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Improving Bitter Gourd Growth and Yield in Different Soil Environments by Combining Biochar and Inorganic Fertilizer

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A B S T R A C T

A study using the assigned Complete Block Design with three replications was carried out at Hobigong, Bangladesh from January to August 2021 to investigate the impact of different combinations of organic and inorganic fertilizers on the growth and production of bitter gourd. The experiment employed five different combinations of organic and inorganic fertilizers, which are listed below: T1: 4 kg of organic fertilizer per plant, T2: 4 kg of organic fertilizer + 2 liters of cow urine + 2 liters of bc (biochar), T3: 2 liters of liquid bc (biochar)) + NPK (44 g urea + 43 g TSP (Triple Super Phosphate) + 77 g MoP (Muriate of Potash), T4: NPK (44 g urea + 43 g TSP + 77 g MoP), and T5: 4 kg of organic fertilizer + 2 liters of bc+ NPK (44 g urea + 43 g TSP + 77 g MoP) on three distinct soils in the villages of Kalonjhora, Madhabpur, and Jointure. The growth and yield of bitter gourd at different study locations were significantly affected by the application of both organic and inorganic fertilizers, according to the results. The results showed that the use of both organic and inorganic fertilizers had a significant effect on the development and yield of bitter gourd at the different study sites. Maximum germination rate (90%), at 45 DAS (days after sowing), longest plant (173.28 cm) at 100 DAS, maximum number, longest and heaviest fruit (6.30 number of fruits per plant, 15.51 cm and 82.50 g, respectively) were obtained from crops grown in Jointer village that were applied with 4 kg organic fertilizer + 2 liters bc + NPK (44 g urea + 43 g TSP + 77 g MOP). According to the previously described research, most development and yield characteristics of bitter gourd are improved when grown in a mixture treated with 4 kg organic fertilizer + 2 liters bc + NPK (44 g urea) + 43 g of TSP + 77 g of MoP.

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Introduction

Bangladesh is mostly an agricultural nation, 75% people work in agriculture directly or indirectly. Vegetables supply most of our nation's people with the nutrients they need. Despite their low cost, vegetables are a great source of vitamins and minerals. Bitter gourd (*Momordica charantia* L.) known also as bitter apple or bitter melon or balsam pear, is a tropical vine belonging to the order Cucurbitales, family Cucubitaceae and genus Momordica. In South East Asia, China, India, and Bangladesh the plant is widely grown as a vegetable and medicinal crop (Behera et al. 2008). Although the entire plant is edible, bitter gourd is mostly produced for its fruit. Since fruits have a mildly bitter flavor, they are often cooked alongside other vegetables, particularly in soups. To lessen bitterness, fruits are typically utilized in cuisines after being blanched, partially boiled, or soaked in salt water (Saeed et al., 2018). Different varieties of bitter gourd have different shapes of fruits, being discoid or ovoid or ellipsoid to oblong and pointed towards the end (Kole et al., 2020). Bangladesh boasts two distinct fruit morph varieties. The two types are cultivated mostly in the summer, the short fruited form known as Uchta and the long fruited variety known as Korolla. The calorific value for leaf, fruit and seed were 213.26, 241.66 and 176.61 kcal / 100 g, respectively (Joseph & Jini, 2013). Vitamin C is one of the abundant compounds in the plant (Goo et al., 2016).

Bitter gourd production requires an abundance of plant nutrients. It is necessary to utilise organic fertilisers and manures for optimal growth and development since organic manures gradually release essential nutrients. Using organic manure improves the soil's texture, structure, and aeration while reducing environmental contaminants. Inorganic fertilizer use for a long period of time, especially in areas where it is cost-effective, has been linked to soil acidification, loss of organic carbon, nutrient imbalances, and a lack of secondary and micronutrients (Roba, 2018). Using organic material has been found to increase soil pH (Paradelo et al., 2024), soil C storage directly (Klinglmair and Thomsen, 2020) and indirectly through plant growth improvement and the activation of the microbial transformations of C (Zhou et al., 2022), increase in aggregate stability after the addition of biochar (Jien and Wang, 2013) increase in water retention (Paradelo et al., 2019), availability of nutrients for plants (Lopes do Carmo et al., 2016). Adding organic materials to the soil, such as cow dung and biochar, can help sustain the physical properties of the soil, improve crop yield and soil fertility, and maintain or enhance the amount of organic matter in the soil in an environmentally friendly manner (Aanchal et al., 2022). Important elements such as Nitrogen (N), phosphorus (P), Potassium (K), Sulphur (S), Magnesium (Mg), Calcium (Ca), and certain micronutrients are all present in significant amounts in cow dung. The application of cow dung to agricultural soil has been observed to positively impact soil structure, facilitating the regeneration process (Fu et al., 2022). Moreover, cow dung has been recognized as a valuable source of essential nutrients required for the cultivation of various plant species, ranging from cereal crops to horticultural plants and even fruits and vegetables. The cultivation of plants can be carried out using organic methods, thereby eliminating the necessity for the application of chemical inputs (Behera & Ray, 2021).

