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Effect of crop geometry and use of nitrogen in various times on maize yield

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Abstract

A field experiment was conducted in 2024 kharif season at the Kunar, Afghanistan to study the Effect of crop geometry and use of nitrogen various doses in various times on yield of Maize (*Zea mays* L.). The experiment was included by 15 treatments combination which included application of three different doses of nitrogen (N₁-Recommended dose of nitrogen (RDN) at 150 kg ha⁻¹ in three splits, N₂ - RDN at 150 kg ha⁻¹ in four splits N₃ - LCC based N application) and five different spacing among the planning rows (M₁-60 × 25 cm- Recommended crop geometry, M₂-30 × 30 cm, M₃-35 × 35 cm, M₄-45 × 45 cm and M₅-50 × 50 cm which were tested in split plot design with planting spacing in main plots and nitrogen doses in different times and approaches in subplots. Result revealed that higher values of grain yield attributes as Length of cob(18.3cm), cob girth (15.4 cm), weight of cob (292.7 g), number of grains (34.1) per row, number of grains (500.5) per cob, 100 grains weight (43.1 g) were significantly higher in M₅ (50x 50) spacing, significantly higher grain yield (9601.3 kg/ha) was noted in M₁ (60x25), Significantly higher Length of cob(17.5 cm), cob weight (264.4 g), significantly higher number of grains per row (32.9), number of grains per cob (475.4), 100 grains weight (42.7 g), grain yield (8943.8 kg/ha), while higher cob girth (14.9) in N₂. M₅ (50x 50) spacing and N₃ - leaf color chart based N application were best treatment for better growth and higher yield and productivity of maize.

Keywords: Kharif, maize, split, nitrogen, yield, productivity, leaf color chart, spacing

Introduction

After rice and wheat, maize (*Zea mays* L.) is the third most important cereal in the world and in India. The crop is highly adaptable and can be grown in a variety of environments. It can be used for a wide range of purposes, including human consumption (17%), animal feed (61%), and the production of numerous industrial products (22%), such as food sweeteners, ethanol, oil, alcoholic beverages, pharmaceuticals, cosmetics, and more (Anonymous, 2013) [3].

According to Chaudhry (1983), maize grains are higher in nutrients since they contain 72% starch, 10% protein, 4.8% oil, 8.5% fiber, 3.0% sugar, and 1.7% ash. Maize may become a significant crop in terms of area and output in the coming decades due to the growing demand for it as food, feed, and industrial products. By 2025, it is anticipated that the demand for maize worldwide would surpass that of rice and wheat, with India's demand reaching 42 million tons. (Unnamed, 2013). Prominent Nobel laureate Dr. Norman E. Borlaug, the founder of the green revolution, has stated that it is the crop of the future (Anonymous, 2013) [3]. A miracle crop known as the "queen of cereals," maize is cultivated on 168 million hectares in more than 166 nations, yielding 854 million tons and 5120 kg of productivity per hectare (USDA, 2012). With 8.71 million hectares and 21.76 million tons, India ranks fourth in terms of both area and production. The average yield is 2498 kg per hectare (FAO, 2012), which is significantly less than the global average. While maize is grown in practically every state in India, 60% of the country is concentrated in six large states: Andhra Pradesh, Uttar Pradesh, Karnataka, Rajasthan, Bihar, and Madhya Pradesh. About 3.46 lakh hectares of maize are grown in Tamil Nadu, yielding 16.95 lakh tons of grain and a productivity of 5173 kg ha⁻¹ (GOI, 2012), which is double the national average.

Any crop plant's productive efficiency is mostly dictated by its genetic makeup and how it reacts to the current conditions in which it is grown. However, because of the constraints imposed by

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different abiotic and biotic factors, the majority of crop plants do not attain their genetic yield potential. Nevertheless, output could be significantly boosted by efficient management through agronomical approaches that are appropriate for the current environment. The maize crop is not an exception to this rule; despite being a C4 photosynthetic plant and being well suited to a tropical climate, a number of environmental constraints limit its yield. Crop shape, density, and fertilization particularly nitrogen are thought to be the most important components in achieving the highest possible yield. The two resources that are most crucial for plant development are light and nitrogen. Photosynthesis, the process by which plants grow, depends on light. Since crop geometry is thought to affect light interception, which is the process by which photosynthesis—the process by which green sections of the plant are used to manufacture energy—occurs, it is a crucial agronomic characteristic. Additionally, it has an impact on how well plants utilize the photosphere and rhizosphere, particularly when they cluster together and are given insufficient room. The number of plants permitted on a specific unit of land area for maximum yield is known as the plant density, and it is determined by proper plant spacing (Hammer *et al.*, 2004) [7]. When the spacing between plants was widened in one direction and shrunk in the other, the maximum rectangularity at a specific density would be achieved. The terms "narrow rows" and "wide rows" relate to the planting patterns of square and rectangle planting geometry, respectively. Generally speaking, maize was grown farther between rows than within a single row.

