Indian Journal of Ecology (2022) 49(4): 1320-1324
DOI: https://doi.org/10.55362/IJE/2022/3665

Manuscript Number: 3665
NAAS Rating: 5.79

Effect of Integrated Nutrient Management on Plant Growth, Yield and Quality of Papaya (*Carica papaya* L.) cv. Red Lady

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***Abstract*:** Continuous use of chemical fertilizers poses soil health issues, whereas organic manures alone are not able to fulfil the requirements of highly nutrient-demanding crops. Indian soils are deficient in NPS, leading to low yield potential, so the only option left is to concentrate on alternate strategies like Integrated Nutrient Management (INM) to maintain the soil fertility. In this view, research was carried out to study the effect of integrated nutrient management on plant growth, yield and quality of papaya (*Carica papaya* L.) cv. Red Lady under Punjab conditions. The main objectives of this study were to adopt organic manures instead of relying only on chemical fertilizers or to find the appropriate combination of organic manures along with chemical and bio-fertilizers. The dose of chemical fertilizers was kept constant (50% for all treatments), whereas different concentrations of organic manures and bio-fertilizers were added. Among all the treatments, the application of 50% NPK + 20 kg FYM + 100 g *Azospirillum* + 100 g PSB resulted in the maximum plant height, stem girth, fruit length, fruit width, and yield. Likewise, all the fruit quality parameters such as TSS, firmness, total sugars, reducing sugars, non-reducing sugars and ascorbic acid were also improved by the same treatment. Hence, integrated nutrient management significantly improved the vegetative growth, yield and quality of papaya cv. Red Lady when 20 kg of FYM and 100g of *Azospirillum* were applied along with 50% NPK.

Keywords: Integrated nutrient management, Papaya, Organic manures, Bio-fertilizers, Fruit yield, Fruit quality

Papaya (*Carica papaya* L.) belongs to the Caricaceae family. In Punjab, papaya was earlier considered a backyard crop or it was mainly grown as a filler crop in the main orchard like mango. But nowadays, farmers in Punjab are more concerned about cultivating papaya as a major crop because of its numerous health and commercial benefits. Among several varieties of papaya, Red Lady is gaining popularity due to its continuous flowering habit and unlike other dioecious varieties there is no need to maintain a female and male plant ratio. The nutritional requirements of papaya vary from those of other fruit crops. If sufficient nutrients are not provided during the growth and flowering phases, a papaya crop will be vulnerable to various biotic and abiotic stresses (Kanwar et al 2020). Use of chemical fertilizers is a primary choice of farmers in order to maximize the productivity. Sole application of chemical fertilizers in huge amounts creates soil health problems, while organic sources alone are not sufficient to fulfil the requirements of high nutrient-demanding crops, as organic manures have low nutrient content and are slow releasing into the soil. Though organic manures are easily available and eco-friendly, the major drawback of adopting organic agriculture is that it would not be possible to feed billions of people solely through organic agriculture. Thus, integrated nutrient management is the only sustainable approach to strengthen fruit production without posing detrimental effects on human health and the environment. INM could be an option where a portion of nutrients are supplied through inorganic fertilizers and the remaining portion with organic manures along with microbial inoculations. It also gives a good return on the economy (Bakshi et al 2018). The main objectives of this study were to assess the effect of integrated nutrient management on vegetative growth, flowering and yield of the papaya.

MATERIAL AND METHODS

Experimental site and planting material: The present investigation was carried out at the Horticultural Farm, School of Agriculture, Lovely Professional University, Phagwara Punjab during the year of 2020-2021. The experimental area is located at 31.2498° North latitude and 75.7084° East longitude. It has an altitude of 232 m above mean sea level (MSL). The soil of the experimental site was sandy loam, well fertile, rich in organic matter and free from perennial weeds. The soil sample was collected from 0 to 15.0 cm depth of the soil from the exploration site before the start of the experiment and analysis of the sample was done physically and chemically.

