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Research Article

Effect of Integrated Nutrient Management and Plant Growth Regulators on Growth Attributes of Fig (*Ficus carica* L.) under Semi-Arid Conditions in Rajasthan

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ABSTRACT

The present investigation entitled "Effect of integrated nutrient management and plant growth regulators on growth attributes of fig (Ficus carica L.) under semi-arid conditions in Rajasthan was conducted on five-year old fig plants grown in sandy loam soils. While studies on fig are limited, this experiment was conducted to assess the response of the fig cultivar 'Black Ischia' to various organic and inorganic nutrient sources, as well as plant growth regulators, through thirty-two treatments replicated three times. During the investigation, the result revealed that the fig plant was studied for the growth parameters viz., shoot length, shoot girth, number of fruiting branches, spread of plant, leaf area and total chlorophyll content was recorded significantly maximum under treatment 50 % RDF + 50 % VC which was over rest of the treatments. However, the treatment 50 % RDF + 50 % PM and 50 % RDF + 50 % FYM was found statistically at par with it. Similarly, the shoot length, shoot girth, number of fruiting branches per plant, the spread of the plant, leaf area and total chlorophyll content were recorded significantly maximum under treatment 50 % GA_3 + 50 % NAA over the rest of the treatments, including control.

INTRODUCTION

Fig (*Ficus carica* L.) is an important sub-tropical fruit crop of the world. It is a deciduous tree that belongs to the Moraceae family and is one of the earliest cultivated fruit trees (Stover et al., 2007). This fruit originated in the Middle East and has since spread around the world, particularly in the Mediterranean region (Kehal et al., 2021). The main growing countries are Turkey, Spain, Italy, Greece, Portugal and Algeria. It is also extensively grown in the state of California (USA) and Afghanistan (Gawade & Waskar, 2005).

India ranks 12^{th} in the world in terms of fig production. Figs are produced in the country in parts of Maharashtra, Gujarat, Uttar Pradesh, Karnataka and Tamil Nadu (Anonymous, 2023a).

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There is a wide scope for expanding the area under this crop. In India, fig cultivation is carried out in an area of 5904 hectares, producing 25,303 thousand tonnes with a productivity of 14,940 tonnes per hectare (Anonymous, 2023b). In Rajasthan, fig cultivation is also being done in Barmer, Dungarpur, and Banswara.

The existing strategy of integrated nutrient management concentrates on imparting technical expertise to key stakeholders with the aim of optimizing the utilization of organic and inorganic fertilizers in agriculture. Integrated nutrient management stands out as a crucial approach for minimizing the reliance on chemical fertilizers, incorporating organic materials like FYM, vermicompost and poultry manure to rectify soil acidity and furnish essential micronutrients. The utilization of FYM, vermicompost, and poultry manure, in conjunction with chemical fertilizers, enhances soil organic carbon and the overall status of nitrogen, phosphorus, and potassium (NPK). Nevertheless, the augmentation of soil microbial growth is observed exclusively when employing organic manure alone or in tandem with inorganic fertilizers. Achieving a high crop yield is feasible through the judicious combination of balanced NPK fertilizers and organic matter amendment (Kumari et al., 2024). Integrated nutrient management involves the judicious use of organic and inorganic fertilizers to enhance soil fertility and improve plant nutrient uptake. Studies have shown that balanced nutrient application positively influences growth characteristics. Moreover, integrated nutrient management practices contribute to sustainable agriculture by reducing environmental pollution and improving soil health.

Promising chemicals that are widely used to improve plant growth attributes, fruit set, yield and fruit quality include micronutrients, plant growth regulators such as gibberellic acid (GA_3) and auxins, and carbohydrates such as sucrose (Lovatt, 2013). Among various PGRs, gibberellic acid (GA_3) promotes plant cell growth, elongation and enlargement (Muniandi et al., 2018 and Castro-Camba et al., 2022). Application of plant growth regulators at specific growth stages can promote parthenocarpic fruit development, increase fruit size, and improve fruit shelf life. Additionally, plant growth regulators aid in mitigating abiotic stressors such as drought and salinity, thereby enhancing plant resilience and productivity.