The advent of single-cross maize hybrids that can withstand increased planting densities has promoted narrow-row maize production in recent decades. In a number of investigations, the maize canopy was regarded as a uniform medium with a random distribution of leaf orientations. A more even distribution of roots and leaves will result from corn cultivated in thin rows, which could lead to a more efficient use of water and light resources (Sharratt and Mc Williams, 2005) [13]. The advantages of square planting in maize were not thoroughly studied by experts. Maize plants are planted in squares and more evenly scattered across the surface, covering the surface area as soon as possible. In maize, a closer square planting arrangement yielded a greater LAI than a larger rectangle pattern. Maize cultivated in a square configuration intercepted more PAR during the blooming stage than maize produced in a rectangular arrangement (Acciaresi and Chidichimo, 2007) [1]. Higher grain output is also a result of improved resource usage and reduced competition from weeds. A number of factors, notably the nitrogen factor, affect maize productivity.

N fertilizers have historically been sprayed consistently throughout the field, disregarding the spatial variance in crop N requirements within agricultural fields. As a result, too much nitrogen lowers nitrogen usage efficiency, whereas too little nitrogen lowers yields. N fertilization significantly increased maize yield (92%) as opposed to rice (47%) and wheat (50%) output (Khosla *et al.*, 2010) [9].

Indian farmers frequently apply larger levels of N fertilizer because they believe that this affects the growth response and greenness of maize crops. Additionally, using broad-based blanket fertilizer N recommendations limits the effective use of N fertilizer due to the significant field-to-field variability of soil N supply (Cassman *et al.*, 1996) [5]. Large N losses from the soil-plant system result in low N fertilizer use efficiency when N delivery is not coordinated with crop needs. N fertilizer application must be timed to the plant in order to maximize nitrogen utilization and reduce pollution in the environment. A

significant obstacle for researchers and producers is the efficient management of fertilizer, especially N. We need a monitoring method to assess the N status of crops in order to respond to the queries of when, where, and how much. The method should ideally be quick and inexpensive, and it should enable quick decisions.

Around the past 15 to 20 years, researchers from all around the world have been working to create precision N management strategies in an effort to overcome the drawbacks of conventional N management techniques. Chlorophyll meters and tissue tests could be utilized to make a choice. Cutting-edge instruments like chlorophyll meters can assist in determining when plants require nitrogen the most and are quicker than tissue testing for the element. Maize farming is significantly impacted by crop geometry, which includes elements like planting density, row spacing, and plant spacing. Light interception, nutrient and water uptake, weed competition, and yield potential are only a few of the aspects of crop growth that it affects (Sangoi & Gracietti, 2018) [11]. A number of variables, such as soil properties, climate, and particular agronomic techniques, influence the choice of appropriate crop geometry for maize crops. There is very little information on the square planting pattern to investigate the resources that are accessible and appropriate N scheduling techniques to optimize maize production and profit.

Hence, this study has been contemplated on hybrid maize with various square crop geometry levels and traditional as well as site-specific N management approaches under irrigated upland conditions with the following objectives.

- To study and find out the optimum planting geometry to hybrid maize,
- To optimize nitrogen scheduling for maize.

Materials and Methods

In 2024, field tests were conducted in Afghanistan's Kunar province to examine the effects of nitrogen timing and planting geometry on hybrid maize grown under irrigated condition. The following describes the specifics of the materials utilized, the approaches taken for the field investigation, and the laboratory analytical techniques employed during the experiment.

Experimental field location

In 2024, the experiments were carried out in Kunar province with technical support of Agriculture faculty of Logar University. The farm is located at 34°N latitude, 68°E longitude, and 1040.44 meters above mean sea level in the semi-tropical Agro-Climatic region.