Biochar is created when organic materials are thermochemically converted at high, low, or intermediate temperatures with a small amount of oxygen (Wang et al., 2022). It has a number of positive effects on soil health, including an increase in soil organic matter, improved soil structural stability, decreased nutrient leaching, increased nutrient availability in soil, improved nutrient utilization in crops, and an increase in the quantity and diversity of microbes in a given area (Ulusal et al., 2021). Biochar has been proven to increase soil organic carbon, nutrient availability, and water holding capacity over a long time period and to sequester carbon (Gross et al., 2021). A recognized method for increasing soil fertility and preserving the environment is an integrated nutrient supply system. In order to maintain an optimal yield and enhance soil fertility, it entails the integrated application of organic manures and mineral fertilizers (Hussainy et al., 2019). Bhatt et al. (2019) state that long-term cropping in tropical settings can be sustained with the combined use of chemical and organic manure fertilizers, which increases nutrient use efficiency. Organic farming can lead to sustainable horticultural output.

Organic vegetables are becoming increasingly popular among health-conscious people in our country and around the world. Cow dung, organic manure, has been utilized since prehistoric times, but its supply is becoming scarce owing to industrialization of agricultural operations. Organic farming has recently gained popularity among vegetable consumers since it improves the quality of the produce (Das et al., 2020). In regard to the previous data, the current study aims to identify the optimal combination of organic and inorganic fertilizers for growing a significant yield of bitter gourds in a range of soil types.

Materials and Methods

Duration and Location

Three distinct villages in the Hobigong district-Madhabpur, Jointure, and Kalonjhora, Bangladesh were the sites of the experiment, which ran from January to August 2021. Situated in the Agro Ecological Zone "AEZ 22," the study area is geographically situated at latitude 24^{o} 24' N and longitude 91^{o} 37' E. 4.85 to 5.25 meters above mean sea level characterize the elevation of the region.

Climate

There were three different seasons in the subtropical climate of the experimental site: the monsoon, which runs from May to October; the winter, or dry season, which runs from November to February; and the pre monsoon, or hot season, which runs from March to April. Good precipitation from April to October and little to no precipitation in the remaining months of the year make up the seasonal conditions.

Planting Materials

The hybrid bitter gourd variety "Papiya" that was used in the experiment was sourced from ACI Seed Limited.

Preparing The Land and Creating Plot

On January 20, 2021, the experiment area's land was initially opened with a big shovel. For a few days, the soil was exposed to the sun. Using the spade, weeds and stubbles were pulled out of the field. Clods were broken up into small pieces of soil, and the top was smoothed to the necessary thickness. Plots were aligned according to the plan, and the trial field was marked. Twenty five (25) pits in each plot were prepared forbitter gourd. Total seventy five pits were prepared for this study. At the second step, collect dry leaves, grass, and rice straw for prepared biochar. After completing biochar (when all dry matters were burn at very high temperature absence of oxygen, added water for out of fire and finally collect biochar. At the third step, collection the fermented (the row urine were kept in a buckets about 7-10 days at a room temperature) cow urine and human urine. At the four steps, prepared combined media for application of experimental plot. Media or treatments are also mixed with the soil at the step fifth, the pits were labeled with tag on sticks and the upper portion of the stick was colored by different color paint, which is representing the treatment number. Finally the experimental plot was prepared. Soil physical and chemical properties of the experimental plots are presented in Table 1.

Table 1. Soil properties of three experimental areas

Soil properties	Location and value			Critical level
	Jointure	Madhabpur	Kalonjhora	
Organic carbon (%	0.45	0.52	0.55	-
Organic matter (%)	1.38	2.17	1.91	-
Total N (%)	0.10	0.09	0.06	0.12
Available P (ppm)	12	6	6	10.00
Exchangeable K (me/100g soil)	0.19	0.21	0.12	0.12
Available S (ppm)	6	3.6	3	10.00
Available Zn (ppm)	0.26	0.20	0.20	
Ph	5.5	5.8	5.4	6.5

Source: SRDI (2018).

Treatments

The experiment was constructed using two parts. Factor A was located in three different locations: Jointure village (T1), Madhabpur village (T2), and Kalonjhora village (T3). Factor B is made up of five tiers of organic and inorganic fertilizers: T1: 4 kg of organic fertilizer per plant, T2: 4 kg of organic fertilizer + 2 liters of cow urine + 2 liters of bc (biochar), T3: 2 liters of liquid bc (biochar)) + NPK (44 g urea + 43 g TSP (Triple Super Phosphate) + 77 g MoP (Muriate of Potash), T4: NPK (44 g urea + 43 g TSP + 77 g MoP), and T5: 4 kg of organic fertilizer + 2 liters of bc+ NPK (44 g urea + 43 g TSP + 77 g MoP

Design and Layout of the Experiments

The experiment was set up using three replications and a randomized complete block design. The treatments were distributed at random in each replication. Seventy-five unit plots made up the experiment. Each plot was 3 by 3 meters in size. The distance between each block and unit plot was one meter, respectively.

