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Effect of organic formulations on growth and yield of Indian noni (*Morinda citrifolia* L.) under southern transitional zones of Karnataka

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Abstract
The experiment was conducted in five years old noni plot in Raminakoppa village, Shivamogga taluk under the Department of Horticulture, College of Agriculture, Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Shivamogga, during 2022-2023 to study the effect of Organic Formulations on Growth and Yield of Indian Noni (*Marinda citrifolia* L.) under Southern Transitional Zone of Karnataka. The experiment was laid out in RCBD with 11 treatment combinations, comprising of organic manures, biofertilizers and organic liquid formulations with 3 replications. The results revealed that the noni plants received 60:30:30 g NPK/plant recorded maximum plant height (3.52 m), plant girth (41.49 cm), canopy spread (4.86 m^2), leaf length (27.70 cm), leaf breadth (12.88 cm), leaf thickness (0.46 mm), leaf area (83873.33 cm^2), leaf area index (0.65) and also registered maximum yield parameters such as highest number of fruits (438.24), maximum fruit weight (165.38 gm), fruit yield (72.55 kg/plant) and (56.04 ton/ha) followed by T_8 (54.68 ton/ha). Maximum gross return (Rs. 13, 65, 500 ha^{-1}), net return (Rs. 11, 13, 747 ha^{-1}) and benefit cost ratio (4.42) were reported in treatment T_8.

Keywords: Noni, Areca husk compost, Neem cake, Panchagavya, Jeevamrutha

1. Introduction
Noni (*Morinda citrifolia* L.) popularly known as Great *Morinda*, 'Indian Mulberry', 'pain killer tree', 'rotten cheese fruit' or 'vomit fruit' due to its unpleasant odour. It is a perennial tree belonging to family Rubiaceae. The crop is native to South-East Asian countries, Australia and Pacific islands. In India, it is grown in Coastal regions of Kerala, Karnataka, Tamil Nadu, Odisha, Andaman and Nicobar Islands. It is a sturdy plant and can tolerate a wide range of agro-climatic conditions and grows well in wet, dry, acidic, alkaline and even saline soil. The crop can tolerate water logging and heavy winds (Singh *et al.* 2009) [12]. Noni was often found growing along with lava flows (Nelson, 2001) [9]. Indian Noni is a medicinal plant due to the presence of Xeronin content, which acts as brain stimulant. It also contains compounds such as scopoletin, octanoic acid and anthraquinone. Noni fruit juice is in high demand in alternative medicine for different kinds of illnesses such as arthritis, diabetes, high blood pressure, menstrual difficulties, headaches, heart disease, AIDS, cancers, mental depression, senility, poor digestion, atherosclerosis, blood vessel problems and drug addiction (Wang *et al*., 2002) [14]. Wholistic studies of organic practice sequences as a package for individual crops are meagre. Hence necessity arises to evaluate different organic inputs for their efficacy in harbouring microbes, beneficial and pathogenic as well; the efficacy of Areca husk compost, Neem cake, Panchagavya, Biodigester liquid, Jeevamrutha and Ghana Jeevamrutha in terms of nutritive support and microbial consortia load were found reported to be different in different soils and cultivation systems (Mohanalakshmi, 2004). Noni being a hardy species can come up well without much care, but it is a proven fact that application of organic manures externally certainly has positive effects on growth and yield crop plants. Hence the present investigation was undertaken to study the influence of external application of nutrients on growth, yield and the cost economics was worked out.