Climate and Weather

The province of Kunar, in eastern Afghanistan, has a continental climate with chilly winters and scorching summers. Nighttime lows in January are typically about 3 °C (37 °F), while daytime highs are around 18 °C (64 °F). The greatest and lowest average temperatures for the cropping period were 30.2 °C and 21.1 °C, respectively, and 31.0 °C and 21.5 °C.

The area typically experiences clear skies with minimal humidity, which makes it comparatively dry. sees 123.65 rainy days (33.88% of the time) and 250.23 to 300 millimeters of precipitation on average every year.

Soil properties of experimental site

The experimental site had clay loam soil. A variety of physico-chemical properties were examined in the composite soil sample that was gathered before the experiment was carried out. The

soil at the experimental sites was found to be slightly alkaline (pH 8.35 and 8.2), with low range of soluble salts (EC 0.65 and 0.76 dSm⁻¹), low levels of organic carbon (0.41 and 0.39 percent), low levels of available nitrogen (212 and 204 kg/ha), medium levels of available phosphorus (15.3 and 16.2 kg/ha), and high levels of available potassium (551 and 525 kg/ha) in 2024.

Crop management and land Preparation

The field was ploughed, harrowed and then leveled to form ridges and furrows.

Seeds and sowing

Maize hybrid (CH124) Seeds were sown on the side of the ridges by adopting various square planting configuration with population densities ranged from low to high as per treatment. Seeds were dibbled at the rate of one seed per hill. The seeds were pre-treated with applying of *Vitavax* (4g kg⁻¹ of seed) before sowing.

Manures and fertilizers

The field was evenly covered with well-decomposed farm yard manure (FYM) at a rate of 12 t ha⁻¹ before to the final plowing. Subplots were given nitrogen scheduling assignments. N₁ treatments received 25, 50, and 25 percent of the RDN at 150 kg ha⁻¹ at basal, 25 and 45 DAS, while N₂ treatments received each 25 percent at basal, 15, 30, and 45 DAS. 30 kg N ha⁻¹ was applied as a base treatment for N₃, and when the average noted LCC value dropped below 5, N was top dressed at 30 kg ha⁻¹ using a need-based approach to LCC-based N scheduling. P₂O₅ was sprayed at the base level in the prescribed full amount of 75 kg ha⁻¹. The K₂O (75 kg ha⁻¹) was applied in two equal split doses viz., basal and with first top dressing of nitrogen. The fertilizers for nitrogen (N), phosphorus (P), and potassium (K) were applied as muriate of potash (60 percent K₂O), single super phosphate (16 per cent P₂O₅), and urea (46 percent N), respectively. By creating tiny furrows, the fertilizers were positioned on the ridge sides at a depth of 5 cm.

Irrigation

First irrigation was given immediately after sowing of maize. Life irrigation was given on six days after sowing (DAS). Irrigations were given on base of need at an interval of 8-10 days after cultivation.

Gap filling

Gap filling was done on after first week of sowing and thinning was done on 15 DAS by leaving one healthy seedling per hill.

Weeds control

Atrazine (50%) WP was sprayed at 0.5 kg a.i. ha⁻¹ on as pre-emergence herbicide using knapsack power generated sprayer which followed by once with hand weeding on 35 DAS. Enough prophylactic measures were taken against pests.

Harvesting and threshing

The net plots were harvested separately after the first two border rows on each of the plot's four sides were harvested separately and then the collected cobs underwent drying, de husking, shelling, and cleaning. The grains were cleaned and then sun-dried until they had a moisture level of 13%. Each treatment's grain weight was noted and represented in kilograms per hectare.

Leaf colour chart observations (LCC)

The standardized new four panel LCC developed by IRRI, Philippines in collaboration with the University of California Co-operative Extension (UCCE) was utilized to test the intensity of the leaf color (Witt *et al.*, 2005) ^[17]. The LCC values at the middle lamina of the third leaf from the top of the maize plant were recorded at weekly intervals of 21 to 22 DAS and up to 72 DAS. The third fully developed leaf from the top of the plant was selected for the evaluation of leaf color because of its close relationship to the nitrogen status of maize plants. The general guidelines for using LCC are as follows.