Application of Manures and Fertilizers

During the last pit preparation, the entire amount of manure-cow dung, biochar, cattle urine, and human urine-was applied. NPK and biochar were applied in liquid form. Prior to treatment, 10 L of fresh water was used to dilute the urine from humans and cattle. Two applications of urea, TSP, and MoP were made: the first time was during the last stages of land preparation, and the second time was approximately 60 days after planting.

Seed Dibbling

Initially, the cleaned seeds were soaked in tap water over night. On February 18, 2021, the seeds were then mixed by hand.Each pit had two seeds planted at a depth of three centimeters and mulched with banana leaf.

Germination

Within 11 days, it was noted that the seeds had germinated. The number of seeds that germinated was counted, and each unit plot's mean value was computed and expressed as a percentage (%). The following formula was used to get the germination percentage (GP; Onofri et al., 2018)

$$GP = \frac{\text{The number of germinated seeds}}{\text{The total number of seeds planted}} \times 100$$

Intercultural Operations

Thinning out

The seedlings were thinned out after 15 days of germination keeping only one healthy seedling per pit.

Gap filling

Additionally, where necessary, gap filling was done. Fresh, vigorous seedlings from the experiment's identical stock were used to replace any dead, wounded, or weak seedlings.

Weedin

In order to maintain the plots free of weeds, weeding was done as needed.

Mulching

Natural mulching were done to conserved the soil moisture by using water hyacinths

Irrigation

Pits were watered as and when needed to ensure sufficient moisture for normal crop growth. Tap water was used for watering during the whole period of the crops.

Staking

Bamboo stick supports were erected over each bed and placing a stick across the bamboo support marked plant distance.

Care of vines

During windy weather, tendering vines on plants may come loose from their supports. To guarantee the plants' healthy growth and development, the upward movement of the vines was manually managed using jute rope.

Pest control

Measures were taken against the attack of fruit fly using sex pheromone and poison baits. In case of sweet gourd, at seedling stage especially at cotyledonary leaves stage the seeding were attacked by red pumpkin beetle. Two sprays were applied with carbaryl (Sevin) 0.1 to 0.2% at 15 days interval.

A trellis

Each plot was equipped with six bamboo poles positioned slantwise, five feet above the ground. The poles formed an opposing "V" configuration when they were securely fastened to one another using jute rope. The iron rope had a net made of rope on it. To allow the agricultural vines to creep, a trellis was built for each plot.

Harvesting of fruits

Fruits were harvested at edible maturity at an interval of 7 days from 29th March to 20th May 2021.

Data Collection

Plant height

At the onset of flowering, the height of the plants was measured. Using a meter scale, the height of each plant was measured from the base to the longest end of the stem and reported in centimeters.

The quantity of leaves

The total number of leaves on each plant was counted before the first flowering, and the mean value was recorded.

Leaf size

The size of the leaf was recorded at the first flowering stage. The length and the breadth of the leaf were measured using a meter scale by randomly selected leaves of each plant. Then the mean was recorded and expressed in cm^2.

The quantity of flower males

The number of male flower of each plant was recorde in every seven days.

The amount of female flowers

Every treatment plant in each plot had its number of female flowers counted. It was completed at intervals of 7 days.

Fruits produced by each plant

The number of fruits on each bitter gourd plant was counted at each harvest, making it possible to determine both the average number of fruits and the total number of fruits on each plant.

Fruit length

A cm scale was used to measure the fruits' length. The average was then calculated following each harvest. Throughout the duration of the investigation, bitter gourd measurements were made six and four times, respectively.

Fruit weight

The weight of the fruits on each plant was recorded after each harvest, and the average weight of each fruit was calculated. Weight was determined using an electronic balance and expressed in grams.

The yield per plot

All of the plants in each plot were taken into account for estimating yield. Next, the area covered by the plants was taken into account for calculating the yield per plots.

Statistical Analyses

The data collected for all parameters underwent statistical analysis using analysis of variance (ANOVA). The Duncan method was employed to compare different treatments at a confidence level of p=0.05, with the least significant difference (LSD) being used for the comparison (Gomez and Gomez, 1984). CropStat 7.2 software was employed for this analysis, and the graphs were prepared using Microsoft Office Excel 2010.

Results and Discussion

Effect Fertilizer on Germination and Plant Height of Bitter Gourd Under Different Locations

Table 2 demonstrates that the interaction between the administration of inorganic and organic fertilizers at various locations had a substantial impact on germination. The greatest rates of bitter gourd germination at Jointure and Kalonjhora, after fertilization with F5, were 90% and 80%, respectively.

At Kalonjhora, the lowest germination rate (40.00%) was observed.. Plants at Jointure with f5 were the tallest at the 15, 30, and 45 DAS (8.44, 53.62, and 173.28 cm, respectively), followed by Kalonjhora and f5 mixed (6.76, 49.50, and 164.49 cm, respectively).

