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Effect of Nutrients on Growth and Yield of Maize (*Zea mays* L.) Under Long Term Fertilizer Experiment

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***Abstract*— *A field experiment was conducted during kharif 2025 at the Instructional Farm, Rajasthan College of Agriculture, Udaipur, under the Long-Term Fertility Experiment (29th maize–wheat cropping sequence) to evaluate the effect of integrated nutrient management on the growth and yield of maize (Zea mays L.). The experiment comprised twelve nutrient management treatments involving different combinations of inorganic fertilizers, farmyard manure (FYM), zinc (Zn), sulphur (S), and Azotobacter arranged in a randomized block design with three replications. The soil of the experimental site was clay loam, slightly alkaline in reaction (pH 8.23), non-saline, and contained 8.10 g kg^{-1} organic carbon. Growth parameters, yield attributes, grain yield, stover yield, biological yield, and harvest index were recorded at harvest. The results revealed that the integrated application of 100% NPK + FYM @ 10 t ha^{-1} (T_7) significantly improved crop growth and productivity over other treatments. This treatment recorded the maximum plant height (232.75 cm), dry matter accumulation (132.70 g plant^{-1}), cob length (18.13 cm), and cob weight (190.50 g). It also produced the highest grain yield (4093 kg ha^{-1}), stover yield (5397 kg ha^{-1}), and biological yield (9490 kg ha^{-1}), representing increases of 209.14%, 146.21%, and 162.44%, respectively, over the control. The T_7 treatment remained statistically at par with FYM @ 10 t ha^{-1} + 100% NPK (excluding the nutrient contribution from FYM) and 150% NPK for most growth and yield parameters. Harvest index was not significantly influenced by the nutrient management treatments. The study demonstrated that the combined application of inorganic fertilizers with FYM under long-term fertility management enhanced nutrient availability, improved soil health, and significantly increased maize productivity compared with the sole application of chemical fertilizers or organic manure.**

***Keywords*— Maize, Integrated nutrient management, Long-term fertility experiment, Farmyard manure.**

I. INTRODUCTION

Maize (*Zea mays* L.), commonly referred to as corn, is among the world's most important cereal crops, providing essential resources for human consumption, livestock feed and various industrial applications. Originally domesticated in Central America over 9,000 years ago, maize has experienced extensive genetic advancement and improved cultivation practices, establishing it as a key component of global agriculture. Its broad adaptability to diverse agro-climatic regions, high yield potential and multiple end uses have led to its recognition as the "queen of cereals" (FAO, 2024). Maize is a versatile crop with multiple uses, functioning as a staple food in many developing nations, an essential component of livestock and poultry feed and an important raw material for various industrial products such as starch, ethanol, corn syrup and biodegradable plastics. In India, nearly 60 per cent of the total maize production is utilized for poultry feed, about 20 per cent is consumed as food by humans, around 10 per cent is used for industrial processing and the remaining portion is allocated for seed production and export (ICAR-IIMR, 2024).

Macronutrients like nitrogen (N) phosphorus (P) and potassium (K) are vital for vegetative growth, root development and reproductive success. Nitrogen is particularly important for chlorophyll synthesis and protein metabolism, directly influencing photosynthesis and biomass accumulation. Phosphorus promotes early root development and energy transfer, while potassium enhances water regulation, enzyme activation and resistance to lodging and diseases (Kumar et al., 2021).

Besides primary macronutrients, secondary and micronutrients such as sulfur and zinc also play a crucial role in improving crop growth and productivity, particularly under intensive farming conditions. Zinc for instance is vital for proper enzymatic activity and regulation of plant hormones. Any deficiency or imbalance of these nutrients can result in physiological abnormalities, decreased photosynthetic efficiency, poor cob development and consequently reduced yield (Tiwari et al., 2018). Maize (*Zea mays* L.) productivity largely depends on balanced nutrient management as inadequate nutrient supply can restrict plant growth and reduce yield. A study was conducted in Kenya reported that the combined application of essential nutrients especially nitrogen and phosphorus significantly enhanced plant height, biomass production and grain yield compared with nutrient deficient treatments. The researchers identified nitrogen and phosphorus as the major limiting nutrients for maize cultivation and emphasized that balanced fertilization is essential for achieving higher productivity and maintaining soil fertility (Muthaura et al., 2017).

II. MATERIAL AND METHODS

Field location and Soil:

The site is situated in South-Eastern part of Rajasthan at an altitude of 582.2 m above mean sea level, at 24°35' N latitude and 73°42' E longitude. The region falls under agro-climatic zone IVa (Sub- Humid Southern Plain and Aravalli Hills) of Rajasthan, Soil of the experimental field was clay loam in texture, non-saline and slightly alkaline in reaction, having pH 8.23, EC 0.75 dS m^{-1}, soil organic carbon 8.10 g/kg.

