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Assessment of Relationships between Growth and Yield Traits in *Kharif* Maize (*Zea mays* L.) under Planting Patterns, Nutrient Regimes and Organic Mulching

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ABSTRACT

Background: Maize (*Zea mays* L.), commonly known as "queen of cereals," The present study was conducted at the Agricultural Research Farm, Lovely Professional University, Phagwara (Punjab), during the *Kharif* season of 2024-25. It was titled "Assessment of relationships between growth and yield traits in *kharif* maize (*Zea mays* L.) under planting patterns, nutrient regimes and organic mulching". This study investigates the correlation of growth and yield parameter of maize under different planting pattern cum nutrient levels and organic mulching enhanced productivity and sustainability.

Methods: The experiment was conducted in a split-plot design (SPD) with three replications.

Result: The correlation matrix results show that plant height was significantly correlated with number of leaves, cob length, cob girth, grains/cob, test weight, grain yield and biological yield and Number of leaves was correlated with cob length, cob girth, grains/cob, test weight, grain yield and also biological yield. Tasseling and silking were correlated to each other and had a non-significant effect on growth and yield parameters. Cob length, cob girth and number of grains have a positive correlation with test weight, grain yield and biological yield and this positive effect is a key point for the production and productivity of maize crop. Test weight was also positively correlated with grain yield and biological yield. Grain yield and biological yield is perfectly correlated to each other. The correlogram result showed that earlier flowering, higher plant height, higher cob length and test weight significantly improved maize yield. These results highlight that optimized planting patterns, balanced nutrient management and organic mulching can improve maize production, productivity and sustainability in the Punjab region.

Key words: Correlation, Maize, Nutrient management, Organic mulching, Planting patterns.

INTRODUCTION

Maize (*Zea mays* L.) is one of the world's most adaptable and commercially significant cereal crops, ranking third in India behind rice and wheat in terms of acreage and production (FAO, 2023). Maize has become an important component in efforts to achieve sustainable agricultural development because to its high productivity potential, resilience to varied agro-climatic conditions and multipurpose use as food, feed and raw material for biofuel and processing industries (Singh *et al.,* 2025). Overall, the area under maize agriculture is declining due to changing climatic conditions, water constraints and other factors. Maize is one of the world's most important cereal crops and it is traditionally farmed in furrow-irrigated systems (Sujatha *et al.,* 2024). Priya *et al.* (2022) implement improved agronomic practices and management strategies aimed at enhancing maize productivity and overall crop performance. In Punjab, where rice-wheat monoculture has had major environmental implications such as groundwater depletion, poor soil health and increased greenhouse gas emissions, *kharif* maize presents a possible alternative (BISA, 2024). Recognizing these concerns, the Punjab government, in collaboration with agricultural research institutions, has actively promoted maize as a key crop to assist crop diversification, resource conservation and agroecological sustainability (CIMMYT India, 2023).

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Despite its significant potential, maize cultivation in Punjab is highly underexploited. According to the Crop Reporting Service of Punjab (2023-24), maize was cultivated across an estimated 94,000 hectares (0.94 lakh/ha) during the *kharif* season, resulting in a total production of approximately 5 lakh/t and an average productivity of 6.25 t/ha (Department of Agriculture, Punjab, 2024). These figures, while promising, fall well below the attainable yield potential of up to 10 t/ha (or 40 quintals per acre), particularly with the use of improved hybrids and scientific management. The shortfall in

productivity is attributed to several biotic and abiotic stress factors, including erratic monsoon patterns, intense weed infestation, nutrient deficiencies and a lack of mechanization and modern agronomic practices (Kumar *et al.,* 2022).

A correlation matrix is a fundamental statistical tool that helps analyze and summarize the linear relationships between multiple variables in a dataset. Presented as a table, each cell in the matrix displays the correlation coefficient between two variables, with values ranging from -1 to +1. This structure allows researchers and analysts to quickly identify which variables have strong, weak, or no relationships, aiding decisions related to variable selection for advanced modeling, such as regression or dimensionality reduction (Limbongan *et al.,* 2024). In agricultural research, correlation matrices are widely used to examine the relationships between growth parameters and yield traits. By understanding these correlations, scientists can identify the growth traits that are positively associated with yield, providing strategic targets for breeding programs aimed at improving crop productivity.

