ZIBELINE INTERNATIONAL PUBLISHING
ISSN: 2710-6012 (Online)
CODEN: JWBMAO

Journal of Wastes and Biomass Management (JWBM)

DOI: http://doi.org/10.26480/jwbm.01.2024.57.63

CrossMark

RESEARCH ARTICLE

EXAMINING THE IMPACT OF DIVERSE BIOFERTILIZER SOURCES ON VEGETATIVE AND REPRODUCTIVE TRAITS IN MAIZE

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ARTICLE DETAILS

Article History:

Received 23 June 2024
Revised 18 July 2024
Accepted 30 August 2024
Available online 23 September 2024

ABSTRACT

Nepal's efforts to achieve sustainable food production and improve rural livelihoods are increasingly challenged by environmental pressures. Maize (*Zea mays* L.), essential to Nepalese agriculture, requires innovative strategies to enhance productivity while minimizing environmental impact. This study, conducted at the G.P. Koirala College of Agriculture and Research Centre in Sundarharaicha, Morang, Nepal, from February to May 2024, investigates the efficacy of various bio-fertilizers on maize growth and development to identify sustainable alternatives to chemical fertilizers. A Randomized Complete Block Design (RCBD) with seven treatments replicated three times was used, including the recommended NPK dosage and various bio-fertilizer sources. Observations were made on plant height, leaf number, cob length, cob diameter, number of rows per cob, number of grains per cob, days to 50% tasselling, days to 50% silking, Soil Plant Analysis Development (SPAD), anthesis-silking interval, test weight, and yield. Statistical analysis revealed significant variations among treatments. NPK treatment significantly outperformed others, resulting in the tallest plants (238.13 cm at 90 DAS), the highest leaf number (18.16 leaves at 90 DAS), and superior reproductive traits, including cob length (21.35 cm), cob diameter (6.13 cm), and grain yield (7.99 t/ha). Organic fertilizers like poultry manure and mustard seed cake, although slower in initial impact due to gradual nutrient release, demonstrated competitive results in cob characteristics and yield. The study underscores the importance of balanced nutrient management in optimizing maize growth and productivity. Future research should explore integrating organic and chemical fertilizers to enhance soil health and sustainability while maintaining high crop yields.

KEYWORDS

Sustainable agriculture, Maize productivity, Bio-fertilizers, Nutrient management, Environmental impact

1. INTRODUCTION

Maize (*Zea mays* L.), one of the most important cereal crops globally (Neupane et al., 2020; Ghimire et al., 2023), has a rich history dating back to its domestication in Mexico around 10,000 years ago (Kandel, 2021; Majhi et al., 2024). This crop is classified under the Poaceae family and serves multiple roles: as a staple food for millions, fodder for livestock, and a vital industrial raw material (Bahadur and Shrestha, 2014; Yadav et al., 2023a). In Nepal, maize ranks second only to rice in terms of both area and production, making it a cornerstone of the country's agricultural sector (Prasai et al., 2015; Yadav et al., 2024b). The cultivation practices for maize in Nepal encompass a mix of traditional and modern techniques, reflecting the diverse agricultural landscape of the country (Waqas et al., 2021; Mehata et al., 2023a; Yadav et al., 2023b).

Predominantly grown in the hilly and terai regions, maize is integral to the livelihoods of countless farmers (Kammo et al., 2019). According to the Ministry of Agriculture and Livestock Development and the Krishi Diary, maize production in Nepal has experienced consistent growth, with recent figures reaching approximately 2.7 million metric tons (MOALD, 2023; Krishi Diary, 2023; Manjunatha et al., 2018). This robust production underscores maize's significant contribution to Nepal's Gross Domestic Product (GDP), providing substantial income and employment opportunities in rural areas (Shrestha et al., 2015; Mehata et al., 2023b). The ongoing advancements in cultivation techniques and improved seed varieties have further bolstered maize yields, solidifying its role as a staple crop critical to national food security regions (Thapa et al., 2022; Yadav et al., 2023a).

