Evaluation of a newly formulated organic fertilizer on growth and yield of curry chilli (*Capsicum Frutescens* L.)

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Abstract

*A study was conducted to formulate a low-cost organic fertilizer using different nutrient sources and to assess the potential use of the formulated organic fertilizer (FOF) on the growth and yield of Curry Chilli (*Capsicum frutescens *L.). The organic fertilizer was formulated based on the nutrient content of dry powders of Spirulina (Sp), Azolla (Az) Palmyrah leaf (Pl), Coconut leaf (Cl) and Banana pseudostem (Bp). A pot experiment was conducted to find the response of different fertilizer combinations: 100% inorganic (T2-NPK-0.9,1.01,0.58 g/pot), 50% inorganic (T3), 100% organic (cattle manure-T4-135g/pot), 50% organic (cattle manure - T5), 50% inorganic + 67.5 g FOF (T6) and 50% organic + 67.5 g FOF (T7) and a control (no fertilizer - T1) on growth and yield of Curry Chilli. Plant height, biomass yield, fruit yield at first picking and plant nutrient uptake were recorded. The nutrient contents of organic sources namely, potassium (19.56 ppm), phosphorous (6.17 ppm), nitrogen (115.03 ppm) and carbon (832.50 ppm), were significantly higher in Bp, Bp, Sp and Pl, respectively, than other sources. Treatment T7 (50% organic + FOF) recorded the highest values in height (51.63 cm), nitrogen (2.0 g/plant), phosphorous (1.77 g/plant), and potassium (44.5 g/plant) uptake, dry biomass yield (42.30 g/plant) and fruit yield at first picking (40 g/plant). However, significant differences ($P<0.05$) were observed only in dry biomass yield and NPK uptake between T7 and T2. Considering height, biomass yield, fruit yield and nutrient uptake substituting 50% organic or inorganic fertilizer with FOF, the performance of Curry Chilli was either equal to or higher than 100% organic or inorganic treatments. Results, therefore, indicate that FOF has potential as an organic fertilizer.*

Keywords: Azolla, curry chilli, palmyrah leaf, formulated organic fertilizer, coconut leaf, *Spirulina subsalsa,* banana pseudostem

Introduction

As the global population expands, so does the need for food, making fertilizers a crucial factor in increasing yields and contributing to their substantial market value. Farmers tend to use inorganic fertilizers in excess amounts in the belief of getting high yields and profit. Excess application of inorganic fertilizer causes environmental problems in Sri Lanka and other parts of the world. Available nutrients from inorganic fertilizers, specifically nitrate, easily leach away into groundwater and cause groundwater pollution (Dahan *et al*., 2014). Increasing the rate of inorganic fertilizer application tends to reduce the carbon sequestration level and emit CO_2 into the environment, which leads to the greenhouse gas effect (Abhiram *et al*., 2022).

Sole organic agriculture and integrated plant nutrient systems (IPNS) are the better solutions to overcome the above adverse environmental and health impacts. IPNS reduces the application of inorganic fertilizers and their negative impacts (Islam *et al.*, 2017). Organic fertilizer is a good alternative source for inorganic fertilizer,

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which is environmentally friendly to produce as well as having many positive impacts on soil quality (Li *et al.*, 2017; Liu *et al.*, 2021; Fan *et al.*, 2023). Organic agriculture is proposed as a promising method for achieving sustainable food systems (Muller *et al.,* 2017). Though farmers are willing to use organic fertilizers, the availability of such quality fertilizers in the required amount is a question. If organic fertilizers could be manufactured at low cost using available underutilized materials, it will be a beneficial way to overcome issues related to inorganic fertilizer application. Palmyrah leaf has been used as manure from ancient times by farmers of the Northern Province, which has been reported to have high nutrient content (Sarmini *et al.*, 2017; Sarmini *et al.*, 2018). Coconut fronds had been used for fencing and roofing. However, with the transformation of life towards other forms of fencing and roofing materials such as walls, tin sheets, and asbestos, the disposal of coconut fronds has become a significant issue. As coconut leaf is rich in nutrients (Gopal *et al.*, 2009; Gopal *et al.*, 2010; Thomas *et al.*, 2012), this could be used as a nutrient source for organic fertilizers. Banana pseudostems are a nutrient-rich organic material (Bijoy and Profile, 2020; Pareek, 2016; Rochana *et al.*, 2020) available in bulk in farms and home gardens. While rich in potassium, the pseudo stem is deficient in nitrogen and phosphorus (Mohapatra et al., 2010). A significantly higher uptake of potassium by onion was reported by Salunkhe (2013) when banana psudostem sap was applied as liquid fertilizer. However, nitrogen and phosphorus uptake was not increased. N, P and K content of coconut leaf was reported as 1.74, 0.1 and 1.24 %, respectively, under recommended inorganic fertilizer treatments (Maheswarappa et al., 2014), while the Palmyrah leaf had a moderate level of N (1.62 – 2.3% N) and a moderate level of P (0.2 -0.44%) (Sarmini *et al.*, 2018). Hence these three resources could be used for organic fertilizer manufacture. A major limitation of these materials is their low nitrogen content. Azolla, a nitrogen-fixing aquatic fern and Spirulina, cyanobacteria, has high nitrogen content (Abdel-Raouf *et al.*, 2012) and can be grown within a short period.

