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Effect of Soil Application of Organic Amendments on Flowering and Yield Parameters of Chilli (*Capsicum annuum* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The present investigation was conducted at Department of Plant physiology, College of Agriculture, Vellayani during the period from January 2023 to May 2023 with an objective to evaluate the effect of soil application of organic amendments on flowering and yield parameters of chilli (*Capsicum annuum* L.). Research was conducted to identify the best organic soil amendment suited to the chilli variety, Vellayani Athulya. Work consisted of 8 treatments and 3 replications with the design simple CRD. The treatments were T1-Control 1 [KAU Organic POP (OPOP) (2017) with FYM (25 t ha^{-1})], T2-Control 2 [KAU POP (2016)], T3-FYM substituted with vermicompost (12.5 t ha^{-1}) as per KAU OPOP (2017), T4 -FYM substituted with goat manure (1t ha^{-1}) as per KAU OPOP (2017), T5 -T1+ Rice husk biochar (0.5% w/w), T6- T2+ Rice husk biochar (0.5% w/w), T7- T3+ Rice husk biochar (0.5% w/w) and T8- T4+ Rice husk biochar (0.5% w/w). The results revealed that the treatment T8- FYM substituted with goat manure (1t ha^{-1}) as per KAU Organic POP(OPOP) (2017)+ rice husk biochar (0.5% w/w) resulted in better flowering and yield attributes in chilli. Also the same treatment showed superior performance in terms of number of flowers $plant^{-1}$ (44.67), days to first flowering (22 days), days to first harvest (41 days), percentage of fruit setting (64.18%), number of fruits $plant^{-1}$ (28.67), fruit length (15.30cm), fruit girth (9.30cm), fruit weight (17.70 g $fruit^{-1}$) and yield (507.41 g $plant^{-1}$). Thus, the combined application of goat manure (1t ha^{-1}) as per KAU OPOP + rice husk biochar (0.5% w/w) proved to be a better soil organic amendment for chilli variety Vellayani Athulya.

Keywords: Soil application; organic amendment; flowering; yield; chilli.

ABBREVIATIONS

OPOP : Package of Practices Recommendations (Organic), 2017, Kerala Agriculture University
KAU POP : Package of Practices Recommendations, 20I6, Kerala Agriculture University
FYM : Farm Yard Manure
W/W : Weight by Weight Basis
CRD : Completely Randomized Design

1. INTRODUCTION

Chilli*(Capsicum annuum* L.) is one of the major spice cum vegetable grown extensively in India. It comes under the family Solanaceae. Solanaceae has major role in balanced diet and the family consists of around 3000–4000 perennial and annual species which comes under 90 genera [1]. Across the world, the key solanaceous members mainly consumed are potatoes, tomatoes, eggplants, and chillies. Overuse of chemical fertilizers results in a number of problems such as air, water, and soil contamination, which is harmful to both human and animal health. But organic manures can replace chemical fertilizers without much reduction in crop yields, if applied effectively. By enhancing the microflora and fauna in the soil, organic manures enhance the quality of the soil and hence increase overall production of crops [2]. Also application of organic manures significantly enhance microbial activities in the soil and improve soil enzyme activities, specifically dehydrogenase and phosphatase, which are crucial for soil health and nutrient cycling [3].

Organic manures such as farm yard manure, sheep manure, pressmud and chicken manure are thought to be storehouses of several nutrients that are necessary for plant growth [4]. Biochar, a carbon-rich product obtained through the pyrolysis of organic matter, has gained attention as a soil amendment due to its potential benefits in plant growth and soil health. Applying biochar increases plant nutrient absorption and enhance physical and chemical characteristics of the soil, including pH, adsorption of plant nutrients, cation exchange capacity (CEC) and water holding capacity. Also, it maintains crop production and improves soil fertility [5]. Organic fertilizers contain some of the nutrients required for better development, and they provide quick growth with higher quality in crops. According to reports, using vermicompost and chicken manure increases the yield of okra and its contributing characteristics [6]. Goat manure is a valuable organic amendment that can enhance soil fertility and plant growth. The application of goat manure increase the soil organic matter content, which improves soil structure and water-holding capacity and it provides essential nutrients like nitrogen, phosphorus and potassium, supporting

plant growth and development. It also enhances soil microbial activity, promoting nutrient cycling and availability of nutrients to plants [7].Therefore, the current study was carried out to assess the effect of soil application of organic amendments on flowering and yield parameters of chilli (*Capsicum annuum* L.) veriety vellayani athulya.