Treatment details: One-month-old (10-15cm) healthy seedlings of papaya cv. Red Lady were taken from the nursery of Punjab Agriculture University (PAU), Ludhiana

and transplanted at Lovely Professional University's horticultural farm with a spacing of 1.8 m x 1.8 m. The experiment was laid out in a Randomized block design with 13 treatments and 3 replications, each studying 2 units of plants per replication. 200:250:250 g NPK/plant was used as a recommended dose of fertilizers and applied as per details of all thirteen treatments including bio-fertilizers and organic manures *viz.* T_0(100% RDF + Control), T_1(50% RDF + 20 kg FYM/plant), T_2 (50% RDF + 20 kg FYM + 100g *Azospirillum*/plant), T_3 (50% RDF + 20 kg FYM + 100g PSB/plant), T_4 (50% RDF + 20 kg FYM + 100g *Azospirillum* + 100g PSB/plant), T_5 (50% RDF + 10 kg Vermicompost/plant), T_6 (50% RDF + 10 kg Vermicompost + 100g *Azospirillum*/plant), T_7 (50% RDF + 10 kg Vermicompost + 100g PSB/plant), T_8 (50% RDF + 10 kg Vermicompost + 100g *Azospirillum* + 100g PSB/plant), T_9 (50% RDF + 2 kg Neem cake/plant), T_{10} (50% RDF + 2 kg Neem cake + 100g *Azospirillum*/plant), T_{11} (50% RDF + 2 kg Neem cake + 100g PSB/plant), T_{12} (50% RDF + Neem cake + 100g *Azospirillum* + 100g PSB/plant). The well-rotted farmyard manure, vermicompost and neem cake along with bio-fertilizers were applied before transplanting according to the details of treatments. Inorganic fertilizers like phosphorus and potash were applied along with the organic manures. Nitrogen was applied in three equal splits, with the first dose applied with organic manures, the second dose applied during flowering and the third dose applied during fruit set. The sources of NPK were Urea, SSP and MOP, respectively.

Estimation of vegetative and reproductive growth: The vegetative growth *viz.* plant height, stem girth, the number of leaves, petiole length, plant spread (N-S) and plant spread (E-W) while reproductive growth *viz.* days taken to first flowering and days from flowering to fruit maturity were determined following the conventional methods previously used by Yadav (2017).

Estimation of fruit quality: Fruits are harvested from the experimental field to determine the fruit weight, fruit length and fruit width and was measured in centimeter (cm). A digital hand refractometer was used to determine the TSS (total soluble solids) of fruit pulp. Physicochemical analysis of fruits for evaluation of quality was done as per standard procedures (AOAC 1980). To determine ascorbic acid content fresh fruit pulp was used by following the methods recently detailed by Baswal et al (2020) and expressed in mg/100 g pulp.

Statistical analysis: The recorded mean of all the field and lab parameters for each replication was subjected to statistical analysis for analysis of using OP Stat software (Sheoran 1998).

RESULTS AND DISCUSSION

Plant height and stem girth: At 210 days after transplanting (DAT), the application of 50% RDF + 20 kg FYM + 100g *Azospiriilum* + 100g PSB/plant was better in increasing the plant height (179.17cm) and stem girth (30.83cm) as compared to the other treatments and control (Table 1). The increase in plant height and stem girth may be due to an improvement in soil physical properties or an increase in nutrients uptake, growth of beneficial soil microorganisms and released growth factors such as auxins, cytokinins and gibberellins in the root zone (Godara and Bakshi 2021). However, the results of the present study are moderately different from the results of Singh and Varu (2013) who reported that in papaya cv. Madhubindu, the application of 50% NPK + 50g *Azotobactor* + 2.5g/m^2 PSB was better in increasing the plant height.