Despite its pivotal role, maize cultivation in Nepal faces several significant challenges, particularly due to the widespread and intensive use of chemical fertilizers (Balassa et al., 2022). Initially, these fertilizers boost crop yields, but their long-term effects on the environment and soil health are profoundly detrimental (Kandel, 2021). The persistent application of chemical fertilizers leads to soil degradation, characterized by the loss of essential nutrients and disruption of soil microbial communities (Thapa et al., 2022). Over time, soils become less fertile, requiring even greater quantities of chemical inputs to sustain crop production, thereby perpetuating a cycle of dependency (Balassa et al., 2022).

Additionally, chemical runoff from agricultural fields contaminates water sources, causing eutrophication—a process that depletes oxygen in water bodies and harms aquatic life (Bhusal and Bhattarai, 2019). This contamination not only affects the environment but also poses health risks to human populations relying on these water sources (Setimela et al., 2017). Farmers have also observed that pests and diseases develop resistance to chemical treatments, necessitating higher and more frequent applications of these inputs (Ghimire et al., 2024). This escalation in

Quick Response Code	Access this article online	
	Website: www.jwbm.com.my	**DOI:** 10.26480/jwbm.01.2024.57.63

Cite the Article: Sushma Neupane, Manisha Chaudhary, Puja Kumari Yadav, Susmita Mishra, Romita Rajbanshi, Ravi Acharya (2024). Examining the Impact of Diverse Biofertilizer Sources on Vegetative and Reproductive Traits in Maize. *Journal of Wastes and Biomass Management, 6(1): 57.63.*

chemical usage exacerbates the environmental impact and further entrenches farmers in an unsustainable cycle of agricultural practices (Mehata et al 2023a; Mehata et al 2023b).

In response to these pressing issues, biofertilizers have emerged as a viable and sustainable alternative (Mehata et al., 2023b). Biofertilizers, derived from natural sources such as animal manure, compost, and specific plant extracts, offer numerous benefits that address the negative impacts of chemical fertilizers (Mehata et al., 2023a; Kumari Sah et al., 2024). These natural fertilizers improve soil structure, enhance nutrient availability, and promote beneficial microbial activity within the soil (Yadav et al., 2024a). By restoring soil health, biofertilizers reduce the dependency on chemical inputs and mitigate the adverse environmental effects associated with conventional farming practices (Majhi et al., 2024). The application of biofertilizers can lead to improved crop resilience, higher yields, and sustainable agricultural production (Kumari Sah et al., 2024). They play a crucial role in maintaining soil fertility over the long term, ensuring that soils remain productive and capable of supporting future generations of crops (Yadav et al., 2024).

Moreover, the use of biofertilizers aligns with broader environmental sustainability goals, as they reduce the ecological footprint of agricultural activities (Mehata et al 2023b). This shift towards biofertilizer use supports the global movement towards more sustainable and environmentally friendly farming practices (Yadav et al., 2024b). The primary aim of this research is to evaluate the efficacy of various biofertilizer sources on the vegetative and reproductive characteristics of maize. By identifying the most effective biofertilizer, this study seeks to enhance maize growth and yield sustainably, contributing to long-term agricultural sustainability in Nepal.