The shortest plant was obtained from the control plot at Madhabpur (4.04, 37.72 and 124.68 cm, respectively). A blend of NPK and biochar promotes root development and increases nutrient uptake through efficient transport of plant-synthesized growth-promoting compounds. With the establishment of large photosynthetic zones with maximum plant height and numerous branches per plant, the rate of several physiological and biochemical processes in bitter gourd increased.

Table 2. Effect of organic and inorganic fertilizer ongermination and plant height of bitter gourd under different locations

Interaction	Germination (%)	Plant height (cm) at different DAS		
		15 DAS	30 DAS	45 DAS
$T1F_1$	50.00±2.00*fgh	5.26 ±0.14*ef	34.20±0.24* j	131.37±0.58* h
$T1F_2$	75.00±6.56 bc	7.26±0.10 b	49.12±0.34 b	158.85±1.62c
$T1F_3$	70.00±5.00 bcd	6.58±0.04 bcd	45.60±0.36 cd	145.61±2.61de
$T1F_4$	60.00±4.00 def	5.92±0.28de	43.32±1.48def	140.05±1.71f
$T1F_5$	90.00±2.65 a	8.44±0.14a	53.62±1.63a	173.28±1.95a
$T2F_1$	45.00±3.00gh	4.04 ±0.09g	37.72±2.43 i	124.68±1.06i
$T2F_2$	60.00±2.00def	5.34±0.17ef	42.56 ±0.51efg	141.42±2.54ef
$T2F_3$	55.00±3.00efg	4.76± 0.11fg	40.74±1.87fgh	137.61±2.44fg
$T2F_4$	50.00±2.00fgh	4.20±0.08 g	38.40 ±0.85 hi	132.49±3.90gh
$T2F_5$	65.00±3.00cde	5.00±0.02 f	44.64±0.80cde	148.60±1.68d
$T3F_1$	40.00±2.00 h	4.82 ± 0.12fg	40.00±2.00ghi	127.86±0.59hi
$T3F_2$	60.00±5.00def	6.36±0.08 cd	46.54±1.77 c	146.41±5.99de
$T3F_3$	60.00±3.00def	6.20±0.11cd	44.36±1.11cde	140.26±2.05f
$T3F_4$	50.00±0.00fgh	5.20± 0.05ef	42.42±2.28efg	137.26±2.15fg
$T3F_5$	80.00 ±3.00ab	6.76±0.09bc	49.50±1.00 b	164.49±1.49b
P	<5%	<5%	<5%	<5%
CV (%)	17.01	10.03	7.50	7.83

*=standard deviation, Numbers in a column followed by different letters differ significantly, but with common letter(s) do not differ significantly at by DMRT. T1: 4 kg of organic fertilizer per plant, T2: 4 kg of organic fertilizer + 2 liters of cow urine + 2 liters of bc (biochar), T3: 2 liters of liquid bc (biochar)) + NPK (44 g urea + 43 g TSP (Triple Super Phosphate) + 77 g MoP (Muriate of Potash), T4: NPK (44 g urea + 43 g TSP + 77 g MoP), and T5: 4 kg of organic fertilizer + 2 liters of bc+ NPK (44 g urea + 43 g TSP + 77 g MoP)

Table 3. Effects of organic and inorganic fertilizers on the number and length of leaves of bitter gourd under different locations

Interaction	Number of leaf at different DAS			Length of leaf (cm) at different DAS	
	15	30	45	30	60
T1F1	7.60±0.85*efg	27.60±0.74*e	44.60± 0.75*g	8.82±0.49*def	9.96±0.48* fg
T1F2	9.80±1.13 bc	33.80±1.31 c	54.80 ±1.40c	11.30±0.36 ab	12.16±0.41 bc
T1F3	9.02±2.00bcd	32.02±0.97 d	52.02 ±0.48d	10.52±0.50bc	11.36±1.54 cd
T1F4	8.40±0.10def	31.40±0.61d	49.40 ± 0.53e	9.24±1.20 cde	10.30±0.30 de
T1F5	12.2±2.03a	37.20±0.72 a	60.20 ±0.92a	12.60±0.70 a	13.42±0.53 ab
T2F1	4.80±1.41 j	19.80±1.04 h	35.80±0.72 k	7.00±0.90 g	7.60 ±0.35 h
T2F2	7.40±1.04efgh	27.40±0.78 e	47.40 ±0.62f	8.66±0.41 def	9.40±0.10efg
T2F3	6.52±1.51 gh	24.52±0.86 f	42.52±0.70 h	7.90±0.36 efg	8.74±0.41fgh
T2F4	5.00±0.46 ij	21.00±1.00 g	39.00±2.65 j	7.50±0.44 fg	8.20±0.26 gh
T2F5	8.60±0.75cde	31.60±1.04 d	52.60±0.78 d	9.60±0.52 cd	10.40±0.40 de
T3F1	6.14±0.75 hi	22.14±0.80 g	38.14±0.92 j	7.60±0.35 fg	10.10±0.35 def
T3F2	8.60±0.75 cde	31.60±0.69 d	51.60± 0.20 d	9.40±0.10cde	11.04±0.46 cd
T3F3	7.70±0.78 defg	27.70±0.30 e	45.70± 0.61 g	8.76±0.41 def	10.40±0.40 de
T3F4	7.10±1.01 fgh	24.10 ±0.95 f	41.10±1.10i	8.04±0.26 d-g	9.90±0.56 def
T3F5	10.10±1.01 b	35.10±1.05 b	57.10±0.66 b	10.50±0.78 bc	12.10±0.46bc
P	<5%	<5%	<5%	<5%	<5%
CV (%)	11.71	7.29	8.96	11.86	9.76