2. MATERIALS AND METHODS

2.1 Experimental Setup

A pot culture experiment was carried out at College of Agriculture, Vellayani from January 2023 to May 2023. Rice husk biochar was prepared at the biochar preparation unit at department of soil science and agricultural chemistry at College of Agriculture, Vellayani.The chilli variety Vellayani athulya was selected to carry out the experiment and the seedlings were raised in portrays and one month old seedlings were transplanted to the pots. Before transplanting, the pots were filled with soil subjected to respective organic treatments as indicated. There were eight treatments comprising of T_1= Control-1 [KAU OPOP (2017) with FYM (25 t ha^{-1}), T_2 = Control -2 [KAU POP (2016)], T_3 = FYM substituted with vermicompost (12.5 t ha^{-1}) as per KAU OPOP (2017),T_4 = FYM substituted with goat manure (1t ha^{-1}) as per KAU OPOP (2017) ,T_5 =T_1+ Rice husk biochar (0.5% w/w) , T_6= T_2+ Rice husk biochar(0.5% w/w), T_7= T_3+ Rice husk biochar (0.5% w/w) and T_8= T_4+ Rice husk biochar (0.5% w/w). For each treatment, three replications were carried out and the design followed for the experiment was CRD.

OPOP - Basal [Based on soil testing, lime was applied to the soil and phosphorous and potash were supplemented as rock phosphate (217 kg ha^{-1}) and potassium sulphate(62.5 kg ha^{-1} respectively). The top dressing was done with soil application of groundnut cake (1 kg per 10 litres of water applied at 10 days interval). It was given for all the treatments except T2. For T2 as per KAU POP, N, P and K were given (N: P_2O_5 : K_2O 75: 40: 25 kg ha^{-1}) .

2.2 Flowering Parameters

The flowering parameters were taken at reproductive stage.Representative samples from chilli plants were taken for the observation. Ideally, plants that were uniform in age and health were used for consistency in the data. Tags and markers were used to identify the plants to be observed. This helped in tracking the same plants over time in understanding the flowering stages of the chilli plants. Chilli flowers typically appeared in clusters, and it became important to note the difference between flower buds and fully opened flowers.

2.2.1 Number of flowers plant^{-1}

At the beginning of the flowering period, the number of flower buds and open flowers which appeared on the tagged plants were marked and counted. This was done daily or on every few days, depending on the flowering rate. A record of number of flowers observed on each plant was maintained. A simple table format was used to log the data such as date and the number of flowers. It was continued to observe and count the flowers at regular intervals throughout the flowering period in all the tagged plants of each replication. After the flowering period the data was analysed to determine the average number of flowers per plant.

2.2.2 Days to first flowering

The dates when the seeds were sown and the seedlings transplanted were carefully recorded. Thus the starting point for recording the days to first flowering was obtained. The plants were observed regularly for signs of flowering. Flower buds which appeared before the flowers started to open were noted and the first flower opening date was recorded. This was the reference point for calculating the days to first flowering. The observations in each of the plants were recorded to gather the comprehensive data and the datas were compiled to analyse the average days to first flowering for the variety under the specific growing conditions.

2.3 Yield Parameters

Following yield parameters were taken at harvest stage. A representative sample of chilli plants were used for the observation. Plants that were uniform in age and health were selected to ensure consistency in the data. Tags or markers were used to identify the plants under observation. This helped in tracking the same plants over time. Analysis of various parameters were then carried out.