Despite their nutrient content, the potential of Palmyra and coconut leaves as organic fertilizer has remained unexplored. Azolla and Spirulina are rich in nitrogen, however, mass scale production and usage of these alone as organic fertilizers to supply N,P,K in sufficient quantities is difficult to achieve. The formulation of organic fertilizers having a combination of organic sources which could provide C, K and P and are available in bulk quantity (Palmyrah leaf, coconut leaf, banana pseudo stem) and those rich in nitrogen and could be cultivated in sufficient quantity (Azolla, Spirulina) has not been studied. However, Such research holds significant promise for advancing sustainable organic fertilizer innovation. Therefore, the present study was conducted at the Department of Agriculture Chemistry, Faculty of Agriculture, University of Jaffna, with the overall objective of formulating a low-cost innovative organic fertilizer using Spirulina, Azolla, Banana Pseudo stem, Coconut leaf, and Palmyrah leaf. Further, this study evaluates the potential of different combinations of organic and inorganic fertilizer application rates on the growth and yield of Curry Chilli **(***Capsicum Frutescens* L.**).**

Materials and Methods

Collection of Raw Materials and Organic Source Powder Preparation

Banana pseudo stems, Palmyrah leaves, and Coconut Leaves were collected from home gardens in Jaffna. Azolla and Spirulina were grown at the Department of Agricultural Chemistry, Faculty of Agriculture, Ariviyalnagar Killinochchi, Sri Lanka. Cattle manure was collected from an animal farm, Faculty of

Agriculture, University of Jaffna. The powder form of organic nutrient sources was prepared using the following method: Samples of organic sources were chopped into small pieces and washed with water to remove unwanted impurities. Then, the samples were sundried for one week and oven-dried for 48 hours at 600 C. After that, the samples were ground and sieved through a 2 mm sieve and stored in an airtight condition for further nutrient analysis.

The nutrient content of organic Sources

Nutrient contents such as N, P, and K were analyzed to ensure enough nutrient availability in organic sources and nutrient uptake by plants. Total nitrogen was estimated by the Kjeldhal method (Horneck and Miller, 1997; Kalra, 1971). Phosphorus content was determined by the Vanadomolybdate method (Burns and Hutsby, 1986; Kalra, 1971). Potassium content was measured by using a flame photometer as described by Kalra (1971) and total organic carbon content was determined by loss on ignition method (Hoogsteen *et al.*, 2015).

Formulation of Organic Fertilizer

Based on the C/N ratio and nutrient content, organic fertilizer was prepared by mixing 25% Banana pseudostem, 25% Palmyrah leaf, 25% Coconut leaf, 1% *Spirulina*, and 24% Azolla powders on a weight basis.