2. MATERIALS AND METHODOLOGY

2.1 Description of experimental site

The study was carried out on an agronomy field at the G. P. Koirala College of Agriculture and Research Centre, Sundarharaicha Municipality, Gothgaun, Morang, in the Eastern Terai of Nepal, between February and May of 2024. Geographically, it is situated at an elevation of 150.7 metres at 26° 40' 49.7" North latitude and 87° 21' 16.8" East longitude. This region has 20.81 to 35.46 °C annual temperatures and 138.68 mm of precipitation on average. With the use of a soil test kit box, the experimental site's soil properties were qualitatively examined (Table 1). A portable instrument for evaluating soil health, a soil test kit box measures pH, nitrogen levels, and occasionally moisture content. Colorimetric tests are used to quantify soil parameters. Chemical reactions result in colour changes, which are then compared to a reference chart. These kits are quick and easy to use, but their results are not as precise and comprehensive as those from laboratory examinations, which makes them unreliable for important agricultural choices. Before the research was done, the soil's nutrient content was just once examined to make sure there was enough of a certain nutrient. Over the course of the research, the maximum and lowest average temperatures were 34.74 °C and 19.08 °C, respectively, and there was an average of 215.03 mm of precipitation.

Table 1: Soil characteristics of research field

Serial Number	Soil features	Nutrient level	Properties
1	Nitrogen	0.18%	High
2	Phosphorous	59.99 mg kg^{-1}	Moderate
3	Potassium	224.43 mg kg^{-1}	very low
4	Organic matter	3.89%	moderate
5	pH	-	6.7
6	Soil texture	-	Clay soil

2.2 Cultivar and treatments selection

The National Agricultural Research Council provided the CP-808 maize hybrid variety, which was employed in the study (NARC). The hybrid maize variety CP-808 is well-known for its excellent production potential. It matures in around 110-120 days on average and shows modest resistance to major diseases and pests. Due to its adaptability to a wide range of weather conditions, growers like this cultivar. Seven distinct sources of biofertilizer were used during the study; table 2 lists the characteristics of each.

Table 2: Treatments list along with their doses and sources

Serial Number	Treatments	Sources	Symbol	Doses
1	RD of NPK	Chemical	T1	120:60:40 NPK kg ha^{-1}
2	Poultry manure	Biofertilizer	T2	8 t ha^{-1}
3	Prangarik mal	Biofertilizer	T3	7 t ha^{-1}
4	Mustard seed cake	Biofertilizer	T4	5 t ha^{-1}
5	Goat manure	Biofertilizer	T5	10 t ha^{-1}
6	Farmyard manure	Biofertilizer	T6	20 t ha^{-1}
7	Control	Untreated	T7	-

2.3 Experimental setup and cultural practices

Five different biofertilizer sources, one recommended NPK dosage, and one treatment without any fertiliser were among the seven treatments in the study's Randomised Complete Block Design (RCBD), which included three replications. There were twenty-one tiny plots total, measuring 12 m2 (4 m*3 m) and holding sixty-four plants apiece. The individual plants inside each row were placed at a distance of 25 cm from the rows, which were spaced 75 cm apart. Every plot in a replication was spaced 0.75 metres apart, with a 1 metre gap between each replication. One week previous to planting, the experimental plot was prepared by heavy ploughing, harrowing, and levelling. A variety of biofertilizer sources, with the exception of the recommended amount of NPK, were administered to each plot during the field preparation and layout phase. At a rate of 120:60:40 NPK kg/ha, chemical fertilisers comprising urea, diammonium phosphate (DAP), and muriate of potash (MOP) were applied. The remaining potassium and phosphorus were administered at full dose, whereas only half of the nitrogen was first applied as a urea. During the tasting time, the second weeding was followed by the application of the remaining nitrogen dosage. Furthermore, earthing up was done at a knee-high level.

2.4 Data collection and observation

Ten plants at random from each plot were chosen for data collection in this investigation. The duration between anthesis and silking, plant height (cm), cob length and diameter (cm), number of rows per cob, number of grains per row, days to 50% tasselling, days to 50% silking, one thousand kernel weight (g), and grain yield per hectare (tonnes) were among the important observations. All the ears from every allotment were gathered during the harvest. The length, diameter, and number of rows per cob as well as the quantity of grains per row were measured.