The correlogram, a graphical representation of a correlation matrix, enhances interpretation by using color codes or patterns to highlight the strength and direction of relationships, making it easier to visually detect patterns and clusters among variables. These techniques play a crucial role in diagnosing multicollinearity, facilitating exploratory analysis and exposing the underlying structure of complex datasets. Research such as that by Graffelman *et al.* (2023) has advanced the visualization of correlation matrices and correlograms, leading to more accurate and insightful data interpretation. In summary, correlation matrix analysis and correlogram visualization are essential for modern data science and they are particularly valuable in exploring the connections among growth and yield parameters, directly supporting improvements in crop management and breeding strategies by Graffelman *et al.* (2023).

In this context, the present study investigated the association between diverse maize growth characteristics and yield components. Specifically, it aims to elucidate the roles of organic mulching (using live mulch, wheat straw, or sugarcane mulch), which offers multiple agronomic and ecological benefits in maize cultivation. By covering the soil surface, mulching suppresses weed emergence and growth by limiting sunlight penetration and providing a physical barrier, conserves soil moisture, reducing irrigation frequency and mitigating water stress, moderates soil temperature, fostering better seedling emergence and root growth and improves soil organic matter, microbial activity and nutrient cycling (Xing *et al.,* 2024). Organic mulching involves applying plant-based materials, such as straw, leaves, compost, or green manure, to the soil surface to suppress weeds, conserve moisture, reduce erosion and enhance soil microbial activity (Bilalis *et al.,* 2010). The multifaceted benefits of mulching have been increasingly recognized. Organic mulches reduce soil water evaporation, improve organic carbon content, buffer soil temperatures and create favorable conditions for root growth and microbial proliferation. Multiple studies have confirmed that the application of mulch can reduce weed biomass by 40-80% and increase maize yields by 10-25% under varied agro-climatic conditions (Shashikanth *et al.,* 2022).

Research has confirmed that wheat or maize straw mulch can reduce weed biomass by up to 80% and increase maize grain yield by 15-33% compared to no mulched controls (Asif *et al.,* 2020). These practices also substantially increase soil organic carbon, improve water-use efficiency and offer a sustainable alternative to synthetic herbicides for weed management. In Punjab and adjoining regions, integrating organic mulching with optimal planting patterns and nutrient regimes has proven to be especially effective for sustainably improving maize productivity and resource-use efficiency (Ranjan *et al.,* 2017). Furthermore, mulching can substantially reduce surface runoff and soil loss, particularly in sloped fields, making it particularly suitable for rainfed maize areas in Punjab. In addition to mulching, optimizing planting patterns is crucial for improving light-use efficiency, water and nutrient uptake and canopy development. Traditional uniform row planting often leads to excessive intra-row competition, allowing weeds to flourish in open inter-row spaces. Modified planting geometries, such as paired row, zigzag and skip row patterns, have been shown to enhance spatial resource utilization, improve photosynthetic efficiency and suppress weed growth by enhancing early canopy closure (Tiwari *et al.,* 2020). Different planting patterns have a significant impact on maize growth, nutrient uptake and yield. Ridge-furrow, bed planting and strip intercropping are examples of innovative layouts that improve dry matter buildup and photosynthetic efficiency while increasing yield by up to 20%. Ridge-furrow or paired-row planting, for example, improves root distribution, soil moisture retention and weed suppression by closing the canopy faster and exposing less soil (Raza *et al.,* 2019). Combining these planting patterns with mulching and proper nutrient management improves crop vigor and productivity. Furthermore, adding legume waste improves soil fertility, nitrogen buildup and maize yield (Gupta *et al.,* 2024).