MATERIAL AND METHODS

This trial was carried out on five years old fig ‘Black Ischia’ cultivar at Horticulture farm, S. K. N. College of Agriculture, S. K. N. Agriculture University, Jobner, Jaipur (Raj.) during 2022 and 2023. The experiment was laid out in two factors of split plot design with three replications of 32 treatments, are as follows:

1. **Integrated nutrient management (Main plot)**

N_0- RDF- 250:300:300 NPK gram per tree
N_1- FYM @ 25 kg per plant
N_2- Vermicompost @ 10 kg per plant
N_3- Poultry manure @ 5 kg per plant
N_4- 50 % RDF + 50 % FYM
N_5- 50 % RDF + 50 % VC
N_6- 50 % RDF + 50 % PM
N_7- 50 % VC + 50 % FYM

2. **Plant growth regulators (Sub plot)**

P0- Control (Water spray)
P1- GA3 @ 25 ppm
P2- NAA @ 50 ppm
P3- 50 % GA3 + 50 % NAA

The nutrient application took place from February to March, with the foliar spray occurring at the time of bud initiation and again 30 days after bud initiation. The observations were recorded for shoot length (m), shoot girth (cm), number of fruiting branch, spread of plant (m), leaf area (cm^2), total chlorophyll content (mg/g) and relative leaf water content (%).

Chlorophyll content (mg/g)

Total chlorophyll, chlorophyll ‘a’ and chlorophyll ‘b’ contents were estimated at harvest by following the procedure of Arnon (1949). Fresh leaf sample (sixth) from the top of the canopy in each of the treatment was brought to laboratory in an ice box from the field. About 0.25 g of leaf was weighed from each sample and was cut into small pieces. Weighed sample was homogenized with pure acetone and extract was filtered through Whatman No. 1 filter fiber and washed twice with 80 per cent acetone. The final volume of the extract was made up to 25 ml and the absorbance of the extract was measured at 645 and 663 nm in spectrophotometer for chlorophyll 'a' and 'b' respectively, (Elico SL-159). Total chlorophyll, chlorophyll 'a' and chlorophyll 'b' contents were calculated using the following formulae and expressed as mg per g fresh weight of leaf.

$$\text{Chlorophyll 'a'} = (12.7 \times A_{663}) + (2.69 \times A_{645}) \times \frac{V}{\alpha \times W \times 1000}$$

$$\text{Chlorophyll 'b'} = (22.9 \times A_{645}) + (4.68 \times A_{666}) \times \frac{V}{\alpha \times W \times 1000}$$

$$\text{Total chlorophyll} = (20.2 \times A_{645}) + (8.02 \times A_{666}) \times \frac{V}{\alpha \times W \times 1000}$$

Where,

A663 = Absorbance of the extract at 663 nm

A645 = Absorbance of the extract at 645 nm

α = Path length of the light in the cuvette (1cm)

V = Volume of the extract (ml)

W = Fresh weight of sample (g)

Relative leaf water content (%)

The leaf relative water content (RWC) was determined according to Barrs and Weatherly (1962) one week after applying water stress. Five leaves from each treatment were weighed (FW). After that, the sample was immediately immersed in distilled water until saturation for 24 hours at 5 °C in darkness (TW). The dry weight (DW) was then measured after oven drying at 80 °C for 48 h, and RWC (%) was calculated as following:

$$\text{RLWC (\%)} = \frac{\text{Fresh weight-Dry weight}}{\text{Turgid weight-Dry weight}} \times 100$$

RESULT AND DISCUSSION

Effect of integrated nutrient management on growth characters

Treatment 50 % RDF + 50 % VC (N_5) recorded maximum shoot length (2.75 m), shoot girth (4.83 cm), number of fruiting branches per plant (18.36), spread of plant (E-W- 2.79 & N-S- 2.93 m), leaf area (183.28 cm^2) and total chlorophyll content (3.96 mg/g) of fig leaves was significant over rest of the treatment and followed by N_6 (50 % RDF + 50 % PM) and N_4 (50 % RDF + 50 % FYM). However, the application of different integrated nutrients had a non-significant effect on the relative leaf water content of leaves pooled mean analysis (Table 1, 2 & 3).