2.3.1 Days to first harvest

Days to first harvest refers to number of days from transplanting seedlings until the first fruits are ready for harvest. Number of days taken from

transplanting to the formation of first fruit was noted from the tagged plants from each replication and the mean value was taken into account.

2.3.2 Percentage of fruit setting

It is the ratio of number of fruits produced to that of total number of flowers produced which gave the fruiting percentage. Observations were taken from the tagged plants from each replication and the mean value was taken into account.

$$\text{Fruit setting (\%)} = \frac{\text{Number of fruits}}{\text{Number of flowers}} \times 100$$

2.3.3 No. of fruits plant^{-1}

Several pickings were required as all the fruits did not mature at a time. In each picking, fruits were counted and after last picking, the average number of fruits per plant was calculated. The number of fruits per plant was recorded from the tagged plants from each replication and the mean value was expressed as number.

2.3.4 Fruit length

Fruit length is typically measured in centimeters or inches and provides a quantitative assessment of the size of the fruit. A measuring scale was used to measure the end to end distance and the mean value from each replication was taken into account and it was expressed in cm.

2.3.5 Fruit girth

Fruit girth is typically measured in centimeters or inches and provides a quantitative assessment of the size of the fruit. A thread was used to measure the fruit girth from the middle most portion of the fruits and the mean value from each replication was taken into account and it was expressed in cm.

2.3.6 Fruit weight

This measurement provides critical data for assessing the yield of fruit. Fruit weight refers to the physical mass of an individual fruit, which can be determined using a weighing balance. Fruit weight was recorded from the tagged plants from each replication and the mean value was expressed as number g fruit^{-1}.

2.3.7 Yield

Fruit yield refers to the total amount of fruit produced by the crop. It quantifies the output of fruit from a given number of plants. Weight of the fresh fruits produced per plant was recorded at every harvest and yield per plant was determined and it was expressed in g plant^{-1}.

3. RESULTS AND DISCUSSION

The experimental data on the effect of various soil organic amendments was statistically analyzed by completely randomized design using GRAPES 1.0.0 software [8]. Flowering characters such as days to first flowering, number of flowers plant^{-1} and yield attributes such as days to first harvest, percentage of fruit setting, number of fruits plant^{-1}, fruit length (cm), fruit girth, fruit weigh and yield plant^{-1} was analyzed and the results for flowering and yield parameters are presented in Tables 1 to 4 and Figs. 1 to 2.

3.1 Number of Flowers Plant^{-1}

The impact of soil application of different organic amendments on the Number of flowers plant^{-1} in chilli are illustrated in (Table 1). T8 resulted in highest number of flowers plant^{-1} (44.67) followed by T7 (41.67) and the lowest value was recorded in the treatment T2(38). T8 (combined application of goat manure and rice husk biochar (0.5% w/w) improved the number of flowers per plant. Biochar enhances physical, chemical and biological properties of soil and there by it enhances nutrient supply in plants [9]. Similarly goat manure also enhances the nutrient availability by means of enhanced microbial activity and there by gives sufficient supply of essential nutrients required for flowering [10]. The result is shown in Table 1.

3.2 Days to First Flowering

Table 1 shows the days to first flowering as influenced by soil application of various organic amendments. The lowest value was recorded for the treatment T8 (22) which was found to be on par with T7(23.67). The highest value was recorded for the treatment T2 (30.33). It indicates that T8 [combined application of goat manure and rice husk biochar (0.5% w/w)] resulted in early flowering and it took lesser number of days for the appearance of first flower. In another study application of goat manure (100%), took

around 104.13 days only for 50% flowering in chilli [11]. It indicates that flowering occurs more faster by application of goat manure. Also another study has shown that application of 3.2 tons of biochar per acre resulted in highest chilli yield (0.95 tons per acre) compared to control (0.346 tons per acre) [12]. This increased yield could be correlated with flowering as well as improvement in chemical properties of soil.

