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Effect of spacing, organic and inorganic nutrient sources on growth and yield of maize (*Zea mays* L.)

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Abstract

A field experiment was conducted on “Effect of Spacing, Organic and Inorganic nutrient sources on growth and yield of Maize (*Zea mays* L.)” during *Kharif* season, 2025 at the Crop Research Farm, Department of Agronomy, NAI, SHUATS, Prayagraj, U.P. The soil of the experimental plot was sandy loam in texture, had a pH of 6.8, contained 0.72 per cent organic carbon, and had 178.48 kg of nitrogen, 27.80 kg of phosphorus, and 233.24 kg of potassium available per hectare. The experiment was laid out in Randomized Block Design with ten treatments which are replicated thrice. The results revealed that effect of 60 cm x 20 cm and 50% Nitrogen through along with 50% through Vermicompost in Treatment 2 was recorded significantly higher growth parameter viz., plant height (199.95 cm) and dry weight (124.06 g). Whereas, yield attributes viz., Cob length (17.21 cm), No. of cobs/plant (1.40), No. of grains/row (32.57), grain yield (6.76 t/ha) and stover yield (12.85 t/ha) was also recorded in treatment 2 as compared to other treatment. Whereas, Maximum gross return (INR 154196.67/ha), net return (INR 106849.27/ha) and Benefit cost ratio (2.26) were also recorded in treatment 2 (60 cm x 20 cm and 50% Nitrogen through Urea along with 50% through Vermicompost) as compared to other treatment which was most economically profitable.

Keywords: Maize, nitrogen, vermicompost, yield and economics

Introduction

Maize (*Zea mays* L.) is one of the most important cereal crops in the world because of its wide adaptability, high productivity, and multiple uses. It belongs to the family *Poaceae* and is popularly known as the “Queen of Cereals” owing to its highest genetic yield potential among cereal crops. Maize is cultivated under a wide range of climatic conditions, from tropical to temperate regions, and is a day-neutral crop that performs well under diverse agro-ecological situations. It serves as a staple food for millions of people and is extensively utilized as livestock and poultry feed was similar to Midde *et al.* (2022) ^[1]. Besides food and feed, maize is an important raw material for several industries, including starch, ethanol, oil, glucose, high-fructose corn syrup, biodegradable plastics, pharmaceuticals, textiles, paper, and alcoholic beverages. Almost every part of the maize plant, including grain, leaves, stalk, tassel, husk, and cob, has considerable economic value. The grain contains about 66.2% carbohydrates, 11.1% protein, 3.6% fat, 2.7% fibre, and 14.9% moisture on a dry weight basis, making it an important source of energy and nutrition (Dragana *et al.*, 2015). In recent years, maize has gained greater importance due to the increasing demand for biofuel production. The Government of India has also emphasized the “Corn to Ethanol” programme to promote ethanol blending with petrol, thereby reducing dependence on fossil fuels and enhancing farmers’ income. Globally, the United States is the leading producer and exporter of maize and diverts a significant proportion of its production towards ethanol manufacturing. Approximately 68–72% of the maize kernel consists of starch, which can be efficiently converted into glucose and subsequently fermented to produce ethanol (FAOSTAT, 2023) ^[4]. Thus, maize plays a crucial role in ensuring food, feed, fodder, industrial raw material, and renewable energy security.

Globally, maize is cultivated over approximately 188 million hectares with an annual production of nearly 1,423 million tonnes. China possesses the largest maize-growing area, followed by the United States, and together these countries account for nearly 39% of the world's maize area. India ranks fourth in maize area with about 9.89 million hectares under cultivation and occupies the

sixth position in global maize production with an annual production of around 31.65 million tonnes. However, the average productivity of maize in India is approximately 3.19 t/ha, which is considerably lower than the world average productivity of about 5.6 t/ha, indicating ample scope for increasing production through improved crop management practices (FAOSTAT, 2023) [4].