From five randomly selected maize plants in a same population places, the five youngest, completely extended, and healthy leaves (third from the top) were chosen for the purpose of measuring leaf color. Holding the LCC, the central portion of each chosen leaf was placed on top of a color strip for comparison in order to measure its color. The leaf did not become detached or be destroyed during the process. The leaf being measured was protected from the sun during the measuring process since the angle and strength of the sun's rays alter the reading of leaf color. Throughout all of the observation days, measurements of leaf color were recorded before 11:00 AM and after 5:00 PM. The average of the two values was used as the reading whenever the leaf's color appeared to fall between two color hues. Five LCC readings were averaged and computed. N fertilizer was top-sprayed right away to address N deficiencies if the average range of the leaf color readings dropped below the predetermined critical threshold.

Yield and yield components

For assessing the relationship between yield and its components, the following parameters were recorded at the time of harvest. The details of the method for estimating each character are indicated below.

Length of cob

Five cobs' lengths were measured for each treatment and replication, and the average cob length was determined. The results are given in centimeters.

Girth of cob

The mean cob girth was computed and the values are given in centimeters. The girth of five cobs were measured for each treatment and replication.

Cob weight

The weight of five cobs, for each treatment and replication wise was noted and the mean weight of the cob was recorded and the values are shown in g per cob.

Number of grains per row

The total number of grains in each row of the cobs of five samples plant was counted and mean was find out and expressed as number of grains per row.

Number of grains per cob

At harvest, five cobs from each treatment and replication were chosen and the samples were threshed and cleaned manually. Number of grains per cob were counted and expressed grains per cob.

Hundred kernel weight

The randomly chosen 100 grains were air dried for each treatment (in three replications) and then weight was recorded.

The mean was noted and expressed in g.

Grain yield

The cobs from the net plot were harvested separately. The cobs were sun dried, shelled, cleaned and grain yield was recorded for individual treatment at 12 per cent seed moisture and expressed in kg per ha.

Statistical analysis

As recommended by Gomez and Gomez (2010) [6], statistical analysis was performed on the obtained data. Critical differences were calculated at the five percent probability level in cases where the treatment differences were deemed significant. Wherever the interaction impact was deemed substantial, it was discussed. NS stood for non-significant treatment differences.

Experimental Results

The impacts of crop geometry and nitrogen scheduling in maize under irrigated conditions were investigated in 2024 through field experiments carried out in Kunar province with assistance from the Department of Agronomy at Agriculture faculty of Logar University. The experimental findings are explained here. Two set of treatments as crop geometry and nitrogen scheduling in the investigations were represented as M and N, respectively. The levels of crop geometry were expressed as M₁, M₂, M₃, M₄, and M₅ and the nitrogen scheduling approaches adopted in the study were denoted as N₁, N₂ and N₃ accordingly for easy interpretation of results obtained.

Length of cob

The effect of length of cob was furnished in table. Crop geometry and N scheduling treatments significantly influenced length of cob. Length of cob was significantly higher in under 50x50 cm spacing (M₅) (18.3 g) respectively. Length of cob was lowered in 30x30 cm spacing (M₂). This could be due to higher photosynthesis due to more spacing and light among the rows which contributed to higher cob length. Similar result was reported by Hashem *et al.*, (2021) [8].

Nitrogen scheduling method significantly impacted cob length under LCC (N₃) which recorded higher cob length (17.5 cm) and lower cob length (16.4 cm) in N₁ treatment than other treatments respectively. This might be due to effective utilization of applied nutrients which increased cob length.

Girth of cob

Crop geometry and N scheduling had a major impact on cob girth; significantly more cob girth was gained at 50x50 cm spacing (15.4 cm), whereas lower cob girth was achieved at 35x35 cm spacing (M₃). Perhaps light interception between the rows is to blame for this. A more consistent light environment within the canopy was thought to be the cause of this improvement in cob girth, since it decreased intra-plant competition for nutrients and light. Shapiro and Wortmann reported a similar outcome (2006) [12]. Cob girth increased with N₂ treatment, and nitrogen scheduling had a major effect on cob length. The divided dose of nitrogen that prevents nitrogen loss and leaching with water from the root zone may be the cause of this.

Cob weight

Crop geometry and N scheduling had a significant effect on cob weight; (M₅) cob weight was highly significant at 50x50 cm spacing (292.7 g), while (M₂) cob weight was lower at 30x30 cm spacing. This discrepancy may occur from the ideal distance

between plants or rows, which has a direct impact on cob weight and size. Closer spacing causes more competition between plants, which reduces cob weight and size. Hewitt and colleagues observed a similar outcome in 2020.

