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Growth pattern and nutrient accumulation in maize (*zea mays* L.) in alluvial soil under different nutrient management practices.

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ABSTRACT
Maize is one of the most important and fastest growing cereals in the world having richness in digestible carbohydrate, protein and fat. The seed quality, soil property, environment and physiology greatly influence productivity of the maize. Proper nutrient management provides high yield in return and informs growth pattern and plant density.
To determine the growth pattern of maize and its different developmental stages , different nutrient levels were applied in alluvial soil to investigate the integrated study starting from germination of the seed to reproduction and finally nutrient accumulation in grains after harvesting.
The treatment was applied into total four main plots , that was divided in to four subplots, each subplots were allocated different nutrient levels such as 75%, 100% and 125% NPK along with FYM (Farm Yard Manure) in the maize field grown in alluvial soil.
The different levels of nutrients along with FYM applied to the field crop of maize showed growth in total nutrient accumulation and increased biomass with 12.5% and 14.2% by application of 100% and 125% of NPK to the subplots. Organic carbon and nature of the soil supported the plant growth.
Different levels of nutrient application in alluvial soil gives different growth pattern , as the soil is rich in potash and lime but poor in nitrogen. Increasing NPK level increases the overall growth and more nutrient accumulated in the crop biomass.

Key words:- Grain yield, nutrient application, growth pattern, organic carbon of soil , and bulk density

INTRODUCTION
Maize is grown predominantly as it covers roughly 7.63% of the total food grain area in India. With green revolution , it has been found a rapid production of most of the cereals such as rice and wheat including maize (Nawaz *et al*. 2019) . The high yielding variety programme (HYVP) launched in 1996 showed success in maize revolution but theses modern efforts brought some environmental issues such as depletion of ground water for irrigation and low nutrient efficiency (Bhatt *et al* 2020a) , also various modern techniques are used today to increase production of cereals with sustainable development . It is very important to use fertiliser in adequate amount after chemical and physical analysis of the soil, as excessive nutrients led to decline in nutrient efficiency, and may cause adverse effects on atmosphere and ground water quality (Lamessa 2016 and Adimalla 2018) . The soil fertility should be increased by

applying organic fertilizers, however the use of chemical fertilizers cannot be completely eradicated as they provide all the types of primary and secondary nutrients in large amount (Sharma *et al*. 2019) . It is advised to use both organic manure and chemical fertilizer to improve the soil structure and the soil activity that helps to increase the overall yield by increased nutrient mobilization (Mengistu *et al*. 2017, Mahapatra *et al*. 2018, and Bhatt *et al*. 2020b) . The objective of the current study was to study the growth pattern and nutrient accumulation in maize with application of different nutrient levels in the river-deposited alluvial soil.

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MATERIALS AND METHODS

1.1 Site of experiment

The experiment was conducted at local farm near Veer Kunwar Singh University , Ara , Bhojpur, Bihar, India (25.55° N latitude and 84.66° E longitude) on alluvial soil formed from sediments deposition of river Ganga and its tributaries. The pH recorded during cropping season (2024-25) was 7.5. The average annual rainfall is 959.0 mm , which is 80-85% of total rainfall during monsoon season (June-September) , with very low winter rainfall and occasional pre-monsoon shower. Monsoon season is marked with pleasant and mild temperature all around with bright sunlight and adequate sunshine hours for vegetation, flowering and maturity. The physical and chemical properties of soil have been recorded and listed in table 1 and 2, focusing on available NPK , pH and organic carbon in the soil.

Soil depth (cm)	Sand(%)	Silt(%)	Clay(%)	Soil texture	Bulk density (Mg m^{-3})
0-20	55.6	20.3	22.4	Loamy sand and loamy clay	1.15
20-40	70.8	40.6	12.6	Loamy sand	1.50
Method used	**International Pipette Method (Piper 1966)**				

Table 1 :- Physical properties of soil of the experimental site for maize cropping.

Chemical property	2024	2025	Status	Methods used
pH	6.9	7.5	Normal	Beckman's glass electrode meter (Jackson 1967)
Organic carbon (%)	0.2	0.7	Low	Walkley and Black's rapid titration method (Jackson 1967)
Available N (kg ha^{-1})	260.5	245.6	Low	Alkaline Potassium Perrmagnate method (Subbiah and Asija 1956)
Available P (kg ha^{-1})	15	11.8	Low	0.5 N sodium bicarbonate extraction method (Olsen *et al* 1954)
Available K (kg ha^{-1})	250.5	200.9	Medium	IN Ammonium acetate extractable method (Muhr 1965)

Table 2 :- Chemical properties of soil for maize cropping in year 2024 and 2025.