Number of leaves, leaf length, petiole length, plant spread (North-South) and plant spread (East-West): Application of Integrated Nutrient Management significantly influenced the number of leaves, leaf length, petiole length, plant spread (North-South) and plant spread (East-West). The application of 50% RDF + 20 kg FYM + 100g *Azospiriilum* + 100g PSB/plant recorded the significantly highest mean number of leaves (32.50), leaf length (66.83cm), petiole length (73.83cm), plant spread in the North-South (172.00cm) and plant spread in the East-West (180.83cm). The inoculation of plant beneficial microorganisms through organic formulations in the root zone and nitrogen content available in inorganic fertilizers may be responsible for the increase in vegetative growth and other parameters (Verma et al 2021, Wani et al 2021). Moreover, might be due to the continuous supply of nutrients and also that organic manures have the capability to restore the fertility of the soil. When organic manures are applied to the soil in addition to inorganic fertilizers, complex nitrogenous compounds slowly degrade and provide a constant source of nitrogen throughout the cropping period. Though organic manures release nutrients very slowly, their residual effect remains available in the soil for a longer time, resulting in improved soil structure, fertility, porosity and physiological activity inside the plants. Moreover, beneficial microorganisms influence cell division and cell elongation, which increase vegetative growth and eventually increase plant height, plant spread and number of leaves per plant. The results of the present investigation are in close conformity to the study done by Ennab *et al* (2016), where application of 50% of NPK + 55 kg of FYM + bio-fertilizers increased the growth parameters of Eureka lemon trees. The variation in concentration might have happened because of variations in different fruit crops, as Eureka lemon required more nutrients compared to papaya.

Days taken to initiation of flowering and from flowering to fruit maturation: During the investigation, the use of Integrated Nutrient Management had a significant impact on the flowering parameters of papaya. The minimum days (135.83) taken for first flowering and for fruit maturation (184.50) were obtained with the combined application of organic manures, inorganic and bio-fertilizers (Table 2). Among all the treatments, the application of 50% NPK + 20 kg FYM + 100 g *Azospirillum* + 100 g PSB was better in terms of enhancement of flowering parameters as compared to control. The earliness in flowering might be due to the higher net assimilation rate on account of better growth, leading to

Table 1. Effect of integrated nutrient management on growth parameters at 210 days after transplanting

Treatment	Plant height (cm)	Stem girth (cm)	Number of leaves per plant	Leaf length (cm)	Petiole length (cm)	Plant spread (N-S)	Plant spread (E-W)
T_0	138.67	20.58	24.00	50.42	56.17	132.50	125.17
T_1	144.17	22.50	26.33	53.33	59.83	143.50	136.17
T_2	156.17	26.67	28.67	58.83	65.33	153.83	146.17
T_3	150.75	27.33	27.50	58.42	63.93	151.67	144.17
T_4	179.17	30.83	32.50	66.83	73.83	172.00	180.83
T_5	141.17	25.58	24.17	58.17	64.58	147.50	144.83
T_6	152.50	26.67	26.00	57.25	63.33	149.50	150.50
T_7	158.67	26.67	26.00	56.67	63.17	148.83	151.50
T_8	170.83	29.17	29.50	64.08	70.75	167.00	172.83
T_9	143.75	24.08	25.67	55.17	61.42	139.67	135.83
T_{10}	149.33	25.17	28.83	58.92	65.00	154.50	154.50
T_{11}	148.83	25.42	26.50	57.42	63.42	148.67	147.50
T_{12}	161.92	27.83	29.17	60.42	66.83	160.83	166.50
Mean	153.53	26.04	27.29	58.15	64.43	151.54	150.50
CD (p=0.05)	5.52	1.86	2.58	3.33	3.23	5.62	6.21