3.3 Days to First Harvest

Table 1. shows the days to first harvest which was found to be influenced by soil application of various organic amendments. The lowest days to first harvest was recorded for the treatment T8 (41.00 days) followed by T3 (44.33 days). The highest days to first harvest was recorded for the treatment T1 (51.00 days) followed by T2 (57.33 days). It indicates that T8 (combined application of goat manure and rice husk biochar (0.5% w/w) resulted in early flowering and it took lesser number of days for the appearance of fruits which resulted in earlier harvest. Combined application of biochar and goat manure results in enhanced nutrient supply and there by promoting early flowering and fruiting as well as early harvest in chilli [12,13].

3.4 Percentage of Fruit Setting

The impact of soil application of different organic amendments on the percentage of fruit setting in chilli was examined and T8 resulted in highest percentage of fruit setting. Also T8 (64.18%) was followed by T7 (57.46%) and the lowest value was recorded in the treatment T2 (57.46%) followed by T1 (57.89%). It indicates that T8 [combined application of goat manure and rice husk biochar (0.5% w/w)] induced formation of more number of flowers per plant and better development of fruits [14,15] and resulted in more yield. Thus the percentage of fruit setting was also found to be higher in T8. The result is shown in Table 1.

Table 1. Effect of soil application of organic amendments on Number of flowers plant^{-1}, Days to first flowering and Days to first harvest and Percentage of fruit setting in chilli

Treatments	Number of flowers plant-1	Days to first flowering	Days to first harvest	Percentage of fruit setting (%)
T1	39.00	29.33	51.00	57.89
T2	38.00	30.33	57.33	57.46
T3	39.33	28.67	47.33	59.32
T4	38.33	29.00	45.67	58.26
T5	39.00	29.33	47.67	58.97
T6	38.33	26.67	45.67	58.26
T7	41.67	23.67	44.33	58.97
T8	44.67	22.00	41.00	64.18
SE(m) (±)	0.782	0.816	1.08	1.384
C.D(0.05)	2.344	2.448	3.238	4.151

CD=critical difference SE=standard error

Table 2. Effect of soil application of organic amendments on Number of fruits plant^{-1} of chilli

Treatments	Number of fruits plant-1
T1	23.00
T2	22.00
T3	23.33
T4	22.33
T5	23.00
T6	22.33
T7	25.67
T8	28.67
SE(m) (±)	0.782
C.D(0.05)	2.344

CD=critical difference SE=standard error

3.5 No. of Fruits Plant^{-1}

Table 2. and Fig. 1 shows the impact of soil application of different organic amendments on the number of fruits per plant in chilli. T8 resulted in highest number of fruits per plant (28.67) followed by T7 (25.67cm) and the lowest value was recorded in the treatment T2 (22.33) which was on par with T1 (12.13 g), T4 (22.33) and T6 (22.33). It indicates that T8 [(combined application of goat manure and rice husk biochar (0.5% w/w)] resulted in better fruiting of chilli. Goat manure is one of the important soil amendments which enhance water retension in soil there by enhances nutrient solubility and availability [9,16]. Biochar enhances soil porosity, organic matter content as well as nutrient availability and thereby it increases fruit setting and yield also [17].

3.6 Fruit Length (cm), Fruit girth(cm), and Fruit Weight (g fruit $^{-1}$)

Table 3. shows the impact of soil application of different organic amendments on yield parameters such as fruit length (cm), fruit girth (cm), and fruit weight (g fruit $^{-1}$) in chilli . T8 was found as the best treatment for fruit length (cm), fruit girth (cm), and fruit weight (g fruit -1). The fruit length was highest for T8 (15.30cm) followed by T7 (14.10cm) and lowest for T2 (10.83 cm) followed by T1 (11.33cm). Similarly fruit girth was highest for T8 (9.30cm) followed by T7(8.60 cm) and T6 (8.56cm) which were found on par. However the lowest was for T2(7.33 cm) which was on par with T1 (7.50 cm). Fruit weight was highest for T8 (17.70 gfruit $^{-1}$) followed by T7 (16.20 gfruit $^{-1}$) and lowest for T2 (11.63 g fruit $^{-1}$) which was on par with T1 (12.13 gfruit -1). It indicates that T8 (combined application of goat manure and rice husk biochar (0.5% w/w) resulted in better yield parameters in chilli. Biochar contributes to better soil fertility by enhancing soil structure, increasing cation exchange capacity (CEC), and improving moisture retention. Biochar also resulted in highest number of fruits per plant, fruit length per plant, fruit diameter per plant and fruit weight per plant in chilli [15]. These changes create a more favorable environment for root development and nutrient uptake, which are crucial for fruit development [12]. The application of goat manure has been linked to increased fruit length and fruit weight in chili plants. Studies indicate that higher doses of goat manure such as 40 tons per hectare give the best results in terms of fruit dimensions and overall quality [9]. Application of 40 tons/ha of goatmanure also exhibited significant effect on number and weight of chili fruits per plant in coastal sandy soil [9].