Experimental details:

The experiment contains 10 treatment combinations viz (T_1 -100% NPK based on soil test value, T_2 - 100% NPK+Zn, T_3 - 100% NPK+Zn+S, T_4 - 100% NPK+S, T_5 - 100% NPK + Seed treatment with *Azotobacter*, T_6 - FYM @10 t ha^{-1} + (100% NPK -NPK Content of FYM), T_7 - 100% NPK + FYM @10 t ha^{-1}, T_8 - FYM @20 t ha^{-1}, T_9 - 150% NPK, T_{10} - 100% NP, T_{11} - 100% N, T_{12} - Control) were comprised in randomised block design (RBD) with three replications. Maize variety Pratap Hybrid Makka – 3 was sown at the rate of 25 kg ha^{-1} at inter row of 60 cm and plant to plant spacing of 30 cm.

Nitrogen, phosphorus and potash were applied @ 120:26:25 kg ha^{-1} on soil test basis. The sulphur and zinc were applied @ 20 kg S ha^{-1} and 5 kg Zn ha^{-1} respectively while FYM was applied as per the treatments. The sulphur, zinc and FYM were applied in a year to *kharif* season. The bio fertilizer for seed inoculation was used at 200 g ha^{-1} during *kharif* seasons. Full dose of phosphorus and potash and half dose of nitrogen were applied at sowing time by drilling in crop rows. The remaining dose of nitrogen was top dressed in two equal split doses at 25-30 DAS and 45-50 DAS. Farm yard manure was thoroughly mixed in soil as per the treatment allocation one month before sowing. The seeds were treated with *Azotobacter* inoculants as per the treatment. The seeds were thoroughly mixed with biofertilizer slurry in such a way that all the seeds were uniformly coated with *Azotobacter* and then allowed to dry in the shade before the sowing of crop. Before sowing seeds were treated with *Bavistin* 2.0 g kg^{-1} seed to protect it from fungal diseases and chlorpyriphos 4 ml kg^{-1} seed to protect the seed from termites just before *Azotobacter* inoculation.

Determination methods

Field data was noted during experimentation, to assess the effect of nutrients on growth and yield of maize. For measuring plant height at harvest, five plants are randomly selected and height was measured from base to tip of main shoot using meter scale and average was taken. Cob length and cob weight was recorded at harvest the same way as plant height. For yield attributes, grain yield was determined by harvesting the crop from the net plot area at physiological maturity. The harvested produce was threshed, cleaned, and weighed. Grain yield was recorded on a plot basis and converted to kg ha^{-1} after adjusting the grain moisture content to the standard level, stover yield was determined by recording the weight of the sun-dried vegetative biomass remaining after threshing the harvested crop from the net plot area. The stover yield obtained from each plot was converted into kilograms per hectare (kg ha^{-1}). Biological yield was calculated as the sum of grain yield and stover yield obtained from the net plot area. The biological yield was expressed in kilograms per hectare (kg ha^{-1}).

III. RESULT AND DISCUSSION

1. Growth parameters and Yield attributes

The maximum plant height (232.75 cm) was observed under the application of 100% NPK + FYM @ 10 t ha^{-1}, which remained statistically at par with FYM @ 10 t ha^{-1} + 100% NPK (excluding nutrient contribution from FYM) as well as the 150% NPK treatment, while dry matter accumulation maximum (142.36 g plant^{-1}) observed under the application of 100% NPK + FYM @ 10 t ha^{-1}. The enhanced plant height and biomass production can be attributed to the balanced and continuous supply of essential nutrients, improved soil structure, better moisture retention, and increased microbial activity, all of which promoted vigorous vegetative growth and efficient photosynthesis. Cob length was recorded highest under application 100% NPK + FYM @ 10 t ha-1. This treatment was found to be statistically at par with FYM @ 10 t ha-1 + 100% NPK (excluding the nutrient contribution from FYM), which recorded a cob length of 17.95 cm, and with the 150% NPK treatment (17.80 cm). This treatment was statistically comparable with 150% NPK which recorded 137.38 g plant-1. The maximum cob weight of maize during 2025 (190.50 g) was recorded under the application of 100% NPK + FYM @ 10 t ha-1. This treatment was statistically comparable with FYM @ 10 t ha 1 + 100% NPK (excluding the nutrient contribution from FYM) and 150% NPK, which registered cob weights of 188.50 g and 188.25 g, respectively. Greater cob length and cob weight observed under FYM integrated treatments indicate improved reproductive development resulting from enhanced assimilate production and translocation to the developing ears. Similar results have been reported by Chaudhary *et al*. (2017), Shahid Rasool *et al*. (2015), Prajapati *et al*. (2018) who also documented significant improvements in maize growth and yield attributes under integrated nutrient management practices.

