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Comparative study on organic and inorganic fertilizers and their effects on growth and yield of Chilli

Nidhi N Chaudhary[1], Dr. N B Patel[2*]
[1] Smt. S.M. Panchal Science College, Talod, Gujarat, India
[2] Associate Professor, Smt. S.M. Panchal Science College, Talod, Gujarat, India

Abstract

Ensuring food security and maintaining environmental health are driving a substantial revolution in India's agriculture. The semi-arid region of North Gujarat is known for its intense vegetable farming and is confronting serious problems including decreasing soil fertility, over-use of chemicals, and lower crop quality. As a result, chemical-intensive farming is losing ground to more sustainable agricultural methods like organic and integrated nutrition management. Soil health, nutrient cycling, and crop resilience are all improved by the use of natural inputs in organic farming, which include compost, biofertilizers, and microbial inoculants. But compared to conventional farming, the nutritional sufficiency and output potential of completely organic systems are still up for debate. Chemical fertilisers, on the other hand, boost production but are often linked to environmental damage and toxicity that lingers after application. North Gujarat is home to a large chilli (*Capsicum annuum L.*) vegetable production, and this research set out to compare the results of using organic, inorganic, and integrated fertiliser treatments on this crop. In order to find effective and sustainable methods of vegetable production, we set out to determine the effects of various nutrient sources on growth metrics, yield characteristics, and quality qualities. The results should help in creating agricultural systems that are better suited to the area, which are more robust, high-quality, and ecologically friendly.

Keywords: Chilli (Capsicum annuum), organic farming, chemical fertilizers, integrated nutrient management, sustainable agriculture

Introduction

Fertilizers play a central role in supplying essential nutrients to plants and improving soil fertility, thereby enhancing crop growth and yield. Broadly, fertilizers are categorized into organic and inorganic based on their origin and nutrient release behaviour. [1] Organic fertilizers such as farmyard manure (FYM), vermicompost, Jeevamrut, biofertilizers like Azotobacter and phosphate-solubilizing bacteria (PSB) are derived from natural biological sources and contribute to soil carbon buildup, improved soil structure, microbial activity, and sustained nutrient availability. [2][3] Jeevamrut, a traditional fermented bio-organic solution made from cow dung, cow urine, pulse flour, jaggery, and soil microbes, has gained importance in sustainable farming due to its role in enhancing nutrient mineralization and rhizospheric microbial populations. [4][5] Similarly, vermicompost provides plant-available N, P, K and improves soil enzymatic activity, while FYM supports long-term soil fertility through gradual humus formation. Microbial inoculants like Azotobacter promote biological nitrogen fixation, whereas PSB facilitates the conversion of insoluble phosphorus into plant-available forms.[6]

In contrast, inorganic or chemical fertilizers such as urea, diammonium phosphate (DAP), sulphate of potash (SOP) offer readily available nutrients that support rapid vegetative and reproductive growth. Urea is widely used due to its high nitrogen content (46% N), whereas DAP (18-46-0) provides an immediate source of nitrogen and phosphorus essential for root development and early crop establishment (FAO, 2021). Sulphate of potash (SOP), containing 50% K_2O and 17–18% sulphur, is commonly applied to vegetable crops for improving fruit quality, colour formation, and resistance to abiotic stress (Mahajan et al., 2019). However, continuous dependence on inorganic fertilizers may lead to soil degradation, nutrient imbalance, and reduced microbial diversity with long-term use.[7]

Pot experiments have become a widely adopted method for evaluating nutrient management strategies in controlled environments. Pot-based cultivation is particularly useful for kitchen gardens, terrace gardens, and urban vegetable production, where space is limited but precise nutrient application and ease of crop management are necessary. Such setups allow researchers to assess the performance of specific fertilizer treatments on plant growth, soil response, and yield under uniform conditions. Chilli, a commonly grown kitchen-garden crop, responds well to nutrient-rich potting mixtures, making pot experiments ideal for comparative fertilizer studies.

To achieve sustainable vegetable production, the use of combined or integrated fertilizers (organic + inorganic) has gained prominence.[8] Integrated nutrient management (INM) enhances fertilizer-use efficiency by combining the rapid nutrient availability of inorganic fertilizers with the soil-ameliorating properties of organic amendments. Numerous studies report that integrated applications of FYM, vermicompost, Jeevamrut, and chemical fertilizers significantly improve plant height, fruit yield, nutrient uptake, and soil biological activity compared to sole use of either fertilizer type. [9] This balanced approach reduces environmental risks, enhances soil health, and supports higher productivity, especially in vegetable crops grown in pots or small garden systems.[10]

Thus, comparing organic, inorganic, and integrated fertilizer approaches in a pot study becomes crucial to identify the most effective nutrient strategy for chilli cultivation under limited-space conditions such as kitchen or terrace gardening.[11]