Pot Experiment - Curry Chilli

The pot experiment was carried out at the net house of the Research and Training Farm, Faculty of Agriculture University of Jaffna, located in Ariviyalnagar Killinochchi, from February 7th to May 7th, 2020. The study was laid out in Complete Randomized Design (CRD) with 7 Treatments and 4 replicates. Table 1 shows the treatments scheduled for the Curry Chilli pot experiment. Black polythene bags were used as pots and ten kilograms of air-dried, sieved (< 2mm) soil was added to each pot. For organic treatments, cattle manure and formulated organic fertilizer were applied to the soil at the rate of 30 MTn/ha. Inorganic fertilizers were applied at the Department of Agriculture - DOA recommended rates as urea (200kg/ha), TSP(225kg/ha) and MOP(130kg/ha). Inorganic fertilizers were mixed with soil two days prior to transplanting. Formulated organic fertilizer and cattle manure were applied two weeks before transplanting. Formulated organic fertilizers and cattle manure release nutrients slowly over time as they decompose, which is beneficial for long-term soil fertility and plant health. Applying them two weeks before transplanting allows them to start breaking down and releasing nutrients into the soil, providing a readily available source for young plants as they establish themselves. Inorganic fertilizers are readily soluble and release nutrients quickly. Applying them two days before transplanting ensures that readily available nutrients are present in the soil when the seedlings are transplanted, promoting initial growth and development. Based on DOA fertilizer recommendation and plant spacing, the fertilizer application rate per pot was calculated.

Table 1: Treatment schedule for pot experiment

Treatments	Combination	N/pot	P/pot	K/pot
T1	Control (no fertilizer application)	-	-	-
T2	100% Inorganic	0.41g	0.46g	0.35g
T3	50% Inorganic	0.21g	0.23g	0.18g
T4	100% Cattle manure	1.91g	0.41g	1.63g
T5	50% Cattle manure	0.96g	0.21g	0.82g
T6	50% Inorganic + 50% Formulated organic fertilizer	1.13g	0.42g	1.06g
T7	50% Cattle manure + 50% Formulated organic fertilizer	1.89g	0.39g	1.70g

Data Collection and Statistical Analysis

Data collection was done on growth parameters such as plant height, and leaf number and reproductive parameters such as flower number and dry matter yield. Harvested fruits were measured separately as per treatments. Fresh, dry biomass yield and nutrient uptake of whole plant were also measured. Nutrients such as N, P, and K were analyzed to ensure the nutrient uptake by the whole plant. Total nitrogen was estimated by the Kjeldhal method (Horneck and Miller, 1997; Kalra, 1971) and Phosphorus content was determined by the Vanadomolybdate method (Burns and Hutsby, 1986; Kalra, 1971). Potassium content was measured by using a flame photometer as described by Kalra (1971). Data analysis was done using a SAS statistical analytical system (University version) with Duncan mean separation at P=0.05.

Results and Discussion

Nutrient Analysis of Nutrient Sources and Formulated Organic Fertilizer

Table 2 shows the results of nutrient analysis of nutrient sources. Among all nutrient sources, Spirulina showed significantly higher N (115.03 ppm), whereas Banana pseudo stem had significantly higher K (19.56 ppm) and P (6.17 ppm) and Palmyrah leaf contained significantly higher organic carbon (832.50 ppm). Based on nutrient analysis organic fertilizer was formulated considering the C/N ratio of the product to be around 25. Nitrogen, Phosphorous, Potassium, organic carbon and C/N ratio of formulated organic fertilizer were 1.47 %, 0.34 %, 1.12 %, 36.25 % and 24.66%, respectively.

Table 2: Nutrient content of organic sources

Nutrient source	N (ppm)	P (ppm)	K (ppm)	C (ppm)
Coconut	1.87^{e}	3.56^{c}	7.19^{d}	430^{b}
Spirulina	115.03^{a}	1.26^{e}	4.97^{f}	415^{b}
Azolla	32.43^{b}	1.06^{f}	14.09^{b}	317.5^{c}
Palmyrah	11.43^{c}	4.07^{b}	6.15^{e}	832.50^{a}
Banana	7.00^{d}	6.17^{a}	19.56^{a}	330^{c}
Cattle manure	14.23^{c}	3.10^{d}	12.14^{c}	332.5^{c}

The same letters within columns are not statistically different by the DUNCAN at P=0.05

Pot Experiment - Curry Chilli

Plant Height

The plant height of different treatments at 2-week intervals is illustrated in Figure 1. In 2nd week after transplanting, comparable and higher height was recorded in T2 (100% IN), T4 (100), T6 (50% IN + 50% FOF) and T7 (50% CM + 50% FOF). In 4th week after transplanting, higher and comparable height was recorded in T2 (100% IN) and T6 (50% IN + 50% FOF) and significantly lowest height recorded in T1 (Control). Similar height records were observed during the 6th and 8th week after transplanting. During these two weeks, the highest plant height was observed in T7 (50% CM + 50% FOF); however, there was no significant difference in height among T2 (100% IN), T6 (50% IN + 50% F OF), T7 (50% CM + 50% FOF). Treatment T2 (100% IN), T6 (50% IN + 50% FOF), and T7 (50% CM + 50% FOF) had significantly higher ($P<0.05$) height than T1 (Control), T3 and T5. The significantly higher ($P<0.05$) and comparable height observed in T2, T6 and T7 was possibly due to similar nitrogen availability during this period as well as growth-promoting factors found in organic sources (Rossetto *et al.*, 2003; El-Araby *et al.*, 2010).