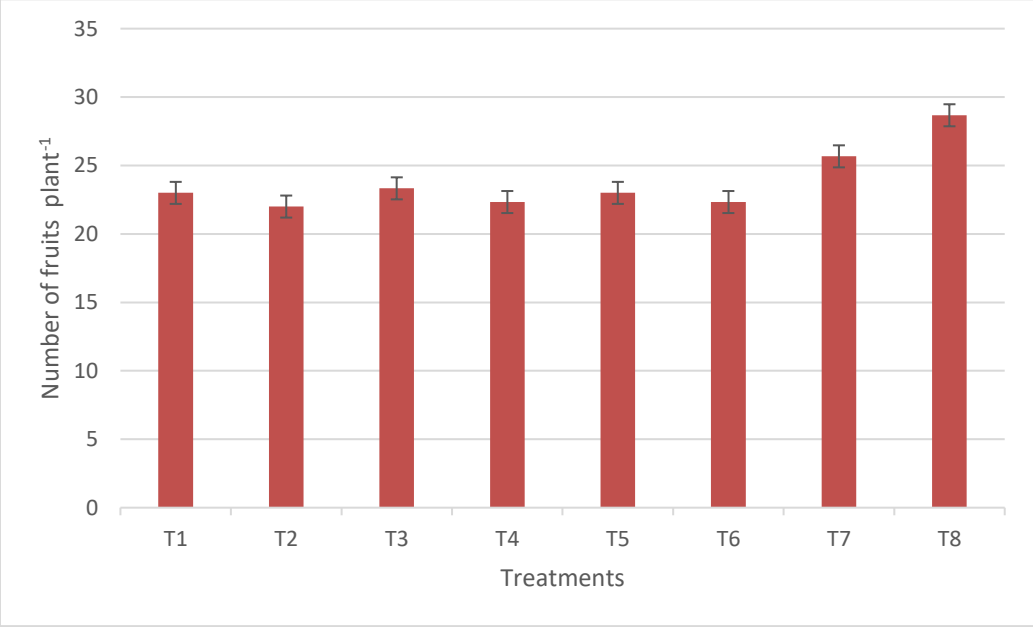

Fig. 1. Effect of soil application of organic amendments on Number of fruits plant^{-1} of chilli

Table 3. Effect of soil application of organic amendments on Fruit length (cm), Fruit girth (cm) and Fruit weight (g) of chilli

Treatments	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)
T1	11.33	7.50	12.13
T2	10.83	7.33	11.63
T3	11.73	7.87	13.33
T4	12.33	8.07	13.10
T5	13.00	8.57	15.13
T6	11.67	8.17	14.00
T7	14.10	8.60	16.20
T8	15.30	9.30	17.70
SE(m) (±)	0.38	0.12	0.474
C.D(0.05)	1.138	0.36	1.421

CD=critical difference SE=standard error

Table 4. Effect of soil application of organic amendments on yield of chilli

Treatments	Yield (g plant^{-1})
T1	279.06
T2	259.80
T3	311.10
T4	290.33
T5	332.93
T6	322.00
T7	415.81
T8	507.41
SE(m) (±)	0.816
C.D(0.05)	2.448