Nutrient management is equally essential. Under mulched conditions, the dynamics of nutrient availability change owing to the slower decomposition of organic material. This requires careful synchronization between native nutrient release and external supplementation through fertilizers or organic sources. Integrated Nutrient Management (INM), which involves a judicious blend of chemical fertilizers with organic amendments and biofertilizers (such as Azotobacter and PSB), has been proven effective in improving nutrient use efficiency, yield stability and environmental safety (Namatsheve *et al.,* 2024). Under mulched soils, maize nitrogen-use efficiency (NUE) improves due to reduced volatilization losses and

enhanced nutrient immobilization and mineralization (Sahoo *et al.,* 2024).

The integration of organic mulching with site-specific planting geometries and adaptive nutrient regimes offers a sustainable approach to enhance productivity and profitability in *kharif* maize systems of Punjab. Environmentally, it reduces the dependence on synthetic agrochemicals, conserves soil moisture, improves organic matter content and supports climate-resilient farming through higher carbon sequestration. Agronomically, it promotes better crop establishment, root growth, weed suppression and grain filling, leading to higher yield and quality. Socioeconomically, these eco-intensification practices lower input costs, increase net returns and align with government initiatives such as the “Mera Pani, Meri Virasat” scheme and the National Food Security Mission (GOI, 2024).

In the present context, Punjab is under pressure to halt groundwater exploitation and mitigate the risks of overreliance on the rice-wheat system. With the state’s vision of expanding maize acreage to 5 lakh hectares in pursuit of sustainable cropping patterns (BISA, 2024), it is imperative to understand the combined effects of mulching and agronomic innovations on maize productivity and system health. Although several isolated studies have analyzed the effects of mulching, planting pattern and fertilization in maize separately, there is limited research on their integrated use in Punjab’s maize-based systems. During the *kharif* season of 2023, maize was cultivated on approximately 97,000 hectares in Punjab, producing approximately 5 lakh tons of grain (Department of Agriculture, Punjab, 2024). The major maize-growing districts include Ludhiana, Hoshiarpur, Kapurthala, Jalandhar, Ferozepur, Bathinda, Sangrur and Amritsar. Ludhiana, in particular, plays a pivotal role in maize research and seed production through institutions such as the Punjab Agricultural University (PAU) and the Borlaug Institute for South Asia (BISA).

Therefore, the present investigation, entitled ”Organic Mulching in *Kharif* Maize (*Zea mays* L.) under Diverse Planting Patterns and Nutrient Levels: Enhancing Resource Use Efficiency, Productivity and Environmental Sustainability,” is designed to fill this research gap. This study aimed to evaluate how organic mulching, when applied in synchronization with optimal planting designs and nutrient levels, contributes to weed suppression, resource use efficiency, yield enhancement and environmental conservation in Punjab’s agro-climatic conditions.

Punjab is a leading state in India for maize cultivation, with major growing districts including Ludhiana, Bathinda, Jalandhar and others selected for this study. The geographical distribution of these maize-producing districts is illustrated in Fig 1.

Table 1: Initial physico-chemical characteristics of soil (0-15 cm depth).

Soil characteristics	Values	References
pH (1:2.4)	6.18	Jackson, 1973
Electrical conductivity (dS m^{-1})	0.18	Jackson, 1973
Organic carbon (%)	0.50	Walkley and Black (1934)
Available N (kg ha^{-1})	148	Subbiah and Asija (1956)
Available P (kg ha^{-1})	15.71	Watanabe and Olsen (1965)
Available K (kg ha^{-1})	172	Jackson, 1973

MATERIALS AND METHODS

Study area

The field experiment was carried out at the Research Farm of the Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India, during the *Kharif* season of 2024. The research site is located in the Northern plain zone, specifically between 31°14′43″N latitude and 75°42′00″E, at 243 m mean sea level, as depicted in Fig 2. Meteorological data were collected from the University’s Agromet Observatory, located at 31°14′41″N, 75°42′05″E latitude and longitude during the crop growth season, as shown in Fig 3. During the cropping period temperature was flluctating from 39.4°C to 10.3°C which alos influence the various plant metabolic activities. The soil texture at study site were sandy loamy, having littal acidic in nature and low in organic carbon content, available