Materials and Methods
An experiment was carried out to study the effect of organic formulations on growth and yield of Indian noni at the Noni plot, Ramenakoppa, Shivamogga during 2022 and 2023. The experiment was laid out in RCBD with 11 treatments replicated thrice. The treatments are, T_1: Control (5 kg FYM/plant) T_2:100% RDF (60:30:30 g NPK/plant), T_3:100%NPK through organic manure (Areca husk compost + Neem Cake), T_4: T_3 +3 sprays of Panchagavya (2.0%) at 30 days interval, T_5:T_3+soil application of Jeevamrutha at (650ml/plant) 30 days interval, T_6:T_3+3 sprays Bio-digester liquid (260 ml/plant) 30 days interval, T_7:T_3 + soil application of Ghana jeevamrutha (1.30 kg/plant) at once, T_8:75% NPK through organic manure +3 sprays of Panchagavya at 30 days intervals, T_9:75% NPK through organic manure + soil application of Jeevamrutha at.(650 ml/plant) 30 days interval, T_{10}:75% NPK through organic manure+3 sprays of Bio-digester liquid (260ml/plant) 30 days interval, T_{11}:75% NPK through organic

manure + soil application of Ghana jeevamrutha(1.30 kg/plant) at once. Application of FYM @ 5kg/plant was common to all treatments. 100g PGPR (N-fixers (*Azotobacter*) + P (*Bacillus megaterium)* and K (*Frateuria aurantia)* solubilizers per plant are common for all treatments except treatment T_1. The plants were about five years old and planted at a spacing of 3.6 m X 3.6 m. As the species flowers and bears fruits throughout the year harvesting were done at monthly interval and yield per plant was recorded. The cost incurred over the year for cultivation was calculated by considering the prevailing rates for the labour and inputs. The data on various biometrical parameters recorded during the study period were subjected to variance as suggested by Sundaraj *et al*., (1972) [13] for randomized complete block design.

Observations Recorded

1. Plant height (m)

Height of the plant was measured using measuring tape, from the ground level to the tip of the longest branch and expressed in meters.

2. Plant girth (cm)

The girth was measured in centimeter at 10 cm above ground level with help of measuring tape.

3. Canopy spread (m^2)

The plant spread in four directions, *i.e*., North-South and East-West directions was measured using a measuring tape and expressed in meters (m). Canopy size was calculated by multiplying the values of N-S and E-W and expressed in square meters.

4. Leaf length (cm)

Five to ten fully matured leaves were plucked randomly during flowering stage from all the directions of the plant. Leaf length was measured using a scale from the base to leaf apex and the values are expressed in centimeters (cm).

5. Leaf breadth (cm)

Five to ten fully matured leaves were plucked randomly from all the directions of the plant during flowering stage. Leaf breadth was measured using a scale and the values are expressed in centimeters (cm).

6. Leaf thickness (mm)

Five to ten fully matured leaves were plucked randomly from all the directions of the plant during flowering stage. Leaf thickness was measured using digital vernier callipers from the middle of the leaf and the values are expressed in millimeters (mm).

7. Leaf area (cm^2)

The leaf area was estimated by using leaf parameters like leaf length and breadth of leaf, number of leaves per plant and the factor 0.75. Leaf area is expressed in cm^2 per plant. *i.e.,* Leaf area per plant = Length of leaves × Breadth of leaves × Factor (K) × Number of leaves

8. Leaf area index (LAI)

The leaf area index was worked out by the method suggested by Williams (1946) [15].

$$LAI = \frac{\text{Total leaf area per plant (cm}^2\text{)}}{\text{Ground area covered by the plant in cm}^2}$$

Yield parameters

1. Number of fruits per tree

The total number of fruits per tree was counted and recorded at the time of harvest.

2. Fruit weight (g)

Five fully matured fruits were randomly picked from plant of each treatment weighed on digital analytical balance and average fruit weight was expressed in grams (g).

3. Fruit Yield per plant (kg/plant)

The mature fruits which have turned from dark green to light yellow or cream color were harvested at regular intervals as bearing is throughout the year and the number of fruits per plant and the weight in terms of kilograms were recorded immediately after the harvest. Cumulative yield per plant was then recorded at the end of the experiment and expressed in terms of kilograms per plant.

4. Total fruit yield (t ha^{-1})

The yield per hectare was computed by multiplying the yield per plant with the number of plants that can be accommodated in one hectare and expressed in tonnes per hectare (t ha^{-1}).

Economics of cultivation

1. Cost of cultivation

The prices of all inputs prevailing at the time of their use and the labor costs were used to work out the cost of cultivation.