Enhanced growth can be attributed to the application of organic and chemical fertilizers, which provide a balanced supply of essential nutrients. This nutrient availability promotes increased shoot length, girth, and overall plant spread, ultimately leading to robust vegetative growth. Organic fertilizers improve soil structure and microbial activity, while chemical fertilizers deliver nutrients more rapidly, ensuring that plants receive the elements they need for optimal growth. Together, these factors create an ideal environment for healthy plant development.

The maximum leaf area might be due to supply of optimum levels of nitrogen, phosphorus and potassium. The addition of vermicompost resulted in higher uptake and accumulation of nutrients in leaf tissues, which in turn ensure photosynthetic efficiency, causing greater synthesis, translocation and accumulation of carbohydrates. These results agree with those of Dahiya et al. (2013) who revealed that sweet orange trees fertilized with 70 kg farmyard manure + 850 g urea/tree produce more leaves, shoot length and tree spread. Also, Khehra and Bal (2014) stated that the combination among farmyard manure, inorganic fertilizer and biofertilizer led to improving vegetative growth parameters of lemon tree in terms of plant height, trunk diameter and tree spread.

The fig plants supplemented with manure combination resulted in vigorous growth and development as reflected in higher chlorophyll content (Table. 3). Higher chlorophyll content might have helped to improve photosynthetic efficiency so as to enable fig crop to trap and utilize higher quantity of solar energy to convert it into chemical energy. Bohane and Tiwari (2014) conformity with the application of 50 % RDF through Vermicompost + 50 % RD through fertilizer NPK + PSB + Azotobacter registered significantly higher physico-chemical attributes in ber.

Effect of plant growth regulators on growth characters

The maximum shoot length (2.65 m), shoot girth (4.77 cm), number of fruiting branches per plant (17.89), spread of plant (E-W- 2.71 & N-S- 2.93 m), leaf area (181.36 cm^2) and total chlorophyll content (3.96 mg/g) of fig leaves under treatment P_3 (50 % GA_3 + 50 % NAA) superior over rest of the treatment including control. Whereas, the minimum growth characters were recorded under control. However, the foliar spray of various plant growth regulators treatments had a non-significant effect on the relative leaf water content of leaves in pooled mean analysis (Table 1, 2 & 3).

The improving effects of foliar application of GA_3 and NAA at the time of bud initiation on vegetative growth might be attributed to the stimulation of growth, which leads to an increase in shoot length and shoot girth. GA_3 and NAA are important growth regulators for the plant since they play an important role in cell division and cell wall elongation and lead to an increase in shoot length. Wang et al. (2013) found that foliar spraying of 'Cara cara' navel orange with GA_3 at concentrations of 10, 20 and 30 ppm during the early period of fruit growth increased significantly shoot length and leaf area in comparison to that of control.

Maleknezhad et al. (2012) found that foliar spray of 'Satsuma' mandarin with GA_3 at 15 and 30 ppm at pre-harvest increased the number of leaves compared with the control. This might be owing to the increase of photosynthetic rates or due to more effective use of photosynthetic yields. Davies (1987) stated that NAA belongs to artificial forms of Auxins. Auxins show main role in cell elongation, cell division, vascular tissue, differentiation, apical dominance, leaf senescence and fruit abscission

The increase in a number of fruiting branches per plant at different vegetative growth cycles of fig might be due to the elongation that happened in shoot length as a result of foliar application with those of GA_3 and NAA. The auxin is also required for cell elongation and has different effects depending on the organ in which it is present; it encourages growth in the shoot and the number of fruiting branches per plant in comparison with that of control. It could be concluded that all growth cycles of fig responded positively to the foliar spraying of combinations between GA_3 and NAA since it stimulated the shoot length, number of fruiting branch per plant as well as leaf area and plant spread in comparison with those of other foliar treatments.

The increase in number of fruits through the application of GA_3 and NAA could be attributed due to less dropping of flower and fruit shedding. This reduction in shedding may result from the use of growth regulators compensating for the deficiency of natural auxin, thereby preventing the formation of an abscission layer, possibly by inhibiting the enzymatic activity at higher temperatures (Kaur et al., 2024).