Materials and Methods

Experimental details

Site of the current investigation was the hamlet of Bhajapura in North Gujarat's Vadali subdistrict. The research focused on the Capsicum annuum pepper crop, specifically the widely grown Pusa Jwala variety, which is a member of the Solanaceae family. This specific variety is recognised for its pungency and versatility; it is of Indian origin and belongs under the Cayenne kind. This experiment was conducted in the growing season of 2024, which runs from August to October. Chillies are considered an all-season crop, therefore this window was ideal for their production. The experiment was developed as a pot-based research, whereby 12-inch diameter pots were used to cultivate the chilli plants under various treatment circumstances. Each treatment was tested three times in a Randomised Block Design (RBD) experimental design. Three pots served as controls, nine were treated with organic fertilisers, six with inorganic or chemical fertilisers, and three received a combination of the two types of fertilisers. A total of twenty-one pots were utilised in the experiment. The purpose of creating this structure was to make it possible to compare how different nutrient management approaches affected the development and performance of chilli plants.

Organic and Chemical (Inorganic) fertilizer treatments for crop

The experimental setup included growing chilli plants in containers with 11 kg of soil and subjecting them to various treatments. T0, the control treatment, consisted of 11 kg of water and soil and did not include any additional fertilisers. Under the organic fertilizer treatments, three variations were applied:

- **T1:** 11 kg of soil with water and 100% Farm Yard Manure (FYM), amounting to 53 grams.

- **T2:** 11 kg of soil with water, supplemented with 100% Jeevamruta (500 ml), along with Phosphate Solubilizing Bacteria (PSB) and Azotobacter.

- **T3:** 11 kg of soil with water and a mixture of 70% Vermicompost (18.9 grams) and 30% FYM (15.9 grams), along with PSB, Azotobacter, and Jeevamruta.

For inorganic fertilizer treatments, two types were used:

- **T4:** 11 kg of soil with water, along with 25% DAP (0.32 grams), 50% Urea (1.03 grams), and 25% NPK (0.49 grams).

- **T5:** 11 kg of soil with water, along with 50% DAP (0.64 grams), 25% Urea (0.51 grams), and 25% NPK (0.49 grams).

The integrated treatment combining organic and inorganic fertilizers was as follows:

- **T6:** 11 kg of soil with water, combined with 20% NPK (0.32 grams), 70% Vermicompost (18.9 grams), 10% FYM, and 500 ml Jeevamruta.

Table 1: Organic and Chemical (Inorganic) fertilizer treatments for crop

Control treatments	**T_0 (11kg soil + water)**
Organic fertilizers treatments	T_1 (11kg soil + water + 100% (53g) FYM) T_2 (11kg soil + water +100 %(500ml) Jeevamruta + PSB+ *Azotobacter)* T_3 (11kg soil + water +70%(18.9g)Vermicompost +30%(15.9g) FYM+ PSB+ *Azotobacter* + Jeevamruta*)*
Inorganic fertilizers treatments	T_4 (11kg soil + water + 25%(0.32g)DAP + 50%(1.03g)Urea +25%(0.49g)NPK) T_5 (11kg soil + water + 50%(0.64g)DAP + 25%(0.51g)Urea + 25%(0.49g)NPK)
Organic + Inorganic fertilizers treatments	T_6 (11kg soil + water + 20%(0.32g)NPK + 70%(18.9g)Vermicompost + 10%FYM+ 500ml Jeevamruta)

Results and Discussion

Physicochemical analysis of soil sample

With a pH of 7.07, the soil sample shows no signs of acidity or alkalinity, making it ideal for growing a variety of crops. Because there are very few soluble salts in the soil, the low electrical conductivity (EC) of 0.31 S/m indicates that the soil is not salty and will not likely cause plants to suffer from salinity stress. Soil fertility and microbial activity are around average, according to the organic carbon content, which is 0.52%. Organic additions might enhance soil structure and nutrient-holding capacity, but this level already supports sufficient nutrient cycling. A macronutrient analysis revealed a phosphorus concentration of 96.39 kg per hectare, which is above average and indicates that plants have more than enough of the element to sustain root growth and blooming. The potash (potassium) level is 230 kg per hectare, which is excellent for boosting crop resilience, water control, and general plant health. It is within the acceptable to high range. Soil organic matter concentration might be improved to increase fertility in the long run, but overall, the soil seems to be suitable for agriculture with controlled salt levels and adequate nutrient availability.