T_0(100% RDF + Control), **T_1**(50% RDF + 20 kg FYM/plant), **T_2**(50% RDF + 20 kg FYM + 100g *Azospirillum*/plant), **T_3** (50% RDF + 20 kg FYM + 100 g PSB/plant), **T_4** (50% RDF + 20 kg FYM + 100 g *Azospirillum* + 100 g PSB/plant), **T_5** (50% RDF + 10 kg Vermicompost/plant), **T_6** (50% RDF + 10 kg Vermicompost + 100 g *Azospirillum*/plant), **T_7** (50% RDF + 10 kg Vermicompost + 100 g PSB/plant), **T_8** (50% RDF + 10 kg Vermicompost + 100 g *Azospirillum* + 100 g PSB/plant), **T_9** (50% RDF + 2 kg Neem cake/plant), **T_{10}** (50% RDF + 2 kg Neem cake + 100 g *Azospirillum*/plant), **T_{11}** (50% RDF + 2 kg Neem cake + 100 g PSB/plant), **T_{12}** (50% RDF + Neem cake + 100 g *Azospirillum* + 100 g PSB/plant)

Table 2. Effect of integrated nutrient management on flowering and yield parameters

Treatment	Initiation of flowering (days)	From flowering-maturity (days)	Number of fruits per plant	Fruit length (cm)	Fruit width (cm)	Fruit weight (kg)	Fruit yield (kg)
T_0	159.33	213.17	19.50	13.42	8.86	0.64	20.84
T_1	150.33	204.83	21.33	15.07	11.38	0.72	22.36
T_2	145.50	198.17	22.17	19.02	14.43	0.97	24.24
T_3	144.33	200.33	22.00	18.43	15.01	0.94	25.74
T_4	135.83	184.50	28.17	24.23	22.11	1.69	37.26
T_5	151.67	207.00	20.67	14.92	11.67	0.72	22.85
T_6	147.17	198.67	22.50	18.21	16.19	0.96	25.48
T_7	145.83	200.83	23.17	17.54	15.57	0.93	24.18
T_8	140.33	188.67	26.33	22.64	20.46	1.40	33.93
T_9	155.00	209.83	20.33	14.92	11.30	0.67	21.58
T_{10}	146.00	203.67	22.33	18.14	15.68	0.95	23.64
T_{11}	149.17	206.50	22.00	16.81	14.58	0.89	24.48
T_{12}	142.83	192.17	24.33	21.17	19.36	1.00	29.32
Mean	147.18	200.64	22.68	18.04	15.12	0.96	25.84
CD (p=0.05)	3.17	2.77	1.99	1.28	1.53	0.10	2.16

See Table 1 for details

the production of endogenous metabolites earlier than optimum level, enabling an early flower (Yadav et al 2011). Similarly, Khalid et al (2013) reported that in strawberry cv. Chandler the combination of Soil + Silt + Vermicompost 200g/kg was beneficial in inducing earliness in flowering. However, in contrast to the present results, Kanwar et al (2020) observed that in papaya cv. Red Lady, the minimum days taken for first flowering was 70.41, which was very early compared to the results obtained under the treatment containing 75% RDF + 10 kg Vermicompost + 100g *Azotobacter* + 100g PSB/plant. As temperature fluctuations under Punjab conditions is very common, variation in flowering might be possible due to the variation in environmental conditions or because of the increased application of inorganic fertilizers and organic manures.

Number of fruits per plant, fruit length, fruit width, fruit weight and fruit yield: The use of integrated nutrient management had a significant impact on the number of fruits produced per plant, fruit length, fruit width, fruit weight and fruit yield (Table 2). Among all the treatments, the application of 50% NPK + 20 kg FYM + 100 g *Azospirillum* + 100 g PSB was better in increasing the number of fruits (28.17), fruit length (24.23 cm), fruit width (22.11 cm), fruit weight (1.69 kg) and fruit yield (37.26 kg/plant). Yield characteristics were enhanced when organic manures were used along with chemical fertilizers, as opposed to when these fertilizers were applied alone. Enhancement in the quality content of fruit might be associated with an increase in phenotypic characters like stem girth, plant height and leaf length also because of better consumption and utilization of major nutrients. This might also be possible due to a rise in the number of leaves, which ultimately enhanced photosynthetic activity, resulting in a greater buildup of carbohydrates and higher carbohydrate levels, which aided in the acceleration of growth and thus increased the yield. The result of the present investigation is in agreement with Singh (2009) on papaya cv. Ranchi dwarf, where the highest yield was achieved with the of 50% of NPK + *Azotobacter* + PSB + FYM was better.