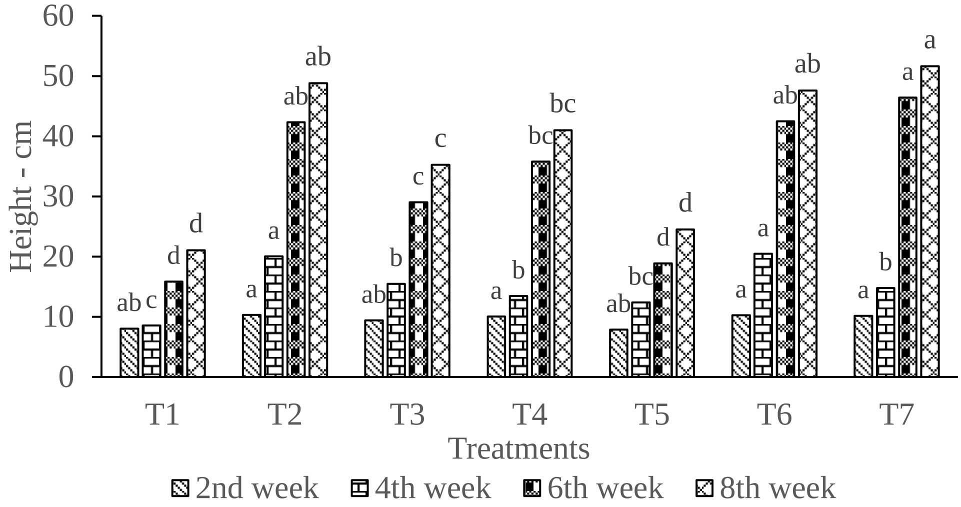

Figure 1: Plant height - Curry Chilli

T1 - Control, T2 - 100% IN, T3 - 50% IN, T4 - 100% CM, T5 - 50% CM, T6 - 50% IN + 50% FOF, T7 - 50% CM + 50% FOF, IN: Inorganic fertilizer based on department recommendation, CM: Cattle manure, OF: Formulated organic fertilizer. Alphabetical letters within the treatment are significantly different.

Leaf Number

The number of leaves per plant at 2-week intervals until 8 weeks after planting is shown in Figure 2. All treatments had significantly higher leaf numbers compared to T1 (control). T6 (50% IN + 50% FOF) recorded a higher or comparable number of leaves per plant as that of T2 (100% IN). In the 8th week, all treatments except T5 and T1 had a similar or higher number of leaves per plant as that of T2 (100% IN). The increased growth of plants in T6 and T7 may be due to the combination of available nitrogen in inorganic fertilizer application and the presence of some growth-promoting substances in the organic sources used to formulate organic fertilizer (Rossetto *et al.*, 2003; El-Araby *et al.*, 2010).

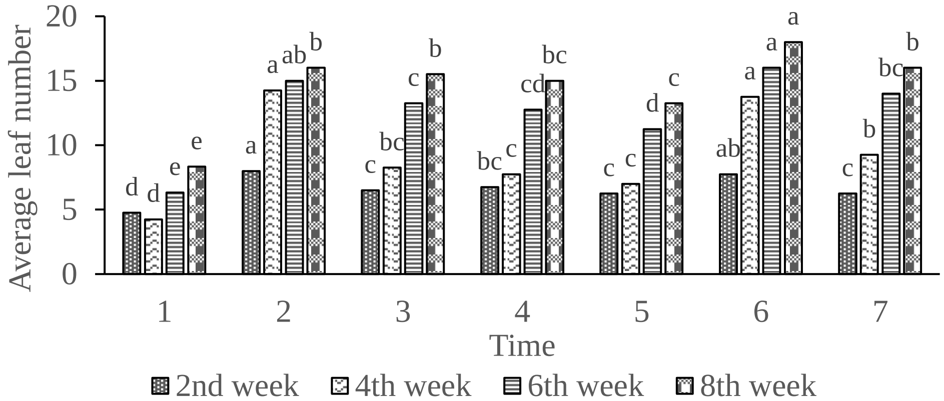

Figure 2: Number of leaves - Curry Chilli

T1 - Control, T2 - 100% IN, T3 - 50% IN, T4 - 100% CM, T5 - 50% CM, T6 - 50% IN + 50% FOF, T7 - 50% CM + 50% FOF, IN: Inorganic fertilizer based on department recommendation, CM: Cattle manure, OF: Formulated organic fertilizer. Alphabetical letters within the treatment are significantly different.