Nitrogen is the most important nutrient limiting maize productivity because of its direct involvement in plant growth and metabolism. It is a structural component of chlorophyll, amino acids, proteins, nucleic acids, enzymes, vitamins, and numerous plant metabolites. Nitrogen is often referred to as the "engine of plant growth" because it regulates photosynthesis, cell division, leaf area development, protein synthesis, and dry matter accumulation. Among cereal crops, maize exhibits a very high response to nitrogen fertilization owing to its rapid growth rate, high biomass production, and greater nutrient demand. Adequate nitrogen supply enhances vegetative growth, chlorophyll content, photosynthetic efficiency, nutrient uptake, and ultimately improves yield attributes and grain yield. Conversely, nitrogen deficiency leads to poor plant growth, reduced leaf area, early leaf senescence, lower grain filling, and substantial yield losses (Fageria and Baligar, 2005) [3].

Although chemical fertilizers are essential for meeting the immediate nutrient requirement of maize, their continuous and indiscriminate use may adversely affect soil fertility, nutrient use efficiency, and environmental quality. Therefore, integrated nutrient management (INM), involving the combined use of organic and inorganic nutrient sources, has emerged as a sustainable strategy for maintaining crop productivity while preserving soil health. Organic manures such as vermicompost improve soil structure, water-holding capacity, microbial activity, nutrient availability, and organic carbon content, whereas inorganic fertilizers provide readily available nutrients during critical stages of crop growth. The integration of these nutrient sources ensures balanced nutrient supply, minimizes nutrient losses, enhances nitrogen use efficiency, and sustains soil productivity over the long term (Palm *et al.*, 2001; Giller *et al.*, 2013) [13, 5].

Among various organic nutrient sources, vermicompost has received considerable attention because of its rich nutrient content, beneficial microorganisms, plant growth-promoting substances, and ability to improve soil physical, chemical, and biological properties. The combined application of vermicompost and inorganic nitrogen fertilizers has been reported to enhance plant growth, yield attributes, nutrient uptake, and profitability of maize compared with the sole application of either source. Integrated nitrogen management also contributes to better soil microbial activity, improved nutrient cycling, and sustainable crop production (Edwards *et al.*, 2011) [2].

Apart from nutrient management, plant spacing is another important agronomic factor that significantly influences maize productivity. Optimum spacing ensures proper plant population and efficient utilization of available resources such as sunlight, moisture, nutrients, and growing space. Plant density directly affects crop growth parameters including plant height, leaf area index, dry matter production, root development, and yield components. Wider spacing may lead to underutilization of land resources, whereas closer spacing increases competition among plants for light, water, and nutrients, thereby reducing individual plant performance. Therefore, the adoption of an optimum spacing suitable for a particular variety and production system is

essential for maximizing yield and resource use efficiency (Patel *et al.* 2015) [15, 16].

Materials and Methods

During the *Kharif* season of 2025, a field experiment was conducted in alluvial soil at the Crop Research Farm of the Department of Agronomy, SHUATS, Prayagraj, U.P. The soil of experimental plot was sandy loam, having a nearly neutral soil reaction (pH 6.9), electrical conductivity 0.48 ds/m, medium in available nitrogen (270.81 kg/ha) and potassium (215.9 kg/ha), and low in available phosphorous (11.5 kg/ha). The experiment was laid out in Randomized Block Design. The treatments composed of two factors *i.e.* different Levels of Spacing, Organic and Inorganic nutrient sources along with Recommended dose of fertilizer 120-60-40 NPK kg/ha was applied as basal dose. There were 9 treatments and each replicated thrice. Treatments were randomly arranged in each replication, divided into 27 plots. Maize seeds (*KBR – 65*) were sown on July 29, 2025 with a spacing of 60 cm x 20 cm and 50 cm x 25 cm. Fertilizers were applied as band placement, for which 4-5 cm deep furrows were made along the seed rows with a hand hoe. The nutrient sources were urea, single super phosphate (SSP) and Murate of potash (MOP), applied as per the recommended dose of 120:60:40 kg NPK/ha. After germination, the gaps were filled by dibbling after 10 days of sowing. Seedlings were thinned out wherever required to maintain spacing of 60 cm x 20 cm and 50 cm x 25 cm. Manual weeding was done with the help of Khurpi at 20 and 40 days after sowing to minimize the crop weed competition. The crop was harvested on November 11th 2025. Plant growth parameters *viz.*, plant height (cm), dry weight (g/plant) were measured at a regular interval from germination till harvest and yield metrics *viz.*, Cob length (cm) cobs/plant, grains/row, seed yield (t/ha), stover yield (t/ha) and harvest index (%) were measured at harvest. And economics analysis was also recorded after harvesting *i.e.*, Gross return, Net Return, B:C Ratio. The observed data was statistically analyzed using analysis of variance (ANOVA) as applicable to randomized block design (Gomez and Gomez, 1984) [7].