Grain moisture content was considered while recording the field weight, or the total weight of harvested ears per plot. One thousand kernels were weighed, and their moisture content was adjusted to 12.5%. According to a study, the provided equations (Eqs. 1 and 2) were used to modify grain yield (tons/ha) at 15% moisture content (Thapa et al., 2022).

$$\text{Grain yield (tons/ha)} = \frac{F.W.\ \left(\frac{kg}{plot}\right) \times (100-HMP) \times S \times 1000}{(100-DMP) \times NPA \times 1000} \quad (1)$$

Were,

F.W. = Fresh weight of ear in kg per plot at harvest

HMP = Grain moisture percentage at harvest

DMP = Desired moisture percentage, i.e., 15%

NPA = Net harvest plot area, m^2

S = Shelling coefficient, i.e., 0.8

$$\text{1000-kernel weight} = \frac{Kernel\ weight \times (100-moisture\ \%)}{100-12.5} \quad (2)$$

2.5 Statistical Analysis

For both replication and treatment blocks, raw data were chronologically entered into MS Excel 2021 (Microsoft Corporation, Washington, USA). Subsequent statistical analyses were conducted using R Studio (Version 4.2.2, Boston, Massachusetts, USA). Analysis of variance (ANOVA) was employed to examine the data, followed by Duncan's Multiple Range Test (DMRT) to compare mean values among treatments at a 5% significance level.

3. Results

3.1 Effect of fertilizers on vegetative growth of maize

3.1.1 Plant height

The research demonstrated significant variations in plant height among the different fertilizer treatments at various growth stages of maize, as detailed in Table 3. At 30 days after sowing (DAS), the NPK treatment resulted in the tallest plants, averaging 57.59 cm. This was followed by the treatments with poultry manure, Prangarik mal, and mustard cake, which recorded mean heights of 48.86 cm, 49.17 cm, and 49.63 cm, respectively. Conversely, the control treatment had the shortest plants, with a mean height of 37.87 cm. At 60 DAS, the trend persisted with the NPK treatment achieving the greatest height of 138.68 cm, while the control treatment had the smallest height at 104.46 cm. By 90 DAS, the NPK treatment continued to outperform the others, reaching a height of 238.13 cm, whereas the control treatment remained the shortest at 196.43 cm. The overall plant height differences were highly significant across the fertilizer treatments at the 1% and 0.1% levels of significance.

Table 3: Effect of biofertilizers on growth and development of plant height

Treatments	Plant height (cm)			Pooled height
	30DAS	60DAS	90DAS	
NPK	57.59^{a}	138.68^{a}	238.13^{a}	144.80^{a}
Poultry manure	48.86^{b}	134.14^{a}	232.11^{ab}	138.37^{b}
Prangarik mal	49.17^{b}	134.14^{a}	229.07^{b}	136.46^{b}
Mustard cake	49.63^{b}	133.03^{a}	234.65^{ab}	139.10^{b}
Goat manure	44.06^{bc}	122.18^{b}	218.55^{c}	128.26^{c}
FYM	43.10^{bc}	113.00^{c}	214.33^{c}	123.48^{d}
Control	37.87^{c}	104.46^{c}	196.43^{d}	112.92^{e}
Mean	47.18	125.23	223.32	131.91
CV (%)	8.37	7.85	6.87	6.75
SEM	1.51	2.73	3.12	2.32
F-test	**	***	***	***

CV: Coefficient of variation; SEM: Significant error of Mean; *Significant at 5% level of significance, **Significant at 1% level of significance, ***Significant at 0.1% level of significance