Number of Flowers

The number of flowers per plant at 2-week intervals from the 4th week to the 12th week is shown in Figure 3. Considering all weeks T2 (100% IN), T6 and T7 (50% CM + 50% FOF), recorded a higher number of flowers per plant. The presence of endogenous hormones in components (Banana, Azolla and Spirulina) (Rossetto *et al.,* 2003; El-Araby *et al.*, 2010) which were used to formulate organic fertilizer may have improved flower initiation in T7 (50% CM + 50% FOF) and T6.

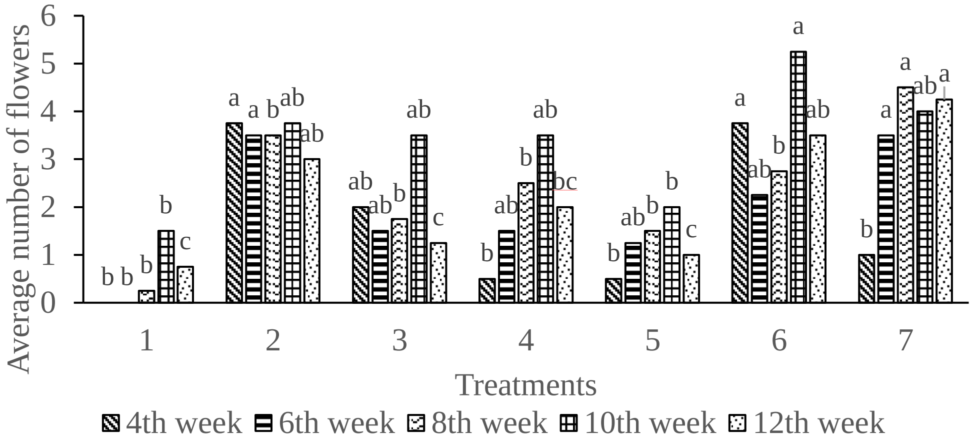

Figure 3: Number of flowers - Curry Chilli

T1 - Control, T2 - 100% IN, T3 - 50% IN, T4 - 100% CM, T5 - 50% CM, T6 - 50% IN + 50% FOF, T7 - 50% CM + 50% FOF, IN: Inorganic fertilizer based on department recommendation, CM: Cattle manure, OF: Formulated organic fertilizer. Alphabetical letters within the treatment are significantly different.

Fresh and Dry Biomass Weight

Figure 4 shows the fresh and dry biomass weight of Curry chilli plants with different treatments. The highest fresh weight per plant was observed in T7 (50% CM + 50% FOF), while the lowest was in T1 (Control). The fresh weight of T2 (100% IN) and T7 (50% CM + 50% FOF) were not statistically significant among each other. The highest dry weight per plant was observed in T7 (50% CM + 50% FOF) while the lowest was in T1 (Control). Treatment T2 and T7 were not significantly different ($P<0.05$) in fresh weight; however, in dry weight, T7 was significantly higher ($P<0.05$) than T2, which means the moisture level of T2 is higher than T7. This is possibly due to higher nutrient uptake in T7 (50% CM + 50% FOF).