1.2 Seed variety used

The sample seed taken for the study constitute of four varieties , two local and two improved hybrid varieties. The two local varieties were Sathi Makka and Desi Makka with a property of early maturation and low input traditional variety and the two hybrid varieties were Pusa HM-4 and Shaktiman-1 with high

yield, drought tolerance and high lysine and tryptophan potential. The hybrid variety Pusa HM-4 and Shaktiman-1 of kharif maize (*zea mays* L.) are medium tall with medium ear placement and single cross product. The tassels were medium sized, ears are long, leaves are broad, green-semi-open anther and pink silks. The seed grains were orange and bigger with dent, and mature in average 100 to 120 days with average yield of 32.5 q acre^{-1}. However the two local varieties were not having much modified characteristics , most of the phenotypical features are average having approximate yield of 30.4 q acre^{-1}.

1.3 Data analysis

The experiment was conducted in split plot design (SPD) with four varieties , two local and two hybrid varieties. The experiment was conducted with kharif maize in both the years 2024 and 2025, with application of various levels of nutrients as to the crop variety. The local variety was treated with 75% , 100% and 125% NPK along with FYM in first experiment in 2024 whereas all the four varieties were treated with 75%, 100% and 125% NPK along with FYM in year 2025. The variance analysis was performed using Proc GLM procedure of SAS version 9.4 (SAS Institute , Inc., Cary , NC , USA) for all parameters. The difference was compared later on performing analysis of variance (ANOVA) with Fisher's least significant difference (LSD) test at 5 per cent probability level.

1.4 Method of analysis

The samples of the grains were collected after harvesting and drying of kharif maize grains. For determining total NPK content the various methods used were, micro Kjeldahl's distillation method, as given by Piper (1966) for nitrogen content in grain sample. Vanado- phospho- molybdate yellow colour method by digesting the sample with di-acid to determine the phosphorous content in grain sample. Flame photometer was used described by Muhr (1965) to determine potassium content in taken grain sample. The soil samples from both the two depths 0-20 cm and 20-40 cm were analysed for organic carbon content and bulk density after harvesting the maize crop.

RESULTS

3. 1 Grain yield and growth stages.

The result depicted for the net grain yield was relatively higher for the hybrid kharif maize variety than that of the local variety (Table 3) . The various nutrient levels applied to the crops showed variable growth pattern recorded at 30 DAS, 60 DAS, 75 DAS and at maturity .The productivity recorded was higher at the time of 75 DAS but had slight decrease at maturity due to decreased photosynthesis and less mobilization of photosynthates. Studying the growth pattern of the kharif maize indicated that number of cobs per plant, cob length, cob girth, number of grain raw per cob and number of grains per cob were higher for hybrid varieties as they were genetically modified. However during second experiment all the crops were applied with 100% NPK the

overall yield was even higher for the hybrid variety. During both the years the treatment involving application of 125% NPK to the subplots significantly higher grain yield (86.5 and 89.4 q ha^{-1}) for both hybrid and local varieties respectively, as compared to the treatment involving application of 100% NPK to the subplots showed average grain yield (81.5 and 83.8 q ha^{-1}). The decrease in percentage NPK to 75% showed even low productivity as recorded grain yield (78.3 and 80.7 q ha^{-1}). These per cent increase in the grain yield with application of 125% of NPK also showed fast and better growth covering all the aspects of crops life cycle.

Treatment	30-60 DAS	60-75 DAS	75 DAS- Maturity
Local variety + 75% NPK + FYM	9.9	19.4	9.2
Local variety + 100% NPK +FYM	11.9	21.2	11.2
Local variety + 125% NPK +FYM	13.4	24.4	13.2
Hybrid variety + FYM	13.8	24.8	13.5
Hybrid variety +100% NPK + FYM	15.5	26.7	15.1

Table 3:- Net primary productivity (g m^{-2} day^{-1}) for kharif maize .

3.2 N, P and K uptake

The data recorded for NPK uptake was showing higher nitrogen uptake as compared to potassium and phosphorous, as the alluvial soil of the experimental site was lacking adequate nitrogen . Nitrogen was applied twice , once before the sowing of the crop and later after 45 DAS by the time before reproductive stage . Among different nutrient level applied to the kharif maize in sub plots , 125 % NPK application showed higher NPK uptake, however NPK applied 75% showed minimum uptake and growth pattern. An average pattern was seen with the application of 100% NPK to the local varieties but the hybrid varieties showed maximum uptake of NPK with application of 100% NPK + FYM (Table 4) . The NPK accumulation was recorded foe different plant parts such as grain, stem, leaves and roots . Grains of the kharif maize were having maximum NPK accumulated whereas the root had least accumulation of nutrients. Pooled mean calculated for the NPK uptake for both the experimental years 2024 and 2025 showed higher uptake of NPK by hybrid varieties.