Results and Discussions Growth parameter

As perusal of the data reveals that there is steady increase in plant height and dry weight at 100 DAS due to different treatment combinations plant height (cm), dry weight (g) and Crop Growth rate (g/m²/day) was significantly influenced by Spacing, Organic and Inorganic nutrient sources on Maize which was shown in Table 1.

Plant height (cm)

At the time of harvest, the highest plant height (199.95 cm) was recorded in Treatment 2 (60 cm × 20 cm spacing + 50% nitrogen through urea + 50% through vermicompost). Treatments 1, 3, 4, and 6 showed statistically similar plant height, indicating that both planting geometry and nitrogen management influenced crop growth. The superior plant height in Treatment 2 may be due to the combined effect of inorganic and organic nitrogen sources. Urea supplied nitrogen in readily available form, which promoted rapid cell division, elongation, and early vegetative growth, whereas vermicompost provided a slow and continuous supply of nutrients and improved soil structure, microbial activity, and nutrient availability. The balanced nutrient supply under integrated nitrogen management enhanced nutrient uptake and supported better plant growth throughout the crop period. Similar results were reported by Kumar *et al.* (2012) [9], Patel *et al.* (2015) [15-16], and Singh *et al.* (2010) [18].

Plant dry weight (g)

At 100 DAS, the maximum plant dry weight (124.06 g) was recorded in Treatment 2 (60 cm × 20 cm spacing + 50% N through urea + 50% N through vermicompost). Treatments 3, 4, and 6 were statistically at par with Treatment 2. The higher dry matter accumulation under integrated nitrogen management may be attributed to the balanced supply of nutrients from both inorganic and organic sources. Urea provided readily available nitrogen, which enhanced chlorophyll formation, photosynthesis, and vegetative growth, while vermicompost improved nutrient availability, soil health, and microbial activity, resulting in better biomass production. Similar findings were reported by Yadav *et al.* (2014) [20] and Singh *et al.* (2010) [18]. The observed that integrated application of organic and inorganic nitrogen sources promotes efficient nutrient uptake and increases dry matter accumulation.

Crop growth rate (g/m²/day)

During the 80–100 DAS period, the highest crop growth rate (4.73 g/m²/day¹) was recorded in Treatment 2 (60 cm × 20 cm spacing + 50% N through urea + 50% N through vermicompost). Treatments 3 (60 cm × 20 cm spacing + 25% N through urea + 75% N through vermicompost) and 7 (50 cm × 25 cm spacing + 25% N through urea + 75% N through vermicompost) were statistically at par with Treatment 2.

The higher crop growth rate under integrated nitrogen management may be due to the balanced availability of nutrients, which enhanced leaf development, photosynthetic activity, and dry matter accumulation during the active growth phase. Urea supplied readily available nitrogen for rapid growth, whereas vermicompost ensured a continuous nutrient supply and improved soil conditions, resulting in efficient nutrient uptake and higher crop growth. Similar findings on the beneficial effects of integrated organic and inorganic nutrient management on crop growth were reported by Yadav *et al.* (2014) [20].