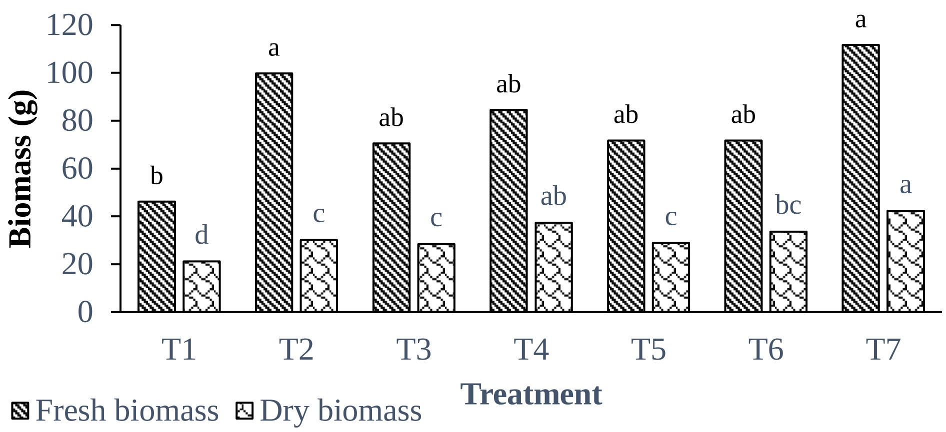

Figure 4: Fresh and Dry biomass weight - Curry Chilli

T1 - Control, T2 - 100% IN, T3 - 50% IN, T4 - 100% CM, T5 - 50% CM, T6 - 50% IN + 50% FOF, T7 - 50% CM + 50% FOF, IN: Inorganic fertilizer based on department recommendation, CM: Cattle manure, OF: Formulated organic fertilizer. Alphabetical letters within the treatment are significantly different.

Capsicum fruit yield

Figure 5 shows the Capsicum fruit yield per plant during first picking. At the end of the 60 days after transplanting, the first harvest was done. The yield of the first harvest ranged between 40 g/pot (T7-50% CM +50% FOF) to 0g/pot (T1-Control and T5-50% CM). The highest yield was obtained from T7 (50% CM +50% FOF). The first picking yield of T2 (100% IN), T6 (50% In+ 50% FOF) and T7 (50%CM+50%FOF) were significantly (P<0.05) higher than T1 (Control), however, there was no significant difference (P<0.05) among T2 (100% IN), T6 (50% In+ 50% FOF) and T7 (50%CM+50%FOF). Yield data for further pickings could not be taken due to the Year of 2020 COVID-19 lockdown situation.

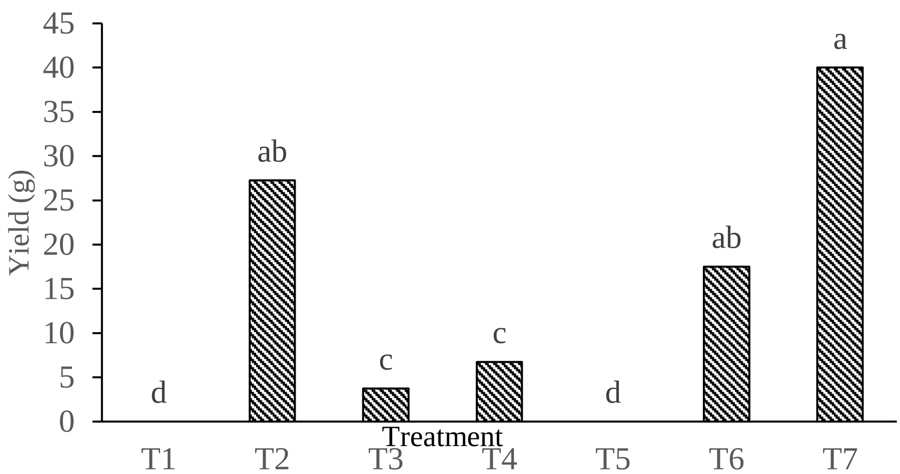

Figure 5: Yield of first picking - Curry Chilli

T1 - Control, T2 - 100% IN, T3 - 50% IN, T4 - 100% CM, T5 - 50% CM, T6 - 50% IN + 50% FOF, T7 - 50% CM + 50% FOF, IN: Inorganic fertilizer based on department recommendation, CM: Cattle manure, OF: Formulated organic fertilizer. Alphabetical letters within the treatment are significantly different.