3.1.2 Leaf Number

The study highlighted significant differences in the number of leaves among the various treatments at different stages of maize growth, as presented in Table 4. At 30 days after sowing (DAS), the treatment with poultry manure produced the highest number of leaves, averaging 6.53, followed by the NPK treatment with 6.33 leaves. The Prangarik mal, mustard cake, and goat manure treatments yielded similar leaf numbers, recording 6.20, 6.16, and 5.26 leaves, respectively. The FYM and control treatments exhibited the lowest leaf numbers, with 4.60 and 4.53 leaves, respectively. At 60 DAS, the NPK treatment once again showed the highest leaf count, with an average of 11.80 leaves, whereas the control treatment had the lowest, with 8.10 leaves. By 90 DAS, the NPK treatment maintained its lead with the highest leaf number of 18.16, while the control treatment recorded the lowest at 13.50 leaves. The coefficient of variation (CV) ranged from 4.42% to 10.88%, indicating moderate variability in leaf numbers across the different growth stages. The F-test results revealed highly significant differences among the treatments at all stages, underscoring the substantial impact of the treatments on maize leaf number.

Table 4: Effect of biofertilizers on growth and development of leaf number

Treatments	Leaf number (LN)			Pooled LN
	30DAS	60DAS	90DAS	
NPK	6.33^{ab}	11.80^{a}	18.16^{a}	12.10^{a}
Poultry manure	6.53^{a}	11.03^{a}	17.46^{ab}	11.67^{a}
Prangarik mal	6.20^{ab}	10.56^{a}	16.80^{abc}	11.18^{ab}
Mustard cake	6.16^{ab}	10.73^{a}	16.90^{abc}	11.26^{ab}
Goat manure	5.26^{ab}	10.56^{a}	16.26^{bc}	10.70^{bc}
FYM	4.60^{c}	9.30^{b}	15.83^{c}	9.91^{c}
Control	4.53^{c}	8.10^{c}	13.50	8.71^{d}
Mean	5.66	10.3	16.41	10.79
CV (%)	10.88	6.44	4.42	4.65
SEM	0.21	0.28	0.33	0.25
F-test	**	***	***	***

CV: Coefficient of variation; SEM: Significant error of Mean; *Significant at 5% level of significance, **Significant at 1% level of significance, ***Significant at 0.1% level of significance

3.2 Effect of fertilizer on reproductive traits of maize

The results demonstrated distinct differences among the treatments for each reproductive growth parameter, which is given in table 5 & table 6.

3.2.1 Cob Length (CL)

The investigation results, as detailed in Table 5, indicate that different biofertilizer sources significantly influence cob length. The overall mean cob length across the various treatments was 19.31 cm. Statistically, the differences in cob length due to the recommended dosages of NPK and the various biofertilizer sources were highly significant, with a p-value of less than 0.001. Poultry manure produced the longest cobs at 21.25 cm, closely followed by Prangarik mal at 20.92 cm and mustard seed cake at 20.71 cm, which were comparable to the NPK treatment at 21.35 cm. In contrast, the control treatment had the shortest cob length at 15.40 cm.

3.2.2 Cob Diameter (CD)

The findings of the cob diameter test, as detailed in Table 5, illustrate that maize cob diameter is significantly influenced by the various treatments. The average cob diameter across all treatments was 5.16 cm. The results showed that cob diameter varied significantly among the treatments at the 1% significance level. Among the biofertilizer sources, poultry manure and mustard seed cake resulted in the largest cob diameters, measuring 5.76 cm and 5.26 cm, respectively. These measurements were similar to those achieved with NPK, which had a cob diameter of 6.13 cm. On the other hand, the treatments involving goat manure, FYM, and the control showed smaller diameters, with the control having the smallest at 4.26 cm. In summary, biofertilizers had a positive effect on cob diameter.

3.2.3 Number of Rows per Cob (NORPC)

The study revealed a highly significant difference ($p<0.01$) in the number of rows per cob among the various fertilizer sources used. Table 5 illustrates the number of rows per cob for the maize variety under different fertilizer treatments. The overall average number of rows per cob was 14.89. Among the biofertilizers, poultry manure produced the highest number of rows per cob, at 15.46, followed closely by mustard seed cake at 15.23 and goat manure at 14.90. These figures were comparable to the number of rows per cob observed with the recommended dose of NPK, which was 17.46. On the other hand, FYM and control treatments resulted in the lowest numbers, with the control treatment having 12.96 rows per cob.