2. Yield

The highest grain yield of maize during 2025 (4093 kg ha-1) was obtained with the application of 100% NPK + FYM @ 10 t ha^{-1}(T_7). This was followed by FYM @ 10 t ha^{-1} + 100% NPK (excluding the nutrient contribution from FYM) (T_6) and 150% NPK (T_9), which produced grain yields of 3866 and 3857 kg ha^{-1}, respectively. Among all the treatments, T_7 recorded the greatest grain yield, representing an increase of 209.14 per cent over the control treatment (1324 kg ha^{-1}) and 24.44 per cent over the recommended dose of fertilizer treatment (3289 kg ha^{-1}).

The maximum stover yield of maize during 2025 (5397 kg ha^{-1}) was recorded under the application of 100% NPK + FYM @ 10 t ha^{-1}(T_7). This treatment was statistically at par with the 150% NPK treatment (T_9). Further analysis indicated that T_7 increased stover yield by 146.21% over the control treatment (2192 kg ha^{-1}) and by 14.66% compared with the recommended dose of fertilizer treatment (4707 kg ha^{-1}). The higher stover yield obtained under integrated nutrient management may be attributed to improved nutrient availability, enhanced vegetative growth, and greater biomass accumulation throughout the crop growth period.

The highest biological yield of maize during 2025 (9490 kg ha^{-1}) was recorded under the application of 100% NPK + FYM @ 10 t ha^{-1}(T_7). The next highest biological yield was obtained under the 150% NPK treatment (T_9). Further evaluation of the data revealed that T_7 increased biological yield by 162.44% over the control treatment (3516 kg ha^{-1}) and by 18.67% compared with the recommended dose of fertilizer treatment (7997 kg ha^{-1}). the harvest index of maize was not significantly influenced by the different nutrient management treatments during 2025, and the observed variations among treatments were statistically non-significant. The harvest index ranged from 37.52% under the control treatment (T_{12}) to 44.39% under T_7. Although T_7 recorded the highest harvest index, representing an increase of approximately 18.31% over the control, this improvement was not statistically significant. The enhanced biological yield under integrated nutrient management may be attributed to improved nutrient availability, vigorous plant growth, and greater accumulation of both grain and stover biomass.

The enhanced performance of these treatments may be attributed to the balanced and continuous supply of nutrients, improved nutrient use development, efficiency, enhanced better root chlorophyll synthesis, and favorable changes in soil physical, chemical, and biological properties, resulting in greater dry matter production and efficient translocation of photosynthates to the developing grains. The addition of FYM also improved soil organic matter content, microbial activity, and moisture retention, thereby creating a conducive environment for sustained crop growth and higher biomass accumulation. However, harvest index remained statistically unaffected by the different nutrient management treatments, indicating that increases in grain yield and total biomass occurred proportionately without markedly altering the partitioning of assimilates between reproductive plant vegetative parts. and Similar observations have also been reported by Devi and Ghosh (2017), Tomar *et al*. (2017), Kumar *et al*. (2018), suggesting that integrated application of organic and inorganic nutrient sources enhances overall crop productivity while maintaining a stable harvest index.

Table 1: Effect of organic and inorganic fertilization on growth parameters and yield attributes of maize under long term fertility experiment

	Treatment	**Plant height at harvest (cm)**	**Dry matter accumulation (g plant^{-1})**	**Cob length (cm)**	**Yield attributes**
					Cob wt.(gm)
T1	NPK	208.25	112.70	15.25	162.75
T2	NPK + Zn	214.50	118.53	15.95	170.50
T3	100% N P K + Zn + S	223.25	124.50	16.75	178.50
T4	100% N P K + S	217.00	116.38	15.65	166.50
T5	100% N P K + Bio	212.50	120.83	16.25	174.50
T6	FYM 10 t/ha + (100% NPK – NPK Content of FYM)	231.00	131.40	17.95	188.50
T7	100% N P K + FYM 10 t/ha	232.75	132.70	18.13	190.50
T8	FYM 20 t/ha	168.63	99.25	13.45	124.75
T9	150% NPK	231.00	131.58	17.80	188.25
T10	100% NP	199.50	104.98	14.25	150.50
T11	100% N	186.50	103.60	13.53	140.50
T12	Control	162.50	82.28	12.15	120.50
	S.Em. +	0.91	0.59	0.15	0.87
	C.D. (P= 0.05)	2.63	1.70	0.43	2.52