Nutrient Uptake (N, P, & K) by Curry chilli plants

Figure 6 shows the nutrient uptake (N, P, K) of Curry chilli plants. The highest N uptake was recorded with T7 (50% CM + 50% FOF), and it was significantly higher (P<0.05) than other treatments. The lowest N uptake was noted in T1 (Control). Jin Yuwan *et al.* (2021) reported that a combination of organic and inorganic could effectively reduce nitrate leaching in vegetable soils in China. When the proportion of organic nitrogen increased against inorganic nitrogen, the leaching loss was reduced in maize fields (Zhou *et al.*, 2021). Increased nitrogen uptake of wheat crops through combining organic and inorganic fertilizers was also reported by other workers (Xiao *et al*., 2023; Rehim *et al*., 2020). The highest P uptake was observed in T7 (50% CM + 50% FOF), which was not significantly different from T4 (100% CM). Treatments T3 and T5 showed significantly (P<0.05) lower P uptake than other treatments except T1. The lowest (P<0.05) P uptake was recorded with T1 (Control). The highest (P<0.05) K uptake was observed in T7 (50% CM + 50% FOF), which was not significantly different from that of T4 (100% CM). Significantly higher uptake of potassium by onion was reported by Salunkhe (2013) when banana pseudostem sap was applied as liquid fertilizer; however, nitrogen and phosphorus uptake was not increased. Among other treatments, the descending order of potassium uptake was T6, T2, T5 and T3, though there was a significant difference (P<0.05) among each treatment, except T3 and T5. The results of N, P and K indicate that the sole organic treatments, namely T4 (100% CM) and T7 (50% CM + 50% FOF), had higher nutrient uptake than that of T2 (100% IN), possibly because of high nutrient leaching losses in 100% inorganic system even though it has high nutrient availability (Di and Cameron, 2002).

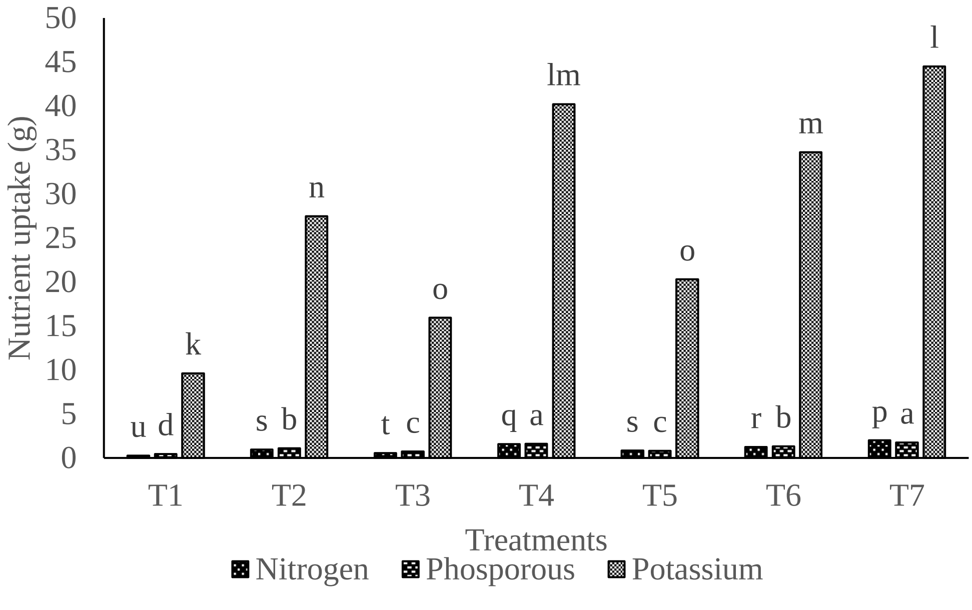

Figure 6: Nutrient uptake by plant - Curry Chilli

T1 - Control, T2 - 100% IN, T3 - 50% IN, T4 - 100% CM, T5 - 50% CM, T6 - 50% IN + 50% FOF, T7 - 50% CM + 50% FOF, IN: Inorganic fertilizer based on department recommendation, CM: Cattle manure, OF: Formulated organic fertilizer. Alphabetical letters within the treatment are significantly different.

Conclusion

In the pot experiment, T2 (100% inorganic), T6 (50% inorganic+50% FOF) and T7 (50% cattle manure+50% FOF) recorded significantly higher ($P<0.05$) figures than other treatments in crop growth parameters, fresh and dry biomass, fruit yield and nutrient uptake of Curry chilli; however, there were no significant differences among them. When we consider environmental and health issues, T6 (50% inorganic+50% FOF) IPNS combination or T7 (50% cattle manure+50% FOF) sole organic combination are better treatments instead of T2 (100% inorganic). The present study concludes that the organic fertilizer produced using Spirulina, Azolla, Coconut leaf, Palmyrah leaf, and Banana pseudo stem positively influenced growth, yield parameters and nutrient availability. This finding indicates that by substituting 50% organic or inorganic fertilizer with FOF, the performance of Curry chilli was either equal to or higher than 100% organic or inorganic treatments.

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