2. Benefit: cost ratio

The benefit: cost ratio for the treatments was worked out based on the expenditure and return to study the effects of organic formulations on the economics of noni production.

$$\text{Benefit : Cost ratio} = \frac{\text{Net income (Rs./ha)}}{\text{Cost of cultivation (Rs./ha)}}$$

Results and Discussions

Growth parameters:

It is evident from the table 1 that significantly higher growth parameters *viz.*, plant height (3.52 m), stem girth (41.49 cm), canopy spread (4.86 m^2) were noticed in the treatment T_2 and it was statistically on par with treatment T_8. Enhanced growth may be due to maximum synthesis of diverse metabolites, which accelerated assimilate movement, increased production of carbohydrates and photosynthates, along with their efficient translocation to the stems and developing branches. This outcome is achieved through the proper application of essential nutrients such as N, P and K in appropriate quantities. These findings can be very well supported with the findings of Ram *et al*. (1999) [11] in *Guava* and Kumar *et al.* (2011) [5] in custard apple. The utilization of diverse organic substances such as areca husk compost, neem cake, rock phosphate, panchagavya and biofertilizers is well-documented for its favorable impact on plant growth and overall development. These organic sources of nutrients foster a thriving microbial population, pivotal for instigating growth-promoting processes that subsequently foster vigorous plant growth. Improved plant growth with Panchagavya application may be due to their role in providing macro nutrients, essential micro nutrients, many vitamins, required aminoacids, growth promoting substances and beneficial microorganisms. This increase in girth might be due to the increased cell wall plasticity ascribed to the stimulatory action of the nutrients and amino acids. Similar results of growth promotion with bio fertilizer also reported by Dwivedi *et al*. (2012) [2] in red flehed *Guava*.

The leaf length and leaf breadth parameter were significantly affected by the different organic formulations. The maximum leaf length (27.70 cm) was observed in (T_2) 60:30:30 g NPK/plant, which was found to be on par with (T_8) 75 % NPK through organic manure + Panchagavya (2.0 %) spray (26.14 cm). Whereas, the minimum leaf length (18.56 cm) was recorded in (T_1) control. The leaf breadth was significantly higher (12.88 cm) with the application

of 60:30:30 g NPK/plant (T_2), followed by (T_8) 75% NPK through organic manure + Panchagavya (0.20 %) spray (12.42 cm). The minimum leaf breadth (7.11 cm) was observed in T_1 (Control). Leaf thickness was significantly found maximum (0.46 mm) in (T_2) 60:30:30 g NPK/plant, which was found to be on par with (T_8) 75 % NPK through organic manure + Panchagavya (2.0 %) spray (0.44 mm). The minimum leaf thickness (0.29 mm) was observed in T_1, where plants supplied with only farm yard manure (5.00 kg/plant).

Recommended dose of fertilizers provide essential nutrients, such as nitrogen (N), phosphorus (P) and potassium (K), which are vital for plant growth. Adequate nutrient availability encourages the development of larger and healthier leaves. Nitrogen is a crucial component of chlorophyll, which is essential for photosynthesis. Increased nitrogen availability promotes efficient photosynthesis, leading to larger leaves. Phosphorus plays a key role in energy transfer and cell division. Adequate phosphorus levels can stimulate cell expansion and growth, resulting in larger leaf size. Larger leaves have a greater surface area for photosynthesis, allowing the plant to capture more sunlight and produce more energy for growth. These findings are in similar with Leghari *et al.* (2016) [7] and Waraich *et al*. (2011). Foliar application of Panchagavya provide nutrients continuously as well as growth hormones that increase number of leaf, leaf area and leaf thickness as well as surface area which result in better plant growth and development Lal *et al.* (2002) [6] in onion found that with increased rate of organic manure application resulted in better plant growth as indicated by increase in leaf length and plant height. The maximum leaf area and leaf area index (83873.33 cm^2, 0.65) were observed in plants treated with 60:30:30 g NPK /plant, followed by (78864.90 cm^2, 0.61) was observed in plants treated with 75 % NPK through organic manure + Panchagavya (2.0 %) spray, while minimum leaf area and leaf area index (28190.19 cm^2, 0.21) was observed in control. Leaf area and leaf area index is a positive indication on plant growth with a direct influence. The quantity of photosynthates produced alone need not be an only factor for enhancing the yield. However, its distribution from source to sink *i.e.*, from leaf and shoot to fruit is important. Inorganic fertilizers provide essential nutrients such as nitrogen (N), phosphorus (P), and potassium (K). Adequate nutrient availability encourages the formation of more leaves and a denser canopy, contributing to a higher LAI.