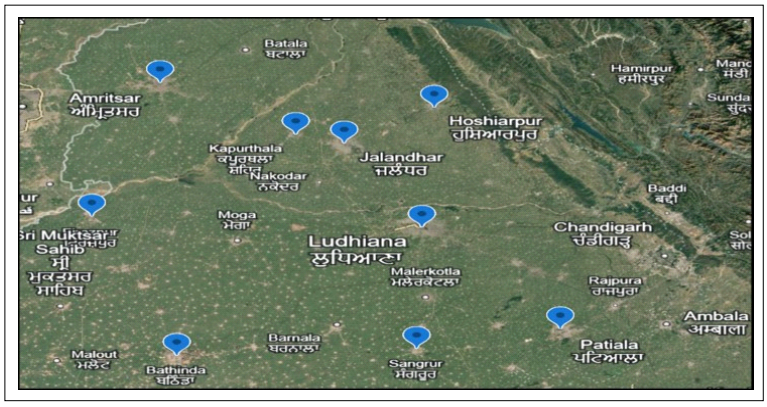


Fig 1: Geographical distribution of maize-growing districts in the Punjab region.

nitrogen and potassium and medium in available phosphorous, as shown in Table 1. The field experiments were carried out in principal maize-growing districts of Punjab (Fig 1), encompassing Ludhiana, Bathinda, Jalandhar and Sangrur, representing diverse agro-ecological zones of the region.

Design and layout

The experiment was based on a split-plot design comprising 12 treatments. In this setup, factors that are more challenging to manage, such as planting geometry and nutrient levels, are assigned to the larger main plots, while the different types of organic mulching are applied within smaller subplots. This arrangement, featuring three main plot treatments combined with four subplot treatments, allows for an efficient evaluation of the individual and combined effects of the treatments. The split-plot design optimizes the practical application of complex field experiments and ensures reliable statistical comparison of both the main effects and their interactions. Treatments in the main plot included 60 × 20 cm @ 80-40-40 (N:P:K) kg/ha, 75 × 20 cm @ 100-50-50 (N:P:K) kg/ha and 90 × 20 cm @ 120-60-60 (N:P:K) kg/ha. In the sub-plot, no mulch, live mulch, wheat straw mulch and sugarcane mulch were used as treatments.

Variety (Maize)

NK 7328 is a high-yielding hybrid maize variety widely cultivated in Punjab, particularly during the *kharif* season, owing to its strong adaptability and robust performance under regional agro-climatic conditions. Sown on July 10, 2024, with a seed rate of 25 kg/ha, NK 7328 features early to medium maturity (110-115 days), good disease and stress tolerance and produces bold, deep orange kernels on well-filled cobs. The crop was harvested on November 2, 2024, demonstrating its suitability for both rainfed and irrigated conditions in Punjab's.

Growth analysis of maize

Growth parameters, such as plant height and number of leaves per plant, were recorded at regular intervals (30, 60 and 90 DAS and at harvest) to assess vegetative

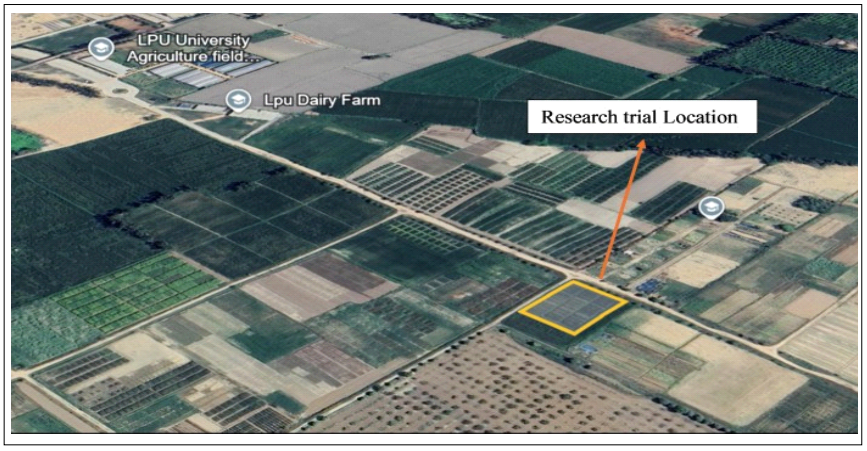


Fig 2: Research trial at Lovely Professional University, Phagwara, Punjab.