3.2.4 Number of Grains per Row (NOGPR)

The results indicated that different sources of biofertilizers and the recommended dose of NPK significantly impacted the number of grains per row, as shown in Table 5. According to our study, the recommended dose of NPK resulted in the highest number of grains per row, with an average of 42.93 grains. Poultry manure followed with 40.00 grains, while Prangarik mal and mustard seed cake treatments recorded 38.70 and 37.80 grains, respectively. Goat manure yielded a slightly lower count with

37.63 grains. FYM and control treatments had the lowest number of grains per row, with the control treatment averaging 31.60 grains.

3.2.5 Days to 50% Tasselling (DTT)

The application of various biofertilizers to the maize variety had a highly significant effect on the days to 50% tasselling, as shown in Table 5. The NPK treatment resulted in the fastest tasselling, occurring at 67.00 days. In contrast, the control treatment required the longest time, taking 73.33 days. Other treatments, including poultry manure, Prangarik mal, mustard cake, and goat manure, had tasselling times ranging from 69.00 to 70.33 days, while FYM took 71.66 days.

Table 5: Effect of biofertilizer on reproductive growth of maize plant

Treatments	CL (cm)	CD (cm)	NORPC	NOGPR	DTT (days)
NPK	21.35ᵃ	6.13ᵃ	17.46ᵃ	42.93ᵃ	67.00ᶜ
Poultry manure	21.25ᵃ	5.76ᵃᵇ	15.46ᵇ	40.00ᵇ	70.33ᵇ
Prangarik mal	20.92ᵃ	5.00ᵇᶜ	14.40ᶜᵈ	38.70ᵇᶜ	70.00ᵇᶜ
Mustard cake	20.71ᵃ	5.26ᵃᵇ	15.23ᵇᶜ	37.80ᶜ	69.00ᵇᶜ
Goat manure	18.51ᵇ	4.83ᵇᶜ	14.90ᵇᶜ	37.63ᶜ	70.33ᵇ
FYM	17.02ᵇᶜ	4.86ᵇᶜ	13.83ᵈᵉ	34.23ᵈ	71.66ᵃᵇ
Control	15.40ᶜ	4.26ᶜ	12.96ᵉ	31.60ᵉ	73.33ᵃ
Mean	19.31	5.16	14.89	37.55	70.23
CV (%)	5.49	9.48	3.54	2.27	2.18
SEM	0.52	0.16	0.31	0.79	0.49
F-test	***	**	***	***	**

CV: Coefficient of variation; SEM: Significant error of Mean; *Significant at 5% level of significance, **Significant at 1% level of significance, ***Significant at 0.1% level of significance, CL: cob length, CD: cob diameter, NORPC: number of rows per cob, NOGPR: number of grains per row, DTT: days to 50% tasselling

3.2.6 SPAD (Soil Plant Analysis Development)

The impact of various biofertilizers and recommended NPK dosages on chlorophyll content, as measured by SPAD values, is detailed in Table 6. The results demonstrated a highly significant correlation between fertilizer treatments and chlorophyll content ($p<0.001$). The NPK treatment exhibited the highest SPAD value at 55.00, reflecting optimal chlorophyll content. Poultry manure and mustard cake treatments followed with SPAD values of 50.66 and 50.33, respectively. Prangarik mal and goat manure yielded intermediate SPAD values of 45.66 and 47.66, respectively. The lowest SPAD values were observed in the FYM and control treatments, at 45.00 and 40.00, respectively.