Nitrogen scheduling significantly impacted cob weight, the maximum (264.4 g) cob weight was reported under LCC based N management in N₃ treatment. The increase in cob weight was due to increase in leaf area, plant height, formation of more number of green leaves per plant and increased photosynthesis rate lead to increased sink size which was due to nitrogen applying on time. Similar finding was also given by Amanullah and Shah (2010) [2].

Number of grains per row

The average values of number of grains per row are furnished in table. The amount of grains per row was significantly impacted by the spacing and N scheduling treatments. When compared to other treatments, the number of grains per row was significantly larger under a wider spacing of 50 x 50 cm (M₅) (34.1). Compared to the other treatments, the number of grains per row was lower (29.8) at 60x25 cm spacing (M₁). This effect may result from increased light interception brought on by greater spacing, which increases photosynthesis.

Nitrogen scheduling approaches also significantly impacted the number of grains per row and N scheduling based on LCC (N₃) recorded more number of grains per row (32.9) respectively than other treatments. Among different approaches, RDN at 150 kg ha⁻¹ in 3 splits (N₁) gained the lowest number of grains per row (31.7), respectively. This might be due to applying of nitrogen on time and on need base. Same result was obtained by Srikanth *et al.*, (2009) [15].

The interaction effect between crop geometry and N scheduling approaches was found to be non-significant.

Number of grains cob⁻¹

Grains cob⁻¹ was significantly influenced by crop shape and N scheduling. Throughout the season, M₅ (50 × 50 cm) had the highest number of grains cob⁻¹ (500.5) among the various spacing treatments. It is evident that M₂ (30 × 30 cm) had the lowest grains cob⁻¹ (427.3). The development of cobs with an ideal number of grains per cob can be encouraged by appropriate crop geometry in conjunction with optimal environmental management techniques. Liang *et al.* reported the same Outcome in 2020.

The quantity of grains cob⁻¹ was positively benefited by nitrogen management techniques as well as compared to other treatments, nitrogen scheduling based on leaf color chart (N₃) produced noticeably more grains cob⁻¹ (475.4). N₂ had the lowest quantity of grains per hectare (454.9) (RDN at 150 kg ha⁻¹ in four splits). Similar result was recorded by Biswas *et al.* (2022) [4].

There was no significant interaction between crop geometry and N scheduling treatments for number of grains cob⁻¹.

100 grain weight

N scheduling and Crop geometry treatments significantly affected the hundred grains weight. The variable spacing had an effect on the hundred grain weight, which was higher (43.1) in M₅ (50 × 50 cm) than in other treatments but statistically comparable to M₄ (45 × 45 cm).

Intra-plant competition for resources like light and nutrients may be the cause of this. Lower plant densities, on the other hand, promote greater kernel growth and could lead to a higher hundred grain weight. Sajjadian *et al.* (2011) [10] reported a similar outcome.

Nitrogen scheduling treatments had also effect on hundred grain weight. The heavier hundred grains weight was (42.7 g), respectively were produced when the maize was nourished with nitrogen based on LCC (N₃) than other treatments. The least hundred grain weight (41.6) was noticed under N₂ (RDN at 150 kg ha⁻¹ in four splits each 25 per cent at basal, 15, 30 and 45 DAS. This might be due to optimal nitrogen application with LCC approach, which insure nitrogen application base on demand of plant prevent from both deficiency and toxic dose. The interaction effect between crop geometry and N scheduling approaches was found to be non-significant for hundred grain weight of maize.

Grain yield

The effect of treatment variables on grain yield (kg ha⁻¹) are provided in Table. The impact of treatments as N scheduling and crop geometry approaches on maize grain yield indicated that it was significantly influenced by both the treatments. Out of all

the crop geometry treatments, maize planted at 60 × 25 cm (M₁) produced a significantly greater grain production (9601.3 kg ha⁻¹) during the season than the other treatments. The widest spacing of 50 × 50 cm (M₅) produced the lowest grain production (7169.3 kg ha⁻¹). Singh *et al.* reported the same outcome in 2013 [14]. This may be the result of maize's improved growth and yield characteristics at densities of 600 x 25 cm. Noticeable variations have been seen due to N scheduling approaches during the period of experiment. Maize crop nourished through LCC based N application (N₃) gained significantly higher grain yield (8943.8 kg ha⁻¹) during season and it was significantly varied from the other treatments. The application of RDN at 150 kg ha⁻¹ in three splits in the (N₁) treatment produced the lowest grain yields (7737.8 kg ha⁻¹). Walia *et al.* (2023) [16] also observed similar findings. This could explain why nitrogen fertilizer is applied on time and nitrogen is not lost in other ways.