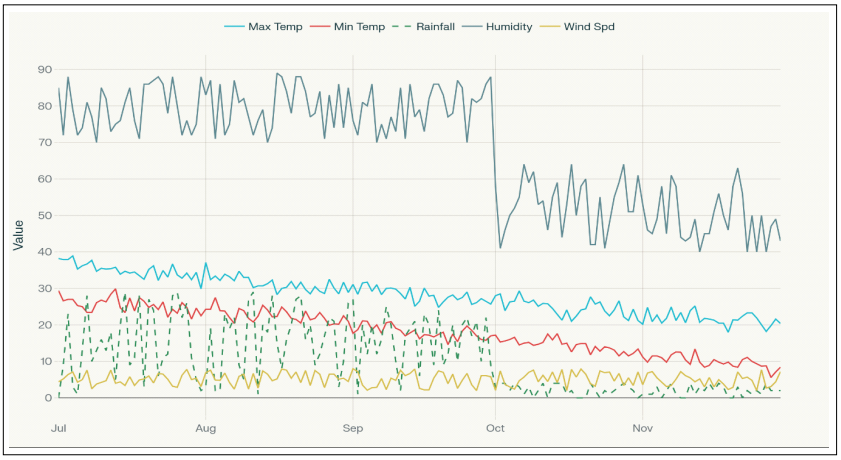


Fig 3: Meteorological data from July to November 2024 at LPU University, Phagwara, Punjab, showing monthly max/min temperature, rainfall, humidity and wind speed.

performance. In each plot, five healthy plants were randomly tagged for uniform observation. Plant height was measured from the ground level to the tip of the terminal leaf (excluding the tassel) using a measuring tape. The mean plant height per plot was calculated from the five tagged plants. For leaf count, the number of fully expanded leaves on each tagged plant was recorded on the same days. The average number of leaves per plant was computed to evaluate foliage development. These data were statistically analyzed to determine the effect of treatments under the split-plot design, providing insights into crop vigor and growth behavior.

Yield attributes of maize crop

The mean value per plant for each experimental unit was determined by recording the number of cobs from five tagged plants at the time of harvest. To estimate the average number of grains per cob, the total number of rows per cob and the number of grains in each row were recorded for each cob. Five plants were randomly selected from each plot and their cob lengths were measured using a centimeter scale. The cobs were then shelled and the grains obtained from these selected plants were cleaned and weighed; this weight was converted to a yield value expressed in kilograms per hectare (kg/ha). For quality assessment, 100 seeds were randomly collected and weighed to determine the test weight. The dry matter yield of the crop, referred to as stover yield, was measured by separating the cobs from the plants, drying the remaining plant material, recording its weight and converting it to a per-hectare basis. Finally, the harvest index (HI) was calculated using the formula provided by Donald and Hamblin (1976), where HI is the ratio of grain yield to the total above-ground dry biomass.

Yield assessment studies

Correlation matrix analysis between growth and yield attributes

Correlation analysis is a statistical technique used to assess the strength and direction of the relationship between two or more variables, such as growth and yield attributes, in crop research. By calculating correlation coefficients, researchers can quantify how changes in one parameter, such as plant height or number of leaves per plant, are associated with changes in yield components, helping to identify which growth traits are most closely linked to crop productivity (Bello *et al.,* 2012). In this study, a correlation analysis was conducted to examine the relationships between growth and yield attributes. The analysis was performed using the GRAPES software platform (general R-based analysis platform empowered by statistics), which is widely used for statistical analysis in agricultural research. Specifically, GRAPES was used to calculate the correlation coefficients, quantifying the strength and direction of the associations between the measured variables.

Correlogram analysis

Correlogram analysis gives a visual summary of the correlation matrix between growth and yield parameters. This makes it easy to understand how different crop traits are related to each other. It shows traits that are either positively or negatively related to yield and groups of variables that are related to each other by using color gradients to show correlation coefficients. This graph makes it easier to understand how different traits interact with each other, which helps with further statistical analysis and decision-making in crop breeding and management. This study utilized the GRAPES software (general R-based analysis platform empowered by statistics) for correlogram analysis to calculate correlation coefficients and illustrate relationships among growth and yield attributes (Graffelman *et al.,* 2023).