The increase in chlorophyll content with NAA treatment was supported by Gutam et al. (2009) and Moneruzzaman et al. (2015), who reported similar positive effects of NAA on the chlorophyll content of bell pepper and wax apple, respectively. According to Czerpak et al. (2002), synthetic auxin stimulated chlorophyll synthesis as well as increased chlorophyll fluorescence by inhibiting the action of the chlorophyllase enzyme, which is responsible for chlorophyll depletion.

Table 1 Effect of integrated nutrient management and plant growth regulators on shoot length, shoot girth and number of fruiting branch per plant of fig plant

Treatments	Shoot length (m)			Shoot girth (cm)			Number of fruiting branch		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
Integrated nutrient management									
N_0-RDF (N:P:K- 250:300:300 g/plant)	2.45	2.54	2.49	4.47	4.55	4.51	16.30	16.50	16.40
N_1- FYM (25 kg per plant)	2.21	2.33	2.27	3.95	4.02	3.98	13.83	14.00	13.91
N_2-Vermicompost (10 kg per plant)	2.28	2.34	2.31	4.29	4.35	4.32	15.43	15.54	15.48
N_{3-}Poultry manure (5 kg per plant)	2.16	2.21	2.18	4.11	4.19	4.15	14.80	14.92	14.86
N_4-50 % RDF + 50 % FYM	2.60	2.68	2.64	4.59	4.66	4.62	17.75	17.87	17.81
N_5-50 % RDF + 50 % VC	2.69	2.80	2.75	4.78	4.89	4.83	18.29	18.43	18.36
N_{6-}50 % RDF + 50 % PM	2.61	2.72	2.67	4.68	4.78	4.73	17.95	18.03	17.99
N_7-50 % VC + 50 % FYM	2.44	2.52	2.48	4.37	4.44	4.41	15.85	16.00	15.93
S.Em±	**0.05**	**0.05**	**0.03**	**0.08**	**0.08**	**0.06**	**0.27**	**0.27**	**0.19**
CD (P=0.05)	**0.14**	**0.15**	**0.10**	**0.24**	**0.26**	**0.17**	**0.81**	**0.83**	**0.55**
Plant growth regulators									
P_0-Control (Water spray)	2.17	2.26	2.22	3.94	4.02	3.98	13.75	13.93	13.84
P_1-GA_3 @25 ppm	2.45	2.52	2.48	4.39	4.48	4.43	17.25	17.37	17.31
P_{2-} NAA @50 ppm	2.50	2.59	2.55	4.56	4.63	4.60	16.28	16.39	16.33
P_3-50 % GA_3 + 50 % NAA	2.61	2.70	2.65	4.73	4.81	4.77	17.82	17.96	17.89
S.Em±	**0.03**	**0.03**	**0.02**	**0.06**	**0.06**	**0.04**	**0.18**	**0.18**	**0.13**
CD5 (P=0.05)	**0.09**	**0.10**	**0.07**	**0.16**	**0.17**	**0.11**	**0.51**	**0.52**	**0.36**

Table 2 Effect of integrated nutrient management and plant growth regulators on spread of plant of fig plant