*=standard deviation, Numbers in a column followed by different letters differ significantly, but with common letter(s) do not differ significantly at by DMRT. T1: 4 kg of organic fertilizer per plant, T2: 4 kg of organic fertilizer + 2 liters of cow urine + 2 liters of bc (biochar), T3: 2 liters of liquid bc (biochar)) + NPK (44 g urea + 43 g TSP (Triple Super Phosphate) + 77 g MoP (Muriate of Potash), T4: NPK (44 g urea + 43 g TSP + 77 g MoP), and T5: 4 kg of organic fertilizer + 2 liters of bc+ NPK (44 g urea + 43 g TSP + 77 g MoP)

Our results are in consistent with the findings of Das et al. (2015), Satish et al. (2017), and Sangeetha et al. (2018) who reported the positive ingluence of organic and inorganic fertilizer on germination and plant height of bottle gourd and bitter gourd.

Effects of Fertilizers on Bitter Gourd Leaf Length and Quantity in Variouslocations

Regarding the quantity of leaves per plant, there was a noteworthy interaction between the sites and the organic and inorganic fertilizers (Table 3). The maximum number of leaves of 12.20 (15 DAS), 37.20 (30 DAS) and 60.20 (45 DAS) were produced by the plant that was cultivated at Jointure withF5. Plant grown at Kalonjhora with F5 produced second highest number of leaves at 15 DAS (10.10), 30 DAS (35.10) and 45 DAS (57.10). The lowest number of leaves at 15 DAS (4.80), 30 DAS (19.80) and 45 DAS (35.80) were found from the plant that was cultivated under control treatment of at Madhabpur.

Because of the interaction between organic and inorganic fertilizers and the different locations, there was a large variation in leaf length (Table 3). At the 30 and 60 DAS,the longest leaf (12.60 and 13.42 cm) was produced by the plant grown at Jointure with F5, The plant grown at Kalonjhora with F5 produced the second longest leaf (10.50 and 12.10 cm) which was at par with the plant cultivated at Jointure with F2 (11.30 and 12.16 cm). It was observed that as vine length increased, the number of branches per plant and the number of leaves per plant increased correspondingly with the amounts of organic, inorganic, and bio-fertilizer combinations applied. The maximum vine length, branch and leaf counts were also recorded at the same treatment. This improved photosynthesis allowed the plants to grow more vigorously. The results of this inquiry are not consistent with the reports of Arancon et al. (2006). Prabha et al. (2007), Prasad et al. (2009), Narkhede et al. (2011) and Thriveni et al. (2015) in bittergourd. Maximum leaf area was recorded with F5. Organic fertilizers have a residual effect, acting as a reservoir for most macro-and micronutrients and increasing leaf area (Gulshan et al., 2013) and reproductive stages (Ali et al., 2003). NPK plays an important role in plant metabolism, leading plants to develop more leaves with maximum area (Din et al., 2005). Our results are consistent with those of (Kameswari et al. 2011) reported that the addition of inorganic fertilizers to organic fertilizers significantly increased the leaf area of ridge gourd.

Effects of Fertilizers on Bitter Gourd Blooms under Various Environments

Both organic and inorganic fertilizers had a substantial effect on the number of male flowers per plant at many places (Table 4). At the 50 and the 60 DAS, plantsthat was cultivated with F5 produced statistically similar maximum number of male flowers at Jointure (38.60 and 52.50) and Kalonjhora (33.80 and 45.97). The minimal numbers of male flowers (18.80 and 24.82) were found from the plant that was cultivated in control treatment at Madhabpur. When it came to the number of female flowers per plant in various locations, the effects of both organic and inorganic fertilizers were impressive at 60 DAS, but not statistically significant at 50 DAS (Table 4). When treated with F5, the highest number of female flowers (6.15) was discovered at Jointure at 60 DAS. Together with 4 kg compost +2 liters urine+ 2 liters liquid biochar (urine + bc mixed before application, Jointure produced the second-highest number of female flowers (5.32) (Table 4). These results were statistically identical to those reported from Kalonjhora. Lowest female flowers (2.66) were found from control plot at Madhabpur. The presence of growth-promoting compounds such as gibberellic acid, indole acetic acid, and dihydrozeatin from organic manure and inorganic fertilizers may have contributed to earliness and closer sex ratios.