Statistical analysis

The collected data were first entered into MS Excel for averaging and performing preliminary calculations. Subsequently, a one-way analysis of variance (ANOVA) was performed using the CVSTAT software to evaluate the significant differences among the treatments at the 95% confidence level ($p = 0.05$). The critical difference (CD) and standard error of mean (SEM) values are presented in tables. To identify specific differences between the treatment means. All statistical analyses were conducted using the CVSTAT software.

RESULTS AND DISCUSSION

Correlation matrix analysis and correlogram of growth and yield traits under different planting patterns, nutrient levels and organic mulching in maize (Table 2, 3 and Fig 4).

Plant height (cm)

Plant height had a strong positive correlation with several growth and yield parameters, including the number of leaves ($r = 0.955$, $p<0.001$), cob length ($r = 0.937$, $p<0.01$), cob girth ($r = 0.985$, $p<0.001$), number of grains per cob ($r = 0.995$, $p<0.001$), test weight ($r = 0.983$, $p<0.001$), grain yield ($r = 0.996$, $p<0.001$) and biological yield ($r = 0.996$, $p<0.001$). Table 2 revealed the substantial negative connection ($r = -0.83$, $p<0.05$) between days to tassel and days to silking. This suggests that taller plants produce flower earlier, perhaps improving yield performance. The substantial positive associations between plant height and yield-related variables demonstrate that taller plants have more vegetative vigor, ultimately translates to better grain output and biomass. Plant height revealed a negative connection with flowering time, indicating that taller plants with earlier flowering maximize growth duration for yield creation. Zhang *et al.* (2021) observed similar findings, indicating that increase in plant height had a favorable impact on kernel weight and grain yield in maize under optimal agronomic conditions.

Table 2: Correlation matrix analysis of growth and yield traits under different planting patterns, nutrient levels and organic mulching in maize.

	Plant height	No. of leaves	Days to tasseling	Days to silking	Cob length	Cob girth	No. of grains/cob	Test weight	Grain yield	Biological yield
Plant height	1	0.955***	-0.828*	-0.828*	0.937**	0.985***	0.995***	0.983***	0.996***	0.996***
No. of leaves	0.955***	1	-0.683	-0.683	0.925**	0.983***	0.963***	0.948**	0.944**	0.958***
Days to tasseling	-0.828*	-0.683	1	1***	-0.819*	-0.782*	-0.796*	-0.855*	-0.832*	-0.839*
Days to silking	-0.828*	-0.683	1***	1	-0.819*	-0.782*	-0.796*	-0.855*	-0.832*	-0.839*
Cob length	0.937**	0.925**	-0.819*	-0.819*	1	0.935**	0.956***	0.978***	0.948**	0.962***
Cob girth	0.985***	0.983***	-0.782*	-0.782*	0.935**	1	0.981***	0.972***	0.972***	0.984***
No. of grains/cob	0.995***	0.963***	-0.796*	-0.796*	0.956***	0.981***	1	0.986***	0.996***	0.996***
Test weight	0.983***	0.948**	-0.855*	-0.855*	0.978***	0.972***	0.986***	1	0.988***	0.995***
Grain yield	0.996***	0.944**	-0.832*	-0.832*	0.948**	0.972***	0.996***	0.988***	1	0.996***
Biological yield	0.996***	0.958***	-0.839*	-0.839*	0.962***	0.984***	0.996***	0.995***	0.996***	1

Note: ***Correlation is significant at 0.001 level (two tailed); **Correlation is significant at 0.01 level (two tailed); *Correlation is significant at 0.05 level (two tailed).