Treatments	Spread of plant (m)					
	(E-W)			(N-S)		
	2022	2023	Pooled	2022	2023	Pooled
Integrated nutrient management						
N_0-RDF (N:P:K- 250:300:300 g/plant)	2.48	2.61	2.54	2.67	2.76	2.72
N_1- FYM (25 kg per plant)	2.18	2.31	2.24	2.39	2.47	2.43
N_2-Vermicompost (10 kg per plant)	2.21	2.35	2.28	2.56	2.63	2.59
N_{3-}Poultry manure (5 kg per plant)	2.07	2.16	2.12	2.48	2.54	2.51
N_4-50 % RDF + 50 % FYM	2.62	2.78	2.70	2.76	2.85	2.81
N_5-50 % RDF + 50 % VC	2.72	2.86	2.79	2.89	2.98	2.93
N_{6-}50 % RDF + 50 % PM	2.66	2.84	2.75	2.79	2.89	2.84
N_7-50 % VC + 50 % FYM	2.30	2.41	2.36	2.59	2.67	2.63
S.Em±	**0.05**	**0.06**	**0.04**	**0.05**	**0.06**	**0.04**
CD (P=0.05)	**0.16**	**0.18**	**0.11**	**0.16**	**0.19**	**0.12**
Plant growth regulators						
P_0-Control (Water spray)	2.16	2.28	2.22	2.39	2.48	2.43
P_1-GA_3 @25 ppm	2.36	2.48	2.42	2.58	2.65	2.62
P_{2-} NAA @50 ppm	2.47	2.61	2.54	2.72	2.79	2.75
P_3-50 % GA_3 + 50 % NAA	2.63	2.78	2.71	2.88	2.98	2.93
S.Em±	**0.04**	**0.04**	**0.03**	**0.04**	**0.04**	**0.03**
CD (P=0.05)	**0.10**	**0.11**	**0.08**	**0.10**	**0.12**	**0.08**

Table 3 Effect of integrated nutrient management and plant growth regulators on leaf area, chlorophyll content and Relative leaf water content of fig plant leaves

Treatments	Leaf area (cm^2)			Chlorophyll content (mg/g FW)			Relative leaf water content (%)		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
Integrated nutrient management									
N_0-RDF (N:P:K- 250:300:300 g/plant)	169.78	171.42	170.60	3.78	3.87	3.83	39.62	40.55	40.08
N_1- FYM (25 kg per plant)	148.49	150.98	149.74	3.34	3.45	3.40	37.67	38.44	38.06
N_2-Vermicompost (10 kg per plant)	160.50	162.11	161.31	3.67	3.74	3.70	38.92	39.60	39.26
N_3-Poultry manure (5 kg per plant)	153.06	154.86	153.96	3.59	3.64	3.62	38.43	38.89	38.66
N_4-50 % RDF + 50 % FYM	175.68	177.50	176.59	3.84	3.94	3.89	39.64	40.69	40.17
N_5-50 % RDF + 50 % VC	182.43	184.13	183.28	3.91	4.02	3.96	40.04	41.20	40.62
N_6-50 % RDF + 50 % PM	178.45	180.33	179.39	3.87	3.97	3.92	39.75	40.90	40.33
N_7-50 % VC + 50 % FYM	165.07	166.60	165.84	3.72	3.79	3.75	39.53	40.38	39.96
S.Em±	**3.16**	**3.46**	**2.34**	**0.05**	**0.06**	**0.04**	**0.77**	**0.93**	**0.60**
CD (P=0.05)	**9.58**	**10.50**	**6.79**	**0.16**	**0.18**	**0.11**	**NS**	**NS**	**NS**
Plant growth regulators									
P_0-Control (Water spray)	150.02	151.57	150.80	3.38	3.46	3.42	38.02	38.80	38.41
P_1-GA_3 @25 ppm	163.68	166.22	164.95	3.72	3.83	3.78	39.28	39.96	39.62
P_2- NAA @50 ppm	172.18	174.30	173.24	3.84	3.93	3.89	39.71	40.28	40.00
P_3-50 % GA_3 + 50 % NAA	180.85	181.88	181.36	3.92	3.99	3.96	39.79	41.28	40.54
S.Em±	**2.17**	**2.39**	**1.62**	**0.04**	**0.04**	**0.03**	**0.54**	**0.65**	**0.42**
CD (P=0.05)	**6.18**	**6.80**	**4.53**	**0.10**	**0.12**	**0.08**	**NS**	**NS**	**NS**

CONCLUSION

The present study concluded that organic and inorganic nutrient along with plant growth regulators having a positive and significant effect on growth attributes. The organic and inorganic treatment 50 per cent RDF + 50 per cent VC as well as foliar application of 50 per cent GA_3 + 50 per cent NAA was found to be best to increases the shoot length, shoot girth, number of fruiting branches per plant, plant spread (E-W & N-S), leaf area and chlorophyll content of fig leaves.

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Author Contribution
All authors have participated in critically revising of the entire manuscript and approval of the final manuscript.

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