Variety	Nitrogen	Phosphorous	Potassium
Local variety 1 (Desi Makka)	103	28	87
Local variety 2 (Sathi Makka)	96	25	85
Hybrid variety 1 (Pusa HM-4)	110	34	98
Hybrid variety 2 (Shaktiman-1	105	30	95

Table 4:- Pooled mean for NPK uptake

3.3 Soil property

The analysis of soil presented the status of soil as the organic carbon available in the soil explains about the fertility of the soil. The upper level of the soil is very crucial as it receives seed,

fertilizer , water and all types of chemicals applied , so it the main indicator of physical , chemical and biological health of the soil. The determination of organic carbon in the soil was very important as it releases nutrients for plant growth, promotes the structure and act as buffer against harmful substances. For both the years of experiment the soil organic carbon was checked for two depths 0-20 cm and 20-40 cm, and it was found lower than required level. The soil got improved after applying FYM + 100% NPK, and the soil was more enriched once the treatment level was increased from 100% to 125% . The organic carbon content

was 0.45% in year 2024 but it was increased to 0.46% in year 2025 due to treatment , and resultantly the crop yield was higher for the second experiment done in year 2025.

The soil physical health and the bulk density was also determined to check the water retention capacity of the soil of experimental site. The bulk density for both the depths 0-20 cm and 20-40 cm was recorded adequate as the alluvial soil had good porosity and water holding capacity. As the levels of nutrient applied a decreased in the bulk density was observed for both the depths, as application of FYM+ 100% NPK gave optimum bulk density but once the level was increased to FYM + 125% NPK the resultant bulk density was lowered by breaking compactness of the soil . The low bulk density showed better results for overall growth of kharif maize during the experiment.

DISCUSSION

The increase in grain yield by the application of FYM was prominent also more cob length and more number of grains per cob gave higher yield. Integrated application of chemical fertilizer and organic manure resulted in higher growth , same reported by Chahal *et al*. (2019), Ejigu *et al*. (2021) and Sigaye *et al*. (2021) . Use of both organic manure and fertilizer gave a better result as the growth pattern recorded was proper and with good quality, as root penetration was better due to improved soil texture that led to better uptake of water and nutrient mobilization all over the plant body, Zhu *et al*. (2010), Chaudhary *et al*. (2013) and Memon *et al*. (2018) also reported the better yield with improved growth pattern. The organic carbon increased due to application of FYM, that also increased the mineral nutrient available in the soil, Jet *et al*. (2013) , Meena *et al*. (2015) and Chaudhary *et al*. (2017) also reported availability of increased organic matter and mineral nutrients in the soil due to application of manure and residue treatment. The bulk density was even improved by the application of manure and fertilizer that improved the soil texture , during first experiment the bulk density was comparatively higher but after treatment in second experiment in year 2025 the bulk density of the soil was relatively lower , as incorporation of organic manure decreased the compactness and increased the porosity. Meena *et al*. (2015) also reported reduction in bulk density of the soil due to treatment with organic manure.

The total yield got increased by increasing the different levels of NPK , as application of 125% NPK to the subplots showed better growth and higher yield. The increased level of NPK increased the rate of photosynthesis and more starch was available for mobilization , so more production of carbohydrate ultimately increased yield , similar finding was recorded by Srivastava *et al*. (2018) , Raj *et al*. (2021) and Adhikari *et al*. (2021). The increased yield was basically the resultant od more number of plants per subplot, more number of cobs per plant and more numbers of grains per cob, collectively showed enhancement in biological yield with proper growth pattern , similar finding was recorded by Tyagi *et al*. (1998) and Alam *et al*. (2003). An increase in nitrogen application enhanced the overall productivity as the alluvial soil of the experimental site was lacking adequate nitrogen content, Gul *et al*. (2009) , Amanullah *et al*. (2009) and Arif *et al*. (2010) also found same results.

CONCLUSION

Higher grain yield was found after application of NPK fertilizer along with the FYM. The hybrid varieties were having modified genetic arrangement so application of NPK + FYM enhanced the productivity even more but the local varieties were also recorded giving higher output after application of NPK based fertilizer and FYM together. Application of 125% NPK + FYM increased the productivity

significantly . The soil texture got improved due to manure treatment , that helped in overall growth of the plant and increased yield at the end.

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