3.2.7 Days to 50% Silking (DTS)

The application of different biofertilizer sources, along with the recommended dose of NPK, significantly affected the days to 50% silking, as shown in Table 6. The average time required to reach 50% silking was 76.28 days. The control treatment had the longest duration, taking 79.33 days to reach 50% silking, indicating delayed development. FYM followed closely, requiring 78.33 days. Prangarik mal and goat manure treatments had intermediate silking times at 76.33 days. Poultry manure and mustard cake treatments were slightly faster, with times of 76.00 and 75.00 days, respectively. The NPK treatment was the quickest, achieving 50% silking in 72.66 days.

3.2.8 Anthesis-Silking Interval (ASI)

Analysis of the anthesis-silking interval (ASI) in Table 6 revealed no significant variations between the treatments. Notably, the NPK, poultry manure, Prangarik mal, and mustard cake treatments all displayed the shortest interval at 3.00 days. Meanwhile, the goat manure, farmyard manure (FYM), and control groups exhibited slightly longer intervals of 4.66, 4.33, and 5.00 days, respectively.

3.2.9 Test Weight (TW)

Fertilizer application significantly boosted test weight across all treatments, as evidenced by highly significant results (p<0001). Table 6 showcases the weight of 1000 kernels (thousand kernel weight, TKW) for each treatment. The average test weight for the maize variety was 286.40 g. The NPK treatment reigned supreme with the highest test weight of 302.99 g, signifying superior grain quality and density. Poultry manure, Prangarik mal, and mustard cake treatments achieved impressive results as well, reaching comparable test weight of 294.49 g, 294.73 g, and 295.08 g respectively. Goat manure and farmyard manure (FYM) treatments yielded moderately lower test weight (286.10 g and 280.70 g), with the control group producing the lowest 1000 weight at a meager 250.70 g.

3.2.10 Yield (t/ha)

A combined application of biofertilizers and chemical fertilizers significantly boosted grain yield across all treatments, as detailed in Table 6. The NPK treatment produced the highest yield of 7.99 t/ha, demonstrating its clear effectiveness. Poultry manure and mustard cake applications yielded impressive results as well, reaching 7.91 t/ha and 7.83 t/ha respectively. Prangarik mal followed with a respectable 7.35 t/ha. Goat manure and farmyard manure (FYM) treatments resulted in moderately lower yields (6.90 t/ha and 6.40 t/ha), with the control group producing the least grain at 5.73 t/ha. The coefficient of variation (CV) and standard error of the mean (SEM) ensured data reliability. Additionally, highly significant F-test results ($p<0.001$) confirmed the substantial differences in grain yield across the treatments, highlighting the positive impact of these interventions on maize growth and productivity.

Table 6: Effect of biofertilizer on reproductive traits of maize plants

Treatments	SPAD	DTS (days)	ASI (days)	TW (g)	Yield (t/ha)
NPK	55.00ᵃ	72.66ᶜ	2.66ᵃ	302.99ᵃ	7.99ᵃ
Poultry manure	50.66ᵇ	76.00ᵃᵇᶜ	3.00ᵃ	294.49ᵃᵇ	7.91ᵃ
Prangarik mal	45.66ᶜ	76.33ᵃᵇ	3.00ᵃ	294.73ᵃᵇ	7.35ᵃᵇ
Mustard cake	50.33ᵇ	75.00ᵇᶜ	3.00ᵃ	295.08ᵃᵇ	7.83ᵃ
Goat manure	47.66ᵇᶜ	76.33ᵃᵇ	4.66ᵃ	286.10ᵇᶜ	6.90ᵇᶜ
FYM	45.00ᶜ	78.33ᵃ	4.33ᵃ	280.70ᶜ	6.40ᶜᵈ
Control	40.00ᵈ	79.33ᵃ	5.00ᵃ	250.70ᵈ	5.73ᵈ
Mean	47.76	76.28	3.66	286.40	7.16
CV (%)	3.70	2.44	33.34	2.15	6.59
SEM	1.05	0.56	0.31	3.80	0.20
F-test	***	*	NS	***	***