Physicochemical analysis of soil sample

Table 2: Physicochemical analysis of soil sample

Sr. No.	Parameters	Soil result
1.	pH	7.07
2.	Electrical conductivity (Siemens/meter)	0.31
3.	Organic carbon (%)	0.52
4.	Phosphorus (kg/hectare)	96.39
5.	Potash (kg/hectare)	230

- **Plant response after 30DAS, 60DAS, 90DAS, 120DAS (days after showing)**
- Primary physiological parameters (pre-harvest parameters)

Significant treatment-wise variation was seen when basic physiological indicators (i.e., plant height, stem diameter, and number of branches) were analysed at 30, 60, 90, and 120 days after sowing (DAS). The control treatment (T0) showed the slowest increase in plant height, with a starting point of 13.17 cm at 30 DAS and a maximum of 40.17 cm after 120 DAS. On the other hand, T6 had the highest plant height across all stages, reaching a maximum of 50.92 cm at 120 DAS, suggesting that the treatment had a significant beneficial effect on vertical development. In the last stage, plants treated with T5 reached 49.46 cm in height while those treated with T3 reached 47.77 cm in height. Both treatments achieved high plant height. All treatments showed a slow but steady increase in stem diameter over time. The stem diameter increased from 0.44 cm at 30 DAS to 1.63 cm at 120 DAS, indicating superior structural development and the possibility of greater nutrient intake, further demonstrating that T6 outperformed other treatments. Conversely, after 120 DAS, the stem thickness of the control group (T0) had remained much lower, at 1.10 cm. Another important measure of plant health was the average number of branches per plant. After T5 (21.00) and T4 (17.66), T6 recorded the most branches at 120 DAS (20.00). The control group, on the other hand, showed very restricted lateral development, with only 11.00 branches. In comparison to the untreated control (T0), treatments T5 and T6 uniformly outperformed the control across all measures, indicating that they effectively improved vegetative development and prospective yield results.

Table 3: Primary physiological parameters (pre-harvest parameters)

Treatments	Plant height (cm)				Stem diameter (cm)				No. of branches			
	30 DAS	60 DAS	90 DAS	120DAS	30 DAS	60 DAS	90 DAS	120DAS	30 DAS	60 DAS	90 DAS	120DAS
T0	13.17	18.70	31.46	40.17	0.19	0.26	0.70	1.10	1.60	4.00	7.06	11.00
T1	14.48	23.46	34.29	45.60	0.26	0.43	1.10	1.47	2.00	5.66	8.66	11.66
T2	15.51	25.42	34.72	46.70	0.29	0.47	1.12	1.42	2.00	4.33	9.33	14.00
T3	16.40	27.33	37.73	47.77	0.35	0.59	1.22	1.53	3.00	8.33	13.00	20.00
T4	16.23	26.33	37.82	47.70	0.32	0.50	1.21	1.52	3.33	6.66	11.33	17.66
T5	16.33	28.36	38.52	49.46	0.42	0.62	1.23	1.63	3.00	8.00	14.66	21.00
T6	16.94	26.86	38.68	50.92	0.44	0.74	1.29	1.63	4.00	8.33	13.00	20.00
SE(m)_	0.502	1.283	0.98	1.341	0.033	0.058	0.075	0.068	0.0313	0.691	1.002	1.497
C. D. at 5%	1.737	4.441	3.389	4.639	0.115	0.201	0.259	0.235	1.084	2.391	3.468	5.18

Yield parameters (post-harvest parameters)

Variations in treatments are most pronounced in the post-harvest yield measures, which include leaf and flower counts, fruit dimensions, seed traits, and fresh fruit weight. T0, the control group, performed poorly in almost every category; each plant produced an average of 99 fruits, 149 flowers, and 5.32 cm in fruit length and 1.10 cm in fruit diameter. This treatment was the least prolific, yielding an average of 1.11 g of fresh fruit per plant, 35.77 g of seeds per fruit, 4.00 g of total seed weight, and 110.9 g of total fruit weight. As compared to the other varieties, T6 stood out due to its high yield (120.66 fruits per plant), large leaves (405 in total), and large fruits (8.30 cm in length, 1.58 cm in diameter, and 1.53 g average weight). The total seed weight was 7.99 g and the total fruit weight was 194.31 g, showing a significant increase in production potential, thanks to T6. Similarly, T5 was one of the best treatments, with 127 fruits, the most flowers (210), and 53.67 seeds per fruit for a total of 177.37 g of fruit weight. Fruit size (8.25 cm length and 1.55 cm diameter) and overall production (178.60 g total fruit weight and 47.87 seeds per fruit) were two areas where T3 demonstrated good results. Although T5 and T6 were much more effective in increasing yield compared to the control, T2 and T4 were also somewhat effective. T5 and T6 treatments outperformed T0 (control) across the board in terms of post-harvest performance, indicating that they are the most effective in boosting plant production and fruit quality.