Number of leaves

Strong correlation between the number of leaves per plant and most yield-related traits, including cob length (r = 0.925, p<0.01), cob girth (r = 0.983, p<0.001), number of grains per cob (r = 0.963, p<0.001), test weight (r = 0.948, p<0.01), grain yield (r = 0.944, p<0.01) and biological yield (r = 0.958, p<0.001) as shown in Table 2. However, obtained results showed considerable negative relationships with flowering time features (days to tassel and days to silking), though these were weaker and not always statistically significant, indicating that leaf development is closely related to vegetative growth and yield. The strong positive relationships between the number of leaves and yield components underline the importance of leaf development in photosynthetic capacity and assimilate supply to the kernel. Moderate negative associations with flowering time support the notion that prolonged vegetative development delays flowering while potentially reducing production efficiency under certain situations. These findings are consistent with those of Gonzalez *et al.* (2022), who said that leaf area duration was critical to maize yield performance.

Days taken to tasseling and days to silking

Days taken to tasseling and silking were substantially positively associated (r = 1.00, p<0.001), as expected given their flowering-related temporal features. Table 2 resulted that both reproductive parameters had significant negative correlations with growth and yield traits such as plant height, cob length, cob girth, grain number, test weight, grain yield and biological yield (correlations ranging from -0.78 to -0.85, p<0.05) during the study period. The preceding results showed that delayed flowering was often related to reduced vegetative growth and production, potentially because to inefficient resource partitioning or prolonged exposure to environmental stress. The perfect link between flowering features has been widely documented, but their negative relationship with yield and growth traits suggests that delayed flowering can reduce maize output due to shorter grain-filling periods or environmental constraints. This pattern was supported by Li *et al.* (2020), who found that early-flowering hybrids produced better grain yields in drought-prone circumstances.

Cob length (cm) and cob girth (cm)

Table 2 showed a positive correlation between cob length and cob girth with almost all yield attributes and growth traits *viz*; number of grains per cob (r = 0.956, p<0.001), test weight (r = 0.978, p<0.001), grain yield (r = 0.948, p<0.01) and biological yield (r = 0.962, p<0.001). These results underscore the importance of cob size in affecting overall kernel and biomass yields. The substantial positive link between cob length and yield attributes emphasizes its significance as a predictor of kernel number and size, which determines total productivity. Silva *et al.* (2023) and Lopez's (2021) found that cob size is a significant morphological characteristic related with production stability in maize crops under stress and favorable settings.

Number of grains per cob

Strong correlation (r = 0.986, p<0.001) between the number of grains per cob and several yield attributes such as test weight, grain yield and biological yield as presented in Table 2. These substantial associations suggested that the quantity of grains was a critical predictor of maize yield outcomes, emphasizing its importance in productivity breeding. The near-perfect correlation between grain number and yield characteristics emphasizes the grain set as a key yield component. Such strong associations are consistent with the findings of Nguyen *et al.* (2022).

Test weight (gm)

Table 2 showed that test weight, an indirect indicator of grain density and quality, has a strong positive correlation with grain yield (r = 0.988, p<0.001) and biological yield (r = 0.995, p<0.001), indicating its importance as an integrative trait reflecting overall grain quality and plant productivity. Strong correlations between test weight and yield factors imply that they are useful as proxies for grain quality and kernel fullness. Kumar *et al.* (2021) found that greater test weights are highly associated with better grain filling and ultimate grain yield in maize.

Grain yield (q/ha)

Table 2 showed that a perfect correlation (r = 0.996, p<0.001) between grain yield and biological yield, indicating that as grain production increases, so does total biomass. This confirms the expectation that biomass accumulation is closely related to grain development in maize. The nearly perfect correlation between grain and biological yields demonstrates that biomass accumulation is inextricably related to grain production, hence establishing the source-sink relationship. Ren *et al.* (2022) reached similar conclusions, observing a substantial relationship between biomass and grain yield in maize across different conditions.

Table 3: Matrix of P-values (Correlation matrix).