Yield parameters

Significant variations were observed in the number of fruits, fruit weight, fruit yield per plant and total yield per hectare across the 11 different treatment combinations of organic formulations. The data pertaining to yield parameters of noni are illustrated in Table 3. The plants supplied with 60:30:30 g NPK/plant exhibits a maximum number of fruits per plant (438.24), fruit weight (165.38 g), fruit yield (72.55 kg/plant) and (56.04 t/ha) which was on line with (T_8) 75% NPK through organic manure along with Panchagavya (2.0 %) spray number of fruits (428.88), fruit weight (163.94 g), fruit yield (70.18 kg/plant and 54.62 t/ha), while minimum number of fruits per plant (279.72), fruit weight (124.40g), fruit yield (38.17 kg/plant and 30.26 t/ha) was recorded in T_1, where plants supplied with only farm yard manure (5.00 kg/plant).

The observed increase in the number of fruits could be attributed to the active role of nitrogen (N), phosphorus (P), and potassium (K) in facilitating diverse metabolic processes. This includes enhancing fruit bud differentiation, intensifying flower production, and promoting a higher rate of fruit set. These findings align with the conclusions of Kumar *et al*. (2009) [4] in *Guava*. Inorganic fertilizers deliver nutrients quickly to plants in their available form. While organic manures which are slow releasers of nutrients (Batino *et al*., 2004) [1] may provide a continuous supply of nutrients to the perennial plant for a longer period of time, promoting both vegetative and reproductive growth and fruit yield. The application of panchagavya might have reduced the flower shedding with corresponding increase in fruit set as reported by Praba *et al*. (2006) [10]. Increase in fruit weight by spray of liquid organic manure may be due to translocation of more amount of carbohydrates to developing fruits and utilization of nutrients from basal applied farm yard manure, areca husk compost and neem cake. The findings are in conformity with Nelson (2001) [9] in noni and Dwivedi *et al.* (2012) [2] in *Guava*. Foliar spray of panchagavya @ 2.0 % resulted in a significant increase in the yield attributes this may be due to the addition of coconut water in panchagavya, which contains kinetin which increases the biomass and yield. This might be due to the faster absorption of nutrients like nitrogen present in panchagavya through cuticle of leaves.

Economics holds significant importance for farmers when making decisions about adopting new technologies. The distinct treatment combinations had a marked impact on the benefit-cost ratio, as outlined in Table 4. In the present investigation the highest gross return (Rs.13, 65, 500 ha^{-1}), net return (Rs.11, 13, 747 ha^{-1}) and benefit cost ratio (4.42) were reported in treatment where plant supplied with 75% NPK through organic manure + Panchagavya (2.0 %). The lowest gross return (Rs.7, 56, 500 ha^{-1}), net return (Rs. 5, 65, 956 ha^{-1}) and benefit-cost ratio (2.97) are observed in control where plants treated with only farm yard manure (5.00 kg /plant). The variations in net returns and benefit-cost ratios among the different treatments can be attributed to a combination of factors. It may be due to either the achievement of maximum fruit yield or the costs associated with inputs used in each treatment. In the case of Indian noni, the treatment that combined biofertilizers, organic manures and organic liquid formulations yielded the highest net returns and benefit-cost ratio. These results align with the research findings reported by Gaikwad *et al*. (2010) [3].