Yields and yield attributes Cob length (cm)

The cob length of sweet corn was significantly influenced by different nutrient management practices. The highest cob length (17.21 cm) was recorded in Treatment 2 (60 cm × 20 cm + 50% nitrogen through urea + 50% nitrogen through vermicompost), which was statistically at par with Treatment 4 (60 cm × 20 cm + 100% nitrogen through vermicompost) and Treatment 5 (50 cm × 25 cm + 100% nitrogen through urea). The increased cob length was attributed to the balanced supply of nitrogen, which enhanced vegetative growth, chlorophyll synthesis, photosynthetic activity, and nutrient uptake. Adequate nitrogen promoted cell elongation, protein synthesis, and efficient assimilate production, resulting in better cob development, improved kernel formation, and higher productivity. These findings are in agreement with Mahapatra *et al.* (2007) [10].

Number of cobs/plant

The number of cobs per plant was significantly influenced by different nutrient management practices. The highest number of cobs per plant (1.40) was recorded in Treatment 2 (60 cm × 20 cm + 50% nitrogen through urea + 50% nitrogen through vermicompost), which was statistically at par with Treatment 3 (60 cm × 20 cm + 25% nitrogen through urea + 75% nitrogen through vermicompost), Treatment 4 (60 cm × 20 cm + 100% nitrogen through vermicompost), and Treatment 8 (50 cm × 25 cm + 100% nitrogen through vermicompost). The higher number

of cobs per plant was attributed to the balanced supply of nitrogen, which promoted better vegetative growth, improved photosynthetic activity, and enhanced nutrient uptake, leading to efficient assimilate translocation and reproductive development. These findings are in agreement with Pandey *et al.* (2000) [14], Sahoo and Mahapatra (2007) [17], and Patel *et al.* (2015) [15-16], who reported that optimum nitrogen management and organic nutrient application improved cob production and overall yield in maize.

Number of grains/row

The number of grains per row was significantly influenced by different nutrient management practices. The highest number of grains per row (32.57) was recorded in Treatment 2 (60 cm × 20 cm + 50% nitrogen through urea + 50% nitrogen through vermicompost), which was statistically at par with Treatment 3 (60 cm × 20 cm + 25% nitrogen through urea + 75% nitrogen through vermicompost), Treatment 4 (60 cm × 20 cm + 100% nitrogen through vermicompost), and Treatment 8 (50 cm × 25 cm + 100% nitrogen through vermicompost). The higher number of grains per row was attributed to the balanced and continuous supply of nutrients through the combined application of urea and vermicompost. This integrated nutrient management enhanced chlorophyll content, photosynthetic efficiency, nutrient uptake, and assimilate production, resulting in better kernel setting, improved grain filling, and reduced unfilled grains. The balanced availability of nitrogen throughout the crop growth period also improved nutrient use efficiency and assimilate translocation towards the reproductive organs, thereby increasing the number of grains per row. These findings are in agreement with the results of Pandey *et al.* (2000) [14], Mahapatra *et al.* (2007) [17], Patel *et al.* (2015) [15-16], and Midde *et al.* (2022) [1], who reported that integrated nitrogen management significantly improved yield attributes, including grains per row, by enhancing growth, nutrient uptake, and reproductive efficiency in maize.

Grain yield (t/ha)

The grain yield of Maize was significantly influenced by different nutrient management practices. The highest grain yield (6.76 t/ha) was recorded in Treatment 2 (60 cm × 20 cm + 50% nitrogen through urea + 50% nitrogen through vermicompost), which was statistically at par with Treatment 3 (60 cm × 20 cm + 25% nitrogen through urea + 75% nitrogen through vermicompost) and Treatment 4 (60 cm × 20 cm + 100% nitrogen through vermicompost). The higher grain yield was attributed to the balanced supply of nitrogen, which enhanced vegetative growth, chlorophyll content, photosynthetic activity, and nutrient uptake. Adequate nitrogen also improved dry matter production and the translocation of assimilates to developing grains, resulting in better grain formation, grain filling, and increased yield. These findings are in agreement with Midde *et al.* (2022) [1].