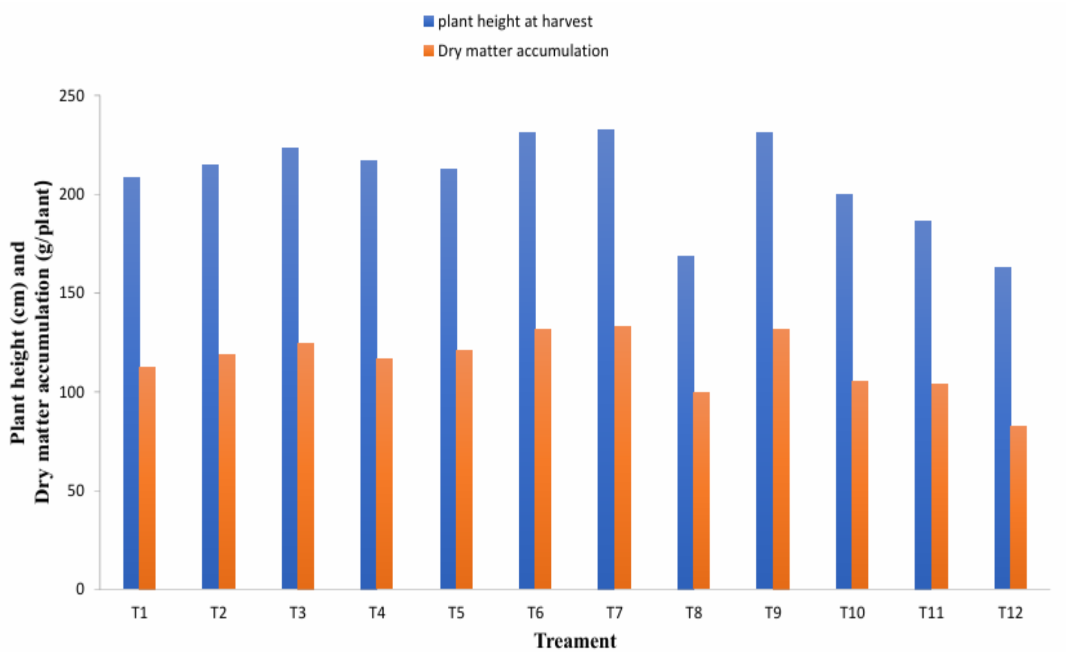

Fig. 1: Effect of organic and inorganic fertilization on Growth parameters of maize under long term fertilizer experiment

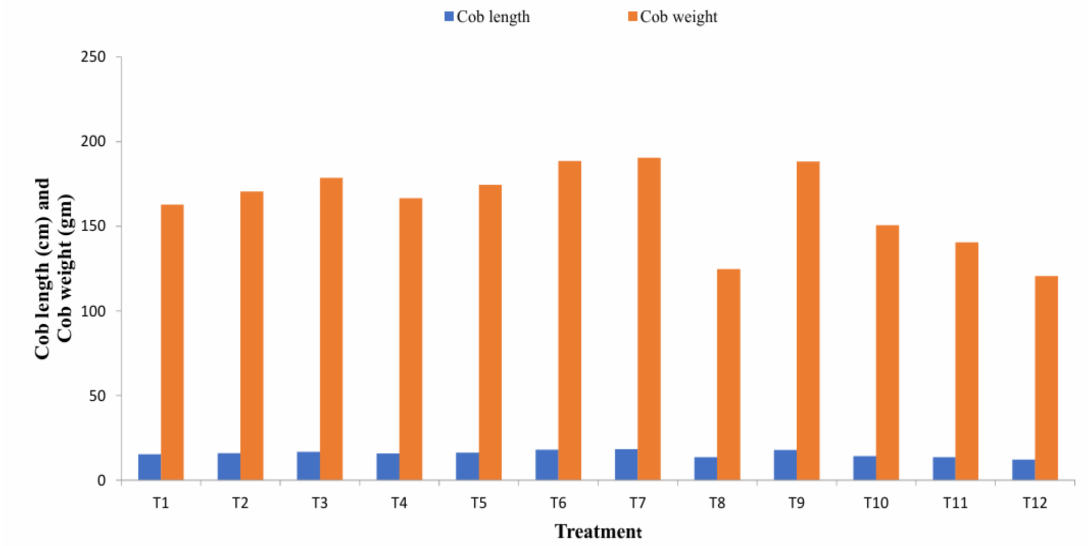

Fig. 2: Effect of organic and inorganic fertilization on yield attributes of maize under long term fertilizer experiment