Table 1: Effect of organic formulations on plant height at different growth stages in Indian Noni

Treatment	Plant height (m)	Plant girth (cm)	Canopy spread (m^2)
T_1	1.82	31.59	3.86
T_2	3.52	41.49	4.86
T_3	2.23	34.04	4.17
T_4	3.23	38.78	4.50
T_5	3.22	37.75	4.37
T_6	2.55	35.55	4.34
T_7	2.38	36.80	4.21
T_8	3.44	40.67	4.74

T_9	2.57	34.33	4.23
T_{10}	2.34	35.53	4.20
T_{11}	2.36	34.77	4.19
S.Em ±	0.10	1.30	0.16
C.D @ 5%	0.31	3.83	0.49

Table 2: Effect of organic formulations on leaf characters during flowering stage in Indian Noni

Treatments	Leaf length (cm)	Leaf breadth (cm)	Leaf thickness (mm)	Leaf Area (cm^2)	Leaf area index
T_1	18.56	7.11	0.29	28190.19	0.21
T_2	27.70	12.88	0.46	83873.33	0.65
T_3	20.32	9.40	0.33	36383.95	0.29
T_4	25.05	11.94	0.41	72915.88	0.56
T_5	24.23	11.61	0.38	58815.87	0.48
T_6	23.58	10.77	0.38	65716.55	0.51
T_7	23.20	10.68	0.36	54488.87	0.42
T_8	26.14	12.42	0.44	78864.90	0.61
T_9	23.24	10.99	0.36	49640.27	0.39
T_{10}	22.06	9.80	0.35	46324.69	0.36
T_{11}	21.34	9.45	0.34	39864.41	0.33
S.Em ±	0.53	0.39	0.02	1717.22	0.10
C.D @ 5%	1.59	1.58	0.05	5065.79	0.36

Table 3: Effect of organic formulations on yield attributes of Indian Noni

Treatment	Number of fruits per plant	Fruit weight (g)	Fruit yield (kg/plant)	Total fruit yield (t/ha)
T_1	309.72	124.40	38.34	30.26
T_2	438.24	165.38	72.55	56.04
T_3	384.41	144.31	55.46	42.47
T_4	427.73	161.05	65.99	50.67
T_5	400.92	155.53	61.44	47.85
T_6	392.21	152.19	59.77	46.05
T_7	387.91	151.97	58.99	45.56
T_8	428.00	163.94	70.18	54.62
T_9	397.11	149.56	59.39	45.28
T_{10}	387.75	148.90	57.23	44.70
T_{11}	386.28	145.97	56.68	43.55
S.Em ±	4.79	3.54	2.22	1.84
C.D @ 5%	14.13	10.45	6.56	5.43

Table 4: Effect of organic formulations on economics of Indian Noni

Treatments	Total cost of cultivation (Rs./ha)	Total fruit yield (t/ha)	Gross return (Rs./ha)	Net return (Rs./ha)	Benefit: Cost ratio
T_1	190544	30.26	756500	565956	2.97
T_2	220924	56.04	1120800	899876	4.07
T_3	258234	42.47	1061750	803516	3.11
T_4	278656	50.67	1266750	988094	3.55
T_5	289013	47.85	1196250	907237	3.14
T_6	286824	46.05	1151250	864426	3.01
T_7	273333	45.56	1139000	865667	3.17
T_8	251753	54.62	1365500	1113747	4.42
T_9	261117	45.28	1132000	870883	3.34
T_{10}	268919	44.7	1117500	848581	3.16
T_{11}	266401	43.55	1088750	822349	3.09

Conclusion

From the results of present investigation, it can be concluded that, the application of 75% NPK through organic manure + Panchagavya (2.0 %) spray T_8 was the most effective approach for improving vegetative and reproductive growth, enhancing fruit yield and quality, optimizing soil and plant nutrient levels, bolstering soil microbial populations and achieving the highest benefit-cost ratio for Indian noni cultivation under the Southern Transitional Zone of Karnataka.

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