Fruit firmness, total sugars, TSS, ascorbic acid and titrable acidity: Maximum fruit firmness (9.50kg/cm^2) and TSS (10.43%) were obtained with the application of 50% RDF + 20 kg FYM + 100 g *Azospiriilum* + 100 g PSB/plant (Table 3). The higher firmness may be due to the higher microbial population and better uptake of nutrients as organic manures make the nutrients mobile for the plants. Ravishankar and Karunakaran (2008) also observed that in papaya cv. Coorg Honey Dew, the application of 20 kg FYM increased the total soluble solids under organic farming, whereas Ghosh et al (2012) reported that the total soluble solids increased with the application of 20 kg FYM + 400:100:300g NPK in pomegranate.

The total sugars (10.90%), reducing sugars (9.54%), non-reducing sugars (1.26%) and ascorbic acid (44.58mg) were maximum with minimum acidity (0.01%) through the application of 50% RDF + 20 kg FYM + 100 g *Azospiriilum* + 100 g PSB/plant (Table 3). This might be due to the addition of organic manure supplements that are high in moisture content, nutrients and growth-promoting substances, which

Table 3. Effect of integrated nutrient management on quality parameters

Treatment	Fruit firmness (kg/cm^2)	Total soluble solids (^{0}Brix)	Titrable acidity (%)	Total sugars (%)	Reducing sugars (%)	Non-reducing sugars (%)	Ascorbic acid (mg/100g of pulp)
T_0	5.57	6.1	0.13	6.55	5.8	0.71	35.75
T_1	6.52	6.83	0.03	7.36	6.4	0.92	37.83
T_2	7.45	8.47	0.03	9.2	8.1	1.07	40.33
T_3	7.63	8.07	0.03	9.334	8.18	1.1	41.25
T_4	9.5	10.43	0.01	10.9	9.54	1.26	44.58
T_5	6.15	6.7	0.08	7.09	6.32	0.92	37.5
T_6	7.42	8.2	0.03	9.12	7.98	1.05	39.5
T_7	7.32	7.77	0.03	9.01	8.02	1.06	39.5
T_8	8.73	9.47	0.02	10.26	8.98	1.22	43.17
T_9	6.08	7.73	0.1	6.91	6.04	0.82	36.83
T_{10}	7.25	8.33	0.04	8.06	6.95	1.04	38.17
T_{11}	7.28	8.1	0.04	8.46	7.35	1.05	38.5
T_{12}	8.28	9.03	0.03	9.59	8.43	1.18	42.58
Mean	7.32	8.09	0.05	8.6	7.54	1.03	29.4
CD (p=0.05)	0.37	0.36	0.04	0.42	0.46	0.28	2.76

See Table 1 for details

may help to increase the hormonal and metabolic activity of the plants, allowing them to produce more photosynthates, which are then stored in the fruits as starch and carbohydrates form. Secondly, this could also be possible due to the insoluble carbohydrates, such as reserved starch and other insoluble carbohydrates in papaya fruits, being converted into soluble sugars, which results in an increase in total sugars and ascorbic acid in papaya fruits. Similar results were obtained by Shukla *et al* (2009) with the application of 50% NPK + FYM + bio-fertilizers in order to improve the fruit quality characteristics in guava.

CONCLUSION

Chemical fertilizers can be used in combination with economic and eco-friendly organic manures to achieve substantial productivity. The integrated nutrient management of papaya is one of the important factors in boosting the yield and improving the quality of fruits. In the present study, increase in crop performance among different treatments, the application of 50% NPK + 20 kg FYM + 100 g *Azospirillum* + 100 g PSB was better in terms of increasing growth, flowering, yield and fruit quality parameters in papaya. Therefore, it is recommended to supply 50% of the nutrients through inorganic fertilizers and the remaining 50% from organic sources.

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Received 22 March, 2022; Accepted 12 July, 2022