	Plant height	No. of leaves	Days to tasseling	Days to silking	Cob length	Cob girth	No. of grains/cob	Test weight	Grain yield	Biological yield
Plant height	NA	0.001	0.021	0.021	0.002	0.000	0.000	0.000	0.000	0.000
No. of leaves	0.001	NA	0.091	0.091	0.003	0.000	0.000	0.001	0.001	0.001
Days to tasseling	0.021	0.091	NA	0.000	0.024	0.038	0.032	0.014	0.020	0.018
Days to silking	0.021	0.091	0.000	NA	0.024	0.038	0.032	0.014	0.020	0.018
Cob length	0.002	0.003	0.024	0.024	NA	0.002	0.001	0.000	0.001	0.001
Cob girth	0.000	0.000	0.038	0.038	0.002	NA	0.000	0.000	0.000	0.000
No. of grains/cob	0.000	0.000	0.032	0.032	0.001	0.000	NA	0.000	0.000	0.000
Test weight	0.000	0.001	0.014	0.014	0.000	0.000	0.000	NA	0.000	0.000
Grain yield	0.000	0.001	0.020	0.020	0.001	0.000	0.000	0.000	NA	0.000
Biological yield	0.000	0.001	0.018	0.018	0.001	0.000	0.000	0.000	0.000	NA

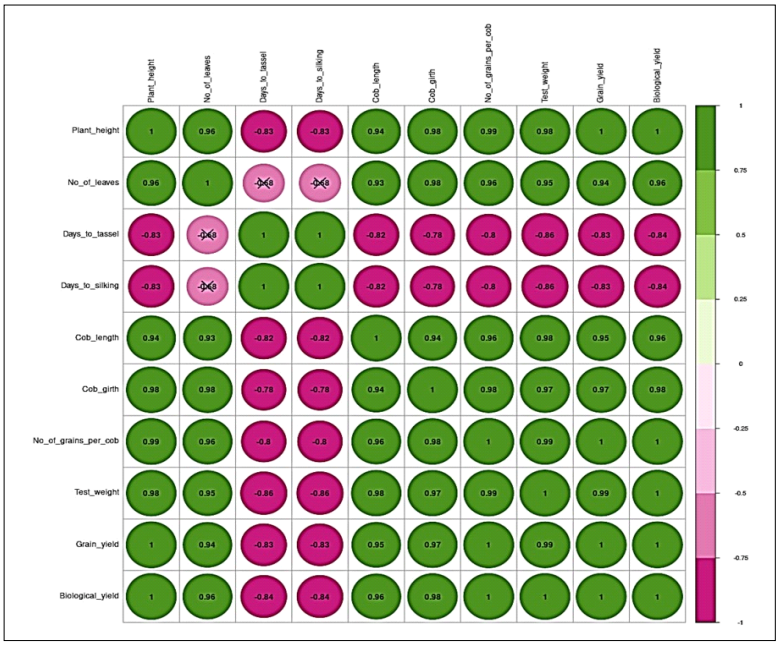


Fig 4: Correlogram analysis of growth and yield parameters in maize.

Biological yield (q/ha)

Biological yield, which includes all aboveground plant material, showed very strong positive correlations with all existing traits except flowering times, reinforcing the fact that high biomass production is directly related to robust vegetative growth and grain yield components shown in Table 2. Biological yield has significant positive associations with all growth and yield components except blooming time, indicating that it reflects overall plant vigor and production potential. This finding is comparable with that of Oliveira *et al.* (2023), who found that biological yield is an important integrative indicator associated to vegetative growth and grain production in maize breeding trials.

CONCLUSION

This study discovered significant connections between growth and yield parameters in maize due to various planting pattern along with nutrient levels and organic mulching. From above discussion it can be concluded that yield attributes directly linked with growth parameters and showed strong positive correlation with each other, while reproductive part showed negative relationship with growth and yield parameters. The study highlights that selecting for higher plant height, cob size and grain quality is crucial for increasing maize yields. Nutrient optimization and organic mulching helped to support these features as well as total biomass accumulation. Overall, plant height, cob length and test weight are critical targets for maize plant density and management to obtain improved long-term yields.

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Disclaimers

The authors of this article are the only ones who wrote the statements, opinions and conclusions. These do not necessarily represent the views or positions of the institutions they work for. The authors are solely responsible for the content's accuracy and honesty and they are not liable for any damages from using or applying the information in this article.

Ethical issues

None.

Informed consent

This study did not involve the use of animals or human participants. Hence, ethical approval and informed consent were not required.

Conflict of interest

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