Table 4. Effects of organic and inorganic fertilizers on flowers of bitter gourd under different locations

Interaction	Number of male flower at different DAS		Number of female flower at different DAS	
	50	60	50	60
T1F$_1$	21.60±2.29*efg	29.38±0.69*def	1.40±0.53*	3.32±1.53*efg
T1F$_2$	31.40±1.04 a-d	42.70±2.04 bc	2.60±0.36	5.32±0.76 b
T1F$_3$	27.80±1.31 b-f	37.81±0.65 b-f	1.80±0.18	3.99±0.87cde
T1F$_4$	23.80±0.94 d-g	32.37±1.48 def	1.70±0.26	3.82±0.22 def
T1F$_5$	38.60±1.15 a	52.50±1.52 a	3.10±0.26	6.15±0.98a
T2F$_1$	18.80±0.98 h	24.82±1.00 g	0.90±0.36	2.36±0.59h
T2F$_2$	25.80±0.87 c-g	35.09±2.60 c-f	1.40±0.26	3.32±0.55efg
T2F$_3$	22.20±0.93efg	31.19 ±0.90def	1.20±0.26	2.99±0.19fgh
T2F$_4$	20.80±1.31 fg	28.29±1.48ef	1.00±0.50	2.66±0.31 gh
T2F$_5$	29.20±1.46 b-e	39.71±2.03 bcd	1.80±0.53	3.99±0.41cde
T3F$_1$	19.20±0.00 gh	27.07±1.01 f	1.00±0.70	2.66±0.85gh
T3F$_2$	33.40±1.93 abc	45.42±0.38 ab	2.20±0.23	4.65±1.26bcd
T3F$_3$	28.00±1.00 b-f	38.08±1.67 b-e	1.90±0.36	4.15±0.75cde
T3F$_4$	23.20±1.00 efg	31.55±1.45 def	1.40±0.20	3.32 ±0.63 efg
T3F$_5$	33.80±2.75 ab	45.97±1.14 ab	2.30±0.30	4.15±0.60bc
P	<5%	<5%	NS	<5%
CV (%)	13.54	8.54	9.13	11.41

*=standard deviation, Numbers in a column followed by different letters differ significantly, but with common letter(s) do not differ significantly at by DMRT. T1: 4 kg of organic fertilizer per plant, T2: 4 kg of organic fertilizer + 2 liters of cow urine + 2 liters of bc (biochar), T3: 2 liters of liquid bc (biochar)) + NPK (44 g urea + 43 g TSP (Triple Super Phosphate) + 77 g MoP (Muriate of Potash), T4: NPK (44 g urea + 43 g TSP + 77 g MoP), and T5: 4 kg of organic fertilizer + 2 liters of bc+ NPK (44 g urea + 43 g TSP + 77 g MoP)

Table 5. Effects of organic and inorganic fertilizers onthenumber and length of fruit of bitter gourd under different locations

Interaction	Number of fruit at different DAS			Length of fruit (cm) different DAS		
	70	85	100	70	85	100
T1F$_1$	3.40±0.36*	3.99±0.20* ef	4.30±0.17*de	6.90±0.56*	7.68±1.04* f	9.86±0.75* ef
T1F$_2$	4.60±0.56	5.49±0.60 b	5.50±0.56abc	9.10±0.36	11.38±1.16 b	13.90±1.05b
T1F$_3$	3.80±0.35	4.66±0.77cde	4.70±0.44 cd	8.30±0.60	10.05±0.40bcd	12.54±0.56c
T1F$_4$	3.70±0.44	4.49±0.36 de	4.10±0.26 de	8.20±0.35	9.51±0.64cde	11.48±0.42cd
T1F$_5$	5.10±0.95	6.82±0.57 a	6.30±0.26 a	9.60±0.40	12.08±1.19 a	15.51±0.44a
T2F$_1$	2.90±0.44	3.20±0.20 f	3.70±0.36 e	5.60±0.53	6.36±0.68 g	7.23±0.67h
T2F$_2$	3.40±0.36	3.99±0.20ef	4.90±0.32 cd	7.90±0.50	9.88±0.68 b-e	10.6±0.96de
T2F$_3$	3.20±0.26	3.66±0.48 f	4.30±0.36 de	7.70±0.56	9.63±0.55 b-e	9.86±0.45ef
T2F$_4$	3.00±0.5	3.33±0.15 f	4.10±0.26 de	7.50±0.62	9.38±0.33 de	8.91±0.79fg
T2F$_5$	3.80±0.2	4.66±0.75cde	5.40±0.53bc	8.30±0.35	10.38±0.39bc	11.79±0.71cd
T3F$_1$	3.00±0.00	3.33±0.58 f	4.10±0.20 de	6.20±0.53	6.90±0.78fg	8.19±1.57gh
T3F$_2$	4.20±0.17	5.32±0.42bcd	5.30±0.40bc	8.80±0.46	10.50±0.44 b	12.97±0.84bc
T3F$_3$	3.90±0.1	4.82±0.64cde	4.90±0.26 cd	8.10±0.35	9.68±0.59 b-e	11.49±0.45cd
T3F$_4$	3.40±0.17	3.99±0.20ef	4.40±0.36 de	7.40±0.72	9.05±1.10 e	10.75±1.75de
T3F$_5$	4.30±0.3	5.99±0.22bc	5.90±0.26 ab	9.38±1.15	11.73±0.72 ab	13.96±0.83 b
P	NS	<5%	<5%	NS	<5%	<5%
CV (%)	13.44	8.57	12.51	8.38	7.23	9.93