Stover yield (t/ha)

At harvest, the highest stover yield of Maize was significantly influenced by different nutrient management treatments. The highest stover yield (12.85 t/ha) was recorded in Treatment 2 (60 cm × 20 cm + 50% nitrogen through urea + 50% nitrogen through vermicompost), which was statistically at par with Treatment 3 (60 cm × 20 cm + 25% nitrogen through urea + 75% nitrogen through vermicompost) and Treatment 4 (60 cm × 20 cm + 100% nitrogen through vermicompost). The higher stover yield was mainly due to the balanced supply of nitrogen, which promoted vigorous vegetative growth, increased leaf area, enhanced

chlorophyll content, and improved photosynthetic efficiency. Adequate nitrogen availability also supported greater dry matter accumulation through increased plant height, stem growth, and leaf production, ultimately resulting in higher biomass and stover yield was similar to Ankita *et al.* (2018) ^[1].

Economics

In Table 3 Data pertaining to economics of growing as effect of was significantly influenced by spacing organic manure and inorganic sources on economics of Maize has been exhibited. The common and variable cost of production has been given in table 3

Cost of Cultivation (INR/ha)

Highest cost of cultivation (INR 61307.40 /ha) was found in the treatment 8 with application of (50 cm x 25 cm + 100% Nitrogen through Vermicompost) as compared to other treatments.

Gross return

Highest Gross return (INR 1,54,196.67/ha) was found in the treatment 2 with application of (60 cm x 20 cm + 50% Nitrogen through Urea + 50% through Vermicompost) as compared to other treatments.

Net return (INR/ha)

Maximum net return (INR 106849.27/ha) was found in the treatment 2 with application of (60 cm x 20 cm + 50% Nitrogen through Urea + 50% through Vermicompost) as compared to other treatments.

Benefit cost ratio (B:C)

Benefit cost ratio (2.26) was shown highest in treatment 2 with application of (60 cm x 20 cm + 50% Nitrogen through Urea + 50% through Vermicompost) and minimum benefit cost ratio (1.05) was shown in treatment 8 with application of (50 cm x 25 cm + 100% Nitrogen through Vermicompost) as compared to other treatments. The economics of sweet corn cultivation were significantly influenced by the application of spacing organic manure and inorganic sources. Higher nitrogen levels enhanced vegetative growth, chlorophyll content, photosynthetic efficiency, and nutrient uptake, which ultimately increased cob yield and Stover yield. The increased yield resulted in higher gross returns, net returns, and benefit–cost ratio. Nitrogen plays a vital role in protein synthesis, enzyme activation, and development of plant tissues, thereby improving cob development and grain filling in Maize was similar to Pandey *et al.* (2000) ^[14].

Table 1: Influence of Spacing, Organic and Inorganic nutrient sources on growth attributes of Maize

		Plant height (cm)	Dry weight (g)	Crop growth rate (g/m ² /day)
S. No.	Treatments	100 DAS	100 DAS	80 - 100 DAS
1	60 cm x 20 cm + 100% Nitrogen through Urea	190.32	105.06	2.14
2	60 cm x 20 cm + 50% Nitrogen through Urea + 50% through Vermicompost	199.95	124.06	4.73
3	60 cm x 20 cm + 25% Nitrogen through Urea + 75% through Vermicompost	196.71	118.36	3.35
4	60 cm x 20 cm + 100% Nitrogen through Vermicompost	195.53	117.73	2.96
5	50 cm x 25 cm + 100% Nitrogen through Urea	190.98	102.37	2.13
6	50 cm x 25 cm + 50% Nitrogen through urea + 50% through Vermicompost	193.49	118.29	2.25
7	50 cm x 25 cm + 25% Nitrogen through Urea + 75% through Vermicompost	188.62	110.99	3.12
8	50 cm x 25 cm + 100% Nitrogen through Vermicompost	182.31	104.41	3.01
9	Control (120-60-40 – N-P-K Kg/ha)	186.55	103.75	3.18
	F test	S	S	S
	SEm(+)	3.93	2.19	0.72
	CD (P= 0.05)	11.79	6.58	2.17