Table 4: Yield parameters (post-harvest parameters)

Treatments	No. of leaves perplant	No. of flowers Per plant	No. of fruit Per plant	Fruit length (cm)	Fruit Diameter (cm)	Average fresh fruit weight per plant (g)	No. of seed Per fruit	Total seed weight per Plant (g)	Total fresh fruit weight per plant (g)
T0	149.00	149	99.00	5.32	1.10	1.11	35.77	4.00	110.9
T1	257.33	120.66	102.00	6.30	1.39	1.27	36.00	4.67	141.78
T2	221.33	122.33	106.33	6.43	1.37	1.23	37.33	4.83	130.78
T3	358.00	174.00	122.33	8.25	1.55	1.46	47.87	5.17	178.60
T4	329.00	163.33	116.66	7.73	1.43	1.32	40.45	6.17	153.90
T5	324.66	210.00	127.00	7.30	1.60	1.47	53.67	7.17	177.37
T6	405.00	141.00	120.66	8.30	1.58	1.53	47.67	7.99	194.31
SE(m)_	5.74	0.60	0.85	0.087	0.04	0.011	0.85	0.53	0.68
C. D. at 5%	16.78	1.78	2.62	0.26	0.12	0.035	1.75	1.10	1.16

Fig 1: Yield parameters (post-harvest parameters)

Sugar reduction, non-reduction, and total sugar percentages for each treatment (T0–T6) are shown in the bar graph. The results show that, relative to the control (T0), the overall sugar content is rising throughout treatments, with different treatments contributing different amounts of reducing and non-reducing sugars. With a total sugar level of 1.3%, reducing sugar of 0.9%, and non-reducing sugar of 0.4%, the control group (T0) had the lowest sugar content. For the sake of comparison, this is the starting point. The overall sugar content steadily decreased as the treatments continued. With comparable amounts of reducing (1.0-1.1%) and non-reducing (0.4%) sugar, T1 and T2 both observed total sugar levels of 1.4% and 1.5%, respectively. Total sugar level increases to 1.6% to 1.7%, the highest of all treatments, in T3, T4, T5, and T6, indicating a discernible improvement. The reducing sugar levels in these groups were between 1.1% and 1.3%, whereas the non-reducing sugar content rose to 0.5% for the most of them (with the exception of T6, which went back to 0.4%). Treatments T4 and T6 had the greatest total sugar content (1.7%), indicating that they are the most effective in increasing sugar accumulation overall. Treatments T3–T6 improved decreasing and total sugar contents relative to the control and previous treatments in a statistically significant manner. T4 and T6 are the most effective treatments for sugar enhancement in the plants investigated because they achieve highest overall sugar accumulation.

Quality parameter

The findings align with existing literature indicating that improved nutrient status and organic amendments influence plant physiology and biochemical composition. For example, organic matter applications can lower soil pH by stimulating microbial activity and ammonium uptake, which leads to hydrogen ion release in the rhizosphere [13]. Additionally, soil enzyme activity, influenced by SOC levels, significantly affects soil chemistry, including pH and nutrient dynamics [14, 15].

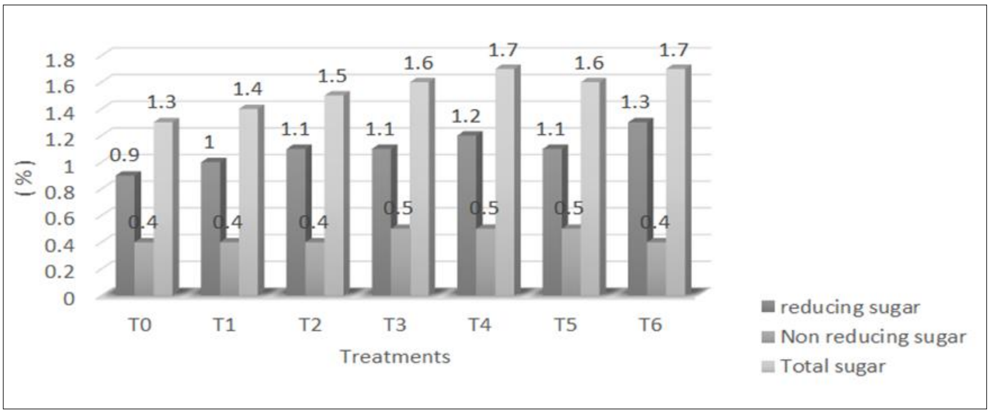

Fig 2: Quality parameter

Conclusion

The findings of the pot experiment clearly demonstrate that the combined fertiliser treatment, which integrates both organic and inorganic nutrient sources, produced the most favourable results compared to individual applications. While organic inputs alone improved soil health and supported moderate plant growth, and inorganic fertilizers enhanced rapid vegetative development, their combination delivered a synergistic effect by improving nutrient availability, plant vigour, yield attributes, and overall fruit quality. This indicates that integrated nutrient management is the most effective strategy for pot-based cultivation, including terrace and kitchen gardening systems, where balanced and sustained nutrient supply is essential for optimal crop performance.

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