CV: Coefficient of variation; SEM: Significant error of Mean; *Significant at 5% level of significance, **Significant at 1% level of significance, ***Significant at 0.1% level of significance, NSNon significant, SPAD: Soil Plant Analysis development, DTS: Days to 50% silking, ASI: Anthesis silking interval, TW: Test weight

4. Discussions

Our study investigated the impact of various fertilizer treatments on both vegetative and reproductive parameters of maize, revealing significant effects across multiple growth stages. The findings underscored the critical role of nutrient management in influencing plant height, leaf number, and reproductive traits such as cob characteristics, grain yield, and physiological indicators. In line with previous studies, the application of NPK fertilizer consistently promoted taller maize plants throughout the growth stages (Akinrinde et al., 2018; Chen et al., 2020). This reflects the well-documented role of balanced nutrient supply in enhancing vegetative growth by supporting essential physiological processes such as cell division and elongation. Conversely, organic fertilizers like poultry manure and mustard cake, while effective, demonstrated slower initial impacts on plant height due to their gradual nutrient release mechanisms (Alam et al., 2017; Atkinson et al., 2010).

This delayed response was similarly observed in leaf number, where organic treatments provided competitive but slightly lower counts compared to NPK-treated plants, highlighting differences in nutrient availability and uptake efficiencies across fertilizer types (Girma et al., 2016; Nigatu et al., 2019). Regarding reproductive traits, our findings on cob length and diameter were consistent with those of who reported comparable cob dimensions between NPK-treated and certain biofertilizer-treated maize plants (Khan et al., 2019; Ogunwole et al., 2015). Poultry manure and mustard cake treatments exhibited cob characteristics similar to those of NPK, underscoring their potential as effective alternatives for optimizing maize yield parameters. The observed differences in cob characteristics among treatments reflect varying nutrient compositions and their impacts on maize reproductive development stages (Girma et al., 2016; Nigatu et al., 2019).

Physiological indicators such as SPAD values, indicative of chlorophyll content and photosynthetic efficiency, were highest in NPK-treated plants, consistent with the findings of (Girma et al., 2016; Nigatu et al., 2019). This suggests that NPK fertilizer enhances nutrient assimilation and utilization, thereby promoting superior grain yield compared to organic sources. The higher grain yields observed in NPK-treated plants underscore its comprehensive impact on both vegetative and reproductive growth stages (Khan et al., 2019; Ogunwole et al., 2015). In comparison with previous studies, our findings corroborate the significant benefits of balanced fertilization in optimizing maize growth and productivity. According to Akinrinde et al. (2018), balanced nutrient supply from synthetic fertilizers like NPK enhances maize growth by providing essential macronutrients in optimal ratios. A group researcher demonstrated that organic fertilizers, while effective in the long term, may initially show slower effects on maize growth parameters due to their gradual nutrient release (Alam et al., 2017). Moreover, some researcher highlighted the importance of nutrient timing and availability in influencing maize yield components, emphasizing the need for strategic fertilizer management practices (Atkinson et al., 2010).

5. Conclusion

In conclusion, the study demonstrated that different fertilizer treatments significantly influence maize's vegetative and reproductive growth parameters. NPK treatment consistently outperformed other treatments, resulting in the tallest plants, the highest leaf count, and superior reproductive traits, such as increased cob length, cob diameter, and grain yield. These results underscore the efficacy of NPK in providing essential nutrients that support vigorous growth and high productivity. Organic fertilizers like poultry manure and mustard seed cake, while effective, showed a slower initial impact due to their gradual nutrient release. However, they still produced competitive results in terms of cob characteristics and yield. The study's findings emphasize the importance of balanced and strategic nutrient management for optimizing maize growth and productivity. Integrating organic fertilizers with chemical ones can potentially offer sustainable agricultural solutions, enhancing soil health while maintaining high crop yields. These insights are crucial for developing effective fertilization strategies that ensure both high productivity and environmental sustainability.

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