Table 2: Effect of organic and inorganic fertilization on yield attributes of maize under long term fertility experiment

	Treatment	Grain yield (kg h^{-1})	Stover yield (kg h^{-1})	Biological yield (kg h^{-1})	Harvest index (%)
T1	NPK	3289	4708	7997	41.11
T2	NPK + Zn	3415	4855	8270	41.27
T3	100% N P K + Zn + S	3578	5013	8591	41.65
T4	100% N P K + S	3350	4843	8193	40.87
T5	100% N P K + Bio	3411	4841	8252	41.32
T6	FYM 10 t/ha + (100% NPK – NPK Content of FYM)	3866	5200	9066	42.65
T7	100% N P K + FYM 10 t/ha	4093	5397	9490	43.12
T8	FYM 20 t/ha	2185	2741	4926	44.39
T9	150% NPK	3857	5301	9158	42.13
T10	100% NP	2854	4183	7037	40.61
T11	100% N	2261	3521	5782	39.05
T12	Control	1324	2193	3517	37.52
	S.Em. +	**95.95**	95.19	131.83	1.22
	C.D. (P=0.05)	**276.06**	273.87	379.30	NS

IV. CONCLUSION

The present study demonstrated that integrated nutrient management significantly improved the growth, yield attributes, and productivity of maize under the long-term fertility experiment. Among all the nutrient management practices, the application of 100% NPK + FYM @ 10 t ha^{-1} (T_7) proved to be the most effective. It recorded the highest plant height, dry matter accumulation, cob length, cob weight, grain yield, stover yield, and biological yield. The integrated use of FYM with recommended NPK fertilizers enhanced nutrient availability, improved soil physical and biological properties, and promoted efficient nutrient uptake, resulting in superior crop performance. Treatments receiving FYM in combination with inorganic fertilizers consistently outperformed the sole application of chemical fertilizers or organic manure. Although the harvest index was not significantly affected, the higher biomass and grain production under integrated nutrient management reflected improved crop productivity. The findings indicate that integrating organic and inorganic nutrient sources is more effective than the exclusive use of either source alone. Therefore, the combined application of 100% NPK + FYM @ 10 t ha^{-1} can be recommended as a sustainable nutrient management strategy for enhancing maize productivity while maintaining long-term soil fertility under the agro-climatic conditions of southern Rajasthan.

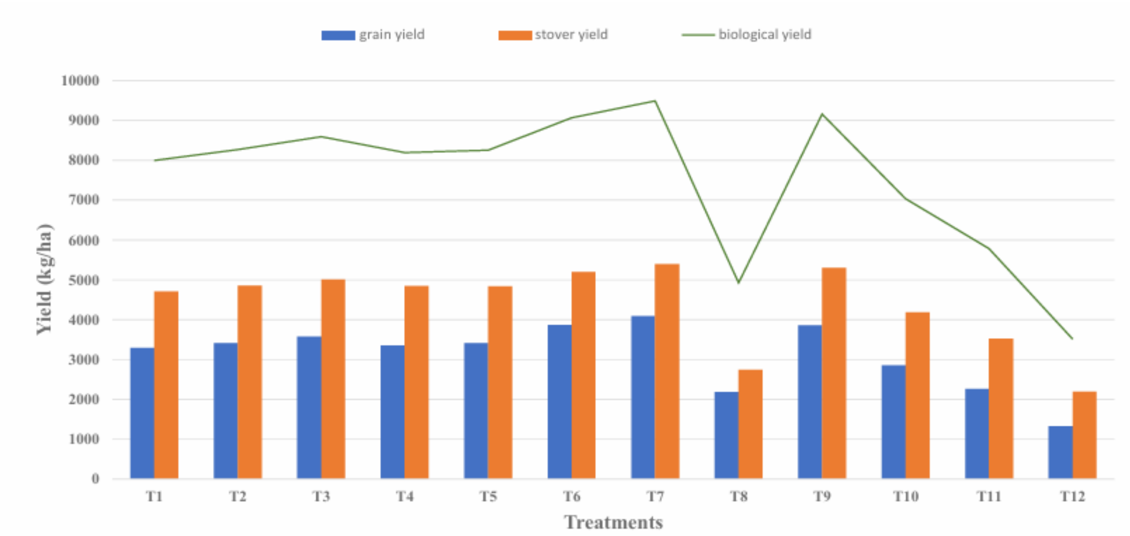

Fig. 3: Effect of organic and inorganic fertilization on yield of maize under long term fertilizer experiment

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