_2O g plant^{-1} in fruit development stage proved to be promising for fetching higher yield and quality of the papaya with the maximum returns and benefit cost ratio under dry zones.

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