*=standard deviation, Numbers in a column followed by different letters differ significantly, but with common letter(s) do not differ significantly at by DMRT. T1: 4 kg of organic fertilizer per plant, T2: 4 kg of organic fertilizer + 2 liters of cow urine + 2 liters of bc (biochar), T3: 2 liters of liquid bc (biochar)) + NPK (44 g urea + 43 g TSP (Triple Super Phosphate) + 77 g MoP (Muriate of Potash), T4: NPK (44 g urea + 43 g TSP + 77 g MoP), and T5: 4 kg of organic fertilizer + 2 liters of bc+ NPK (44 g urea + 43 g TSP + 77 g MoP)

These substances had a positive effect on the physiological activity of the plant and may have helped the host plant induce female flowers, thereby favorably modifying the sex ratio and increasing yield. These outcomes agree with those of Patil (1998) for both cucumbers and bottle gourds. The fact that vegetative development stopped at the commencement of the flowering phase may help to explain the rise in the number of hermaphrodite blooms per plant. As a result, incoming nitrogen that was intended for use by vegetative portions moved in the direction of the reproductive organs. Therefore, it's possible that the quantity of hermaphrodite blooms per plant rose in the current experiment when the amounts of nitrogen and organic manure were increased. The aforementioned results roughly align with those of Pandey and Singh (1973), Patil (1998), and Ali et al. (1995) about bottle gourds and bitter gourds, respectively, whereas Suresgkumar et al. (2008) reported on sponge gourds.

Impact of Fertilizers On Bitter Gourd Fruit Length and Quantity at Various Locations

Due to the interaction between the administration of organic and inorganic fertilizers at different sites, the quantity of fruits per plant varied significantly at 85 and 100 DAS, but not significantly at 70 DAS (Table 5). At the70 DAS, higher number of fruits (5.10) was harvested from the plant cultivated at Jointure with 4 kg compost + 2 liters biochar + NPK (44g urea+ 43g TSP + 77g MOP) and the lowest (2.90) was obtained from control plot at Madhabpur.

Table 6. Effects of organic and inorganic fertilizers on fruitweight and yield of bitter gourd under different locations

Interaction	Individual fruit weight (g) at different DAS			Yield (kg)/plot
	70	85	100	
T1F1	29.05±0.13* f	37.38±0.23*i	49.63±1.37*gh	33.11±0.34* cd
T1F2	38.31±0.52ab	53.83±0.40bc	70.03±0.11bc	38.83±2.08 b
T1F3	34.94±1.73 cd	48.20±0.30 de	66.71±0.93 d	35.16±3.51 cd
T1F4	34.52±0.47 cd	44.17±0.15fg	61.06±0.82 e	32.23±0.45 cd
T1F5	40.42±0.37 a	58.81±1.29 a	82.50±1.50 a	42.20±1.68 a
T2F1	21.22±0.76 h	27.09±0.83 k	32.46±1.05 k	31.76±0.87cde
T2F2	29.94±0.81ef	42.07±0.85gh	47.95±1.33 hi	34.93±1.40 cd
T2F3	29.18±0.16ef	38.58±0.58 hi	44.28±0.99ij	32.66±1.61 cd
T2F4	28.43±0.43 f	36.19±0.97ij	40.01±0.47 j	30.36±0.51cde
T2F5	31.46±0.40ef	44.20±0.75fg	52.96±1.44fg	34.06±0.51 cd
T3F1	24.74±0.64 g	33.05±1.33 j	39.81±0.30 j	28.76±0.25 e
T3F2	35.11±0.22 cd	50.30±0.92cd	60.59±1.34 e	32.73±0.68 cd
T3F3	32.32±0.41 de	46.34±0.22ef	55.83±0.47 f	30.50±1.00cde
T3F4	29.53±1.10ef	43.35±0.30fg	52.22±1.99fgh	28.75±0.90 e
T3F5	37.43±0.37bc	56.16±0.31 ab	77.66±1.60 b	34.41±1.38 cd
P	<5%	<5%	<5%	<5%
CV (%)	8.42	7.68	9.54	2.35