Table 1: Effect of crop geometry and nitrogen scheduling on yield attributes of maize Table. Effect of crop geometry and nitrogen scheduling on yield and harvest index of maize.

Treatments	Length of cob (cm)	Cob girth(cm)	Cob weight (g)	Numbers of grains row ⁻¹	Numbers of grains cob ⁻¹	100 grain weight (g)	Grain yield (kg/ha)
Crop geometry							
M ₁ - 60 × 25 cm	16.4	14.3	242.9	29.8	443.5	41.1	9601.3
M ₂ - 30 × 30 cm	16.3	14.6	238.5	31.9	427.3	41.0	8047.9
M ₃ - 35 × 35 cm	16.5	14.2	252.2	32.5	463.2	41.7	8486.3
M ₄ - 45 × 45 cm	17.0	15.3	271.1	33.2	486.9	42.9	7643.9
M ₅ - 50 × 50 cm	18.3	15.4	292.7	34.1	500.5	43.1	7169.3
Sed	0.13	0.01	0.02	0.42	0.81	0.12	1.74
CD (P=0.05)	.30	0.02	0.05	0.97	1.86	0.28	4.01
Nitrogen scheduling							
N ₁	16.4	14.7	260.0	31.7	462.6	41.7	7737.8
N ₂	16.8	14.9	254.1	32.3	454.9	41.6	7887.6
N ₃	17.5	14.7	264.4	32.9	475.4	42.7	8943.8
Sed	0.1	0.01	0.04	0.48	0.68	0.09	1.41
CD (P=0.05)	0.21	0.01	0.08	0.99	1.48	0.20	2.94

N₁-Recommended dose of nitrogen (RDN) at 150 kg ha⁻¹ in 3 splits; N₂ - RDN at 150 kg ha⁻¹ in 4 splits N₃ - LCC based N application.

M₁-60 × 25 cm (66,666 plants ha⁻¹) - Recommended crop geometry

M₂-30 × 30 cm (1,11,111 plants ha⁻¹)

M₃-35 × 35 cm (81,632 plants ha⁻¹)

M₄-45 × 45 cm (49,382 plants ha⁻¹)

M₅-50 × 50 cm (40,000 plants ha⁻¹)

N₁-Recommended dose of nitrogen (RDN) @ 150 kg ha⁻¹ in three splits

N₂ - RDN at 150 kg ha⁻¹ in four splits

N₃ - LCC based N application in five splits at basal, 30, 40, 45, 50and 57 DAS)

Conclusion

- Maize planted at 60× 25 cm found to be optimum under square planting pattern for higher crop productivity, grain and Stover yield.
- Nitrogen scheduling based on LCC critical value in 5 splits at basal, 30, 40, 45, 50and 57 DAS) would be the suitable N management strategy for sustainable production of hybrid maize.
- Thus, the combination of M₁ (60 × 25 cm) spacing and N₃ (LCC-based nitrogen application) emerged as the most effective for achieving better growth, yield, and productivity of maize under irrigated conditions of Kunar, Afghanistan.

Recommendations

- Adopt optimal crop geometry:** Farmers in Kunar and similar agro-climatic zones are advised to use the M₁ (60 × 25 cm) crop spacing for better growth attributes and

productivity of maize.

- Implement LCC-based nitrogen application (N₃):** Utilizing LCC (Leaf Color Chart) for nitrogen application ensures better nitrogen use efficiency, leading to improved grain and stover yields.
- Refinement for specific goals:** Depending on priorities (e.g., maximizing grain yield, stover yield, or harvest index), farmers can adapt the crop geometry:
 - M₁ (60 × 25 cm) for maximum grain yield.
 - M₂ (30 × 30 cm) for highest stover yield.
 - M₃ (35 × 35 cm) for optimal harvest index.
- Further research:** Future studies could explore economic analysis, environmental impact, and scalability of these practices for different maize varieties and climatic conditions.

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