CD=critical difference SE=standard error

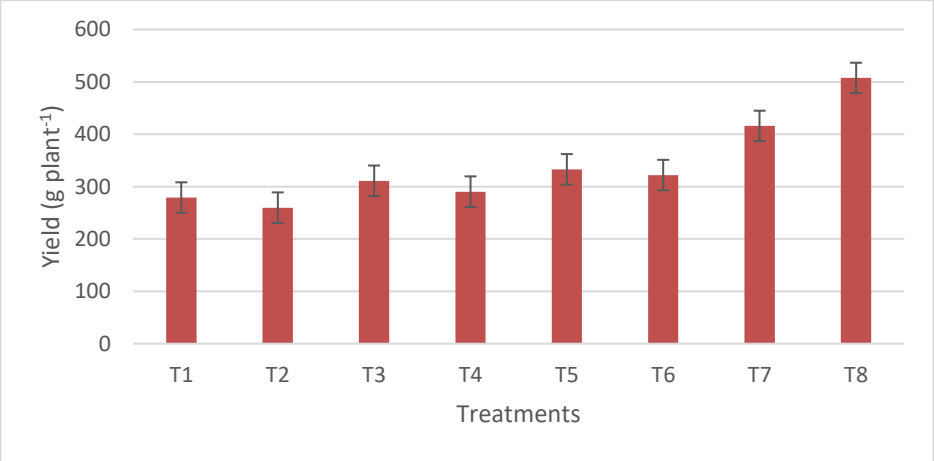

Fig. 2. Effect of soil application of organic amendments on yield of chilli

3.7 Yield (g Plant $^{-1}$)

Table 4. and Fig. 2 shows the impact of soil application of different organic amendments on chilli yield. T8 is reported as the best treatment for yield (507.41 g plant^{-1}). However the lowest yield was obtained in T2(259.80 g plant-1). It indicates that T8[(combined application of goat manure and rice husk biochar (0.5% w/w)] resulted in better yield, compared to other treatments. Goat manure improves soil structure and nutrient availability, which is crucial for the healthy growth of chili plants. Enhanced soil fertility leads to better nutrient uptake by the plants, which directly correlates with increased yield [14]. The application of biochar has been

shown to enhance soil fertility, which is crucial for plant growth. It improves the physical and chemical properties of soil, leading to better nutrient retention and availability. This results in healthier plants that can produce more fruits [18]. Biochar treatment has been shown to increase soil pH, nitrogen, phosphorus, potassium, and organic matter content, which contributes to better plant growth and yield and addition of 3.2 tons of biochar per acre resulted in a significant increase in chilli yield (0.95 tons per acre) compared to control plots (0.346 tons per acre) [12,18]. Different quantities of goat manure applications also enhanced yield attributes (fruit diameter and weight) of the wild watermelon (*Citrullus lanatus* subsp.) [19]. The combined application of biochar and organic fertilizeralso enhanced rhizosphere microbial diversity there by enhanced the yield in potato [20].

4. CONCLUSION

Organic farming minimizes the use of synthetic fertilizers, reducing the risk of nutrient leaching, greenhouse gas emissions, and water pollution. It promotes the recycling of on-farm resources and making the nutrient cycling system more sustainable. It overcomes the ill effects of indiscriminative use of fertilizers in the environment as well as in soil. Organic matter from sources like manure, compost and plant residues including biochar enhances soil structure, porosity and water-holding capacity.It increases the activity and diversity of beneficial soil microorganisms, promoting nutrient cycling and disease suppression.Organic nutrients are released slowly and steadily, matching the nutrient demands of crops throughout their growth cycle. They improve the availability of essential nutrients like nitrogen (N), phosphorus (P), and potassium (K) for plant uptake.Overall, the use of organic amendments in soil can improve flowering and yield parameters in chilli. The present study revealed that soil application of organic amendments (goat manure along with biochar) had significant effect on flowering and yield parameters of chilli (*Capsicum annuum* l.) and contributed to the sustainable production in chilli.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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