*=standard deviation, Numbers in a column followed by different letters differ significantly, but with common letter(s) do not differ significantly at by DMRT. T1: 4 kg of organic fertilizer per plant, T2: 4 kg of organic fertilizer + 2 liters of cow urine + 2 liters of bc (biochar), T3: 2 liters of liquid bc (biochar)) + NPK (44 g urea + 43 g TSP (Triple Super Phosphate) + 77 g MoP (Muriate of Potash), T4: NPK (44 g urea + 43 g TSP + 77 g MoP), and T5: 4 kg of organic fertilizer + 2 liters of bc+ NPK (44 g urea + 43 g TSP + 77 g MoP)

At the 85 and the100 DAS, the highest number of fruits (6.82 and 6.30) was produced by the plant grown at Jointure with 4 kg compost + 2 L biochar + NPK (44g urea+ 43g TSP + 77g MoP). Plant grown at Kalonjhora with 4 kg compost + 2 litre biochar + NPK (44g urea+ 43g TSP + 77g MOP) produced the second highest number of fruit (5.99 and 5.90) which were as par with the plant cultivated with 4 kg compost +2 liters cow urine+ 2 liters biochar Jointure (5.49 and 5.50) and at Kalonjhora (5.32 and 5.30). The minimum number of fruits (3.20 and 3.70) was obtained from the plant grown with under control treatment at Madhabpur.

Because of the interaction between sites and inorganic and organic fertilizers, fruit length differed significantly at the 85 and 100 DAS but not at the 70 DAS (Table 4). At the 70 DAS, numerically longer (9.60 cm) fruit was obtained from the plants cultivated at Jointure with 4 kg compost + 2 liters biochar + NPK (44g urea+ 43g TSP + 77g MoP) and shorter (5.60 cm) was obtained from control plot at Madhabpur. At the 85 and the 100 DAS, the longest fruits (12.08 and 15.51 cm) were obtained from the plant cultivated at Jointure with 4 kg compost + 2 liters biochar + NPK (44g urea+ 43g TSP + 77g MOP). Plant cultivated at Kalonjhora with 4 kg compost + 2 liters biochar + NPK (44g urea+ 43g TSP + 77g MOP) produced the second longest fruits (11.73 and 13.96 cm) that was at par with plant grown with 4 kg compost +2 liters cow urine+ 2 liters bc at Jointure (11.38 and 13.90 cm) and at Kalonjhora (10.50 and 12.97 cm). The shortest fruits (6.36 and 7.23 cm) were harvested from plant sown with under control treatment at Madhabpur. It was demonstrated that the average fruit length and number of fruits per plant rose with gradual plant growth and the application of both organic and inorganic fertilizer. The findings of the inquiry align with reports on bitter gourd published by Bindiya et al. (2006), Mulaniet al. (2007), Karuppaiah and Balasankar (2008), Sreeniva et al. (2000), and Kameswariet al. (2011).

Effects of Fertilizers On Bitter Gourd Fruit Weight and Production in Variouslocations

The application of both organic and inorganic fertilizers at different sites had a substantial effect on the fruit weight (Table 6). The plant grown at Jointure F5 produced the heaviest fruits (40.42, 58.81, and 82.50 g, respectively) at the 70, 85, and 100 DAS. With F5 fruit (37.43, 56.16, and 77.66 g, respectively), the fruit collected from Kalonjhora scored second.

The smallest fruits (21.22, 27.09 and 32.46 g, respectively) were found in control treatment at Madhabpur. The use of mixed fertilizers at Jointure resulted in the bitter gourd’s highest fruit weight because the addition of organic sources like biochar to inorganic sources of nutrients enhanced plant growth favorably by increasing the synthesis of more carbohydrates. This resulted in a maximum assimilation flow to the sink, which may have increased fruit weight and length as well as the crop’s maximum output (Hilliet al., 2009). Similar results were seen by Basumatary et al. (2022) in sponge gourd, who stated that the quality and yield of sponge gourd are greatly increased when inorganic fertilizers are combined with organic manure.The usage of organic and inorganic fertilizers in different places has a substantial impact on bitter gourd yield.The highest yield was achieved by the plant grown at Jointure using F5 42.20 Kg/plot. Using F2, the fruit output from Jointure village came in second 38.83Kg/plot . After applying NPK (44 grams of urea, 43 grams of TSP, and 77 grams of MP) to the top soil, the village of Kalonjhora reported the lowest fruit output. The findings of Anjanappa et al. (2012) and Thriveni et al. (2015) regarding the impacts of phosphorus and nitrogen on yield parameters were comparable. By boosting the generation of carbohydrates in plants, biochar, when combined with inorganic nutrient sources such as compost, promotes plant growth.

Conclusions

According to the findings, combining organic and inorganic fertilizers in various areas had a major impact on the bitter gourd's development and yield-contributing traits. Based on the previously described results, it was seen that bitter gourds cultivated in Jointure Village and fertilized with 4 kg compost + 2 liters bc + NPK (44g urea + 43g TSP + 77g MP) exhibited the highest effectiveness for almost every attribute related to the vegetable's development and production.

Declarations

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