Table 2: Influence of Spacing, Organic and Inorganic nutrient sources on yield and yield attributes of Maize

S. No.	Treatments	Cob length (cm)	Number of Cobs/plant	No. of grains/row	Grain yield (t/ha)	Stover yield (t/ha)
1	60 cm x 20 cm + 100% Nitrogen through Urea	16.22	1.13	29.65	4.54	9.16
2	60 cm x 20 cm + 50% Nitrogen through Urea + 50% through Vermicompost	17.21	1.40	32.57	6.76	12.85
3	60 cm x 20 cm + 25% Nitrogen through Urea + 75% through Vermicompost	16.37	1.27	28.38	6.44	12.35
4	60 cm x 20 cm + 100% Nitrogen through Vermicompost	16.62	1.27	28.60	6.36	12.22
5	50 cm x 25 cm + 100% Nitrogen through Urea	16.69	1.00	30.25	4.64	9.55
6	50 cm x 25 cm + 50% Nitrogen through urea + 50% through Vermicompost	15.59	1.13	31.40	5.45	11.37
7	50 cm x 25 cm + 25% Nitrogen through Urea + 75% through Vermicompost	16.05	1.13	28.44	5.43	10.67
8	50 cm x 25 cm + 100% Nitrogen through Vermicompost	15.16	1.20	28.43	5.53	10.37
9	Control (120-60-40 – N-P-K Kg/ha)	15.87	1.20	27.87	4.46	9.14
	F test	S	S	S	S	S
	SEm (+)	0.23	0.08	0.86	0.13	0.27
	CD (P= 0.05)	0.69	0.25	2.57	0.50	0.83

Table 3: Influence of Spacing, Organic and Inorganic nutrient sources on economics of Maize

S. No.	Treatments	Cost of cultivation (₹/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	Benefit-cost ratio (B:C)
1	60 cm x 20 cm + 100% Nitrogen through Urea	33387.40	104580.00	71192.60	2.13
2	60 cm x 20 cm + 50% Nitrogen through Urea + 50% through Vermicompost	47347.40	154196.67	106849.27	2.26
3	60 cm x 20 cm + 25% Nitrogen through Urea + 75% through Vermicompost	53807.40	139303.33	85495.93	1.59
4	60 cm x 20 cm + 100% Nitrogen through Vermicompost	61307.40	135406.67	74099.27	1.21
5	50 cm x 25 cm + 100% Nitrogen through Urea	33387.40	107196.67	73809.27	2.21
6	50 cm x 25 cm + 50% Nitrogen through urea + 50% through Vermicompost	46307.40	126290.00	79982.60	1.73
7	50 cm x 25 cm+ 25% Nitrogen through Urea + 75% through Vermicompost	54327.40	124503.33	68175.93	1.29
8	50 cm x 25 cm + 100% Nitrogen through Vermicompost	61307.40	125873.33	61145.93	1.05
9	Control (120-60-40 – N-P-K Kg/ha)	33387.40	103090.00	69702.60	2.09

Conclusion

It is concluded that application of Treatment T2 [60 cm x 20 cm and 50% Nitrogen through Urea along with 50% through Vermicompost] was recorded highest Cob yield, Stover yield, Gross Return, Net Return and maximum B:C Ratio in Maize.

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Competing interests

Authors have declared that no competing interests exists.

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