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Study on Omission Plot Technique in Popcorn

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ABSTRACT

There are various limiting factors in production of popcorn in Nepal among one of them is lack of limited information on nutrient management particularly the macronutrient nitrogen, phosphorous and potassium. Therefore, a field experiment was conducted at National Agronomy Research Centre, Khumaltar, Nepal to study the limiting nutrient for popcorn Lumle yellow in 2022/23 and 2023/24 in loam soil. The experiment consisted of five treatments and four replications arranged in randomized complete block design. Five different treatment comprised of FYM (unfertilized/farmer practice), –N,+PK (N omitted), -P,+NK (P omitted) ,-K+NP (K omitted), +NPK applied plots. In 2022/23 and 2023/24 +NPK applied treatment produced significantly highest grain yield of 4.27 t ha^{-1} and 3.13 t ha^{-1} while N omitted treatment gave lowest grain yield of 1.36 t ha^{-1} and 1.30 t ha^{-1} respectively and this yield was at par with only FYM applied treatment. Grain yield levels obtained for different fertilizer treatments were ranked as +NPK>-P,+NK>-K,+NP>FYM>-N. The results concluded that application of optimum doses of three primary nutrients such as nitrogen, phosphorus and potassium were essential to achieve optimum growth and productivity of maize.

Keywords: Indigenous nutrient supply, nutrient omission, nutrient use efficiency, recovery efficiency

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INTRODUCTION

The estimation of role of each nutrients nitrogen (N), phosphorous(P), potassium(K) is one of major challenges for particular location. In this context, omission plot method could be an easy approach. Omission plot technique is useful tool to quantify soil nutrient supply (Regmi et al 2002). The yield response (YR) is related to indigenous nutrient supply which determines the yield in omission plots (Xu 2014). Knowing soil nutrient condition is the premise of optimized fertilization. Soil indigenous nutrient supply can reflect soil nutrient condition or soil fertility and can be developed as guidelines for fertilizer recommendation. Nutrient use efficiency is affected by grain yield, soil indigenous nutrient supply, amount of fertilizer application and overall timeliness and quantity of other crop management operations (Dobermann 2007).

Popcorn is produced under low N condition generally without fertilizer or with only farm yard manure because of high price ratios between fertilizer and grain, limited availability of fertilizer and low purchasing capacity of farmers. Due to potential differences in production between maize and popcorn, doses of fertilizers used for popcorn may be overestimated or underestimated. Recovery of applied N in rainfed popcorn is very low due to various losses and poor management practice. Application of diammonium phosphate (DAP) and potash is negligible in mid-hill region of Nepal (Paudyal et al 2001). The existing fertilizer recommendation is based on blanket recommendation which assumes that the need of a crop for nutrients is constant over time and large areas and not a site specific nutrient management and is common for corn and popcorn. Blanket dose of fertilizer will not fit to all fields. Therefore, quantification of indigenous nutrient supply (INS) of soil for major nutrients like N, P, K, etc. is a prerequisite to increase nutrient use efficiency and yield. Imbalanced fertilizer application during maize cultivation will make depletion of soil nutrients leading to production decline as well as to deterioration of soil physical and chemical properties. Individual field has to be assessed for their nutrient supplying capacity so that fertilizer required for certain targeted yield can be developed based on inherent nutrient supplying capacity of soil. As the maize respond well to added nutrients, an ample dose of nutrients is to be provided to exploit the yield. Therefore, nutrient management for a heavy-feeder like crop should be in judicious manner for agricultural sustainability (Mohanta et al 2021). In this context, omission plot method could be an easy and handy approach which shows the relative influence of each nutrient on crop growth and development. The crop yields from nutrient omission and non-omission plot refers to ability of soil to supply nutrients and crop response to given nutrient input, respectively. There is no information in the literature regarding the effects of N and its application forms on the expansion capacity index of popcorn. This is mainly due to the scant results on experimental results for the growing of corn.

Currently recorded average popcorn yields compared with the yield potential for given variety and climate indicate significant scope to further increase its productivity through site-specific based on crop requirements, soil test values and yield targets. Hence, the current study was made to recognize the flaws of blanket recommendations and to determine effect of omitted nutrients on growth, productivity of popcorn. Therefore, the objectives of this study were to identify the most yield limiting nutrient in popcorn and to quantify the magnitude of yield limitation due to different nutrient omission namely N, P, K.

MATERIALS AND METHODS

Experimental site and climatic condition

A field experiment was carried out in upland research block of National Agronomy Research Centre (NAgRC) in 2022/23 and 2023/24. Geographically the station lies at 27˚40'north latitude and 85˚20'east longitude at an elevation of 1360 masl with temperate climate. The meterological data was taken from meterological station of NAgRC. The total rainfall during the crop growing season was 1007.1 mm and 934.1mm in 2022/23 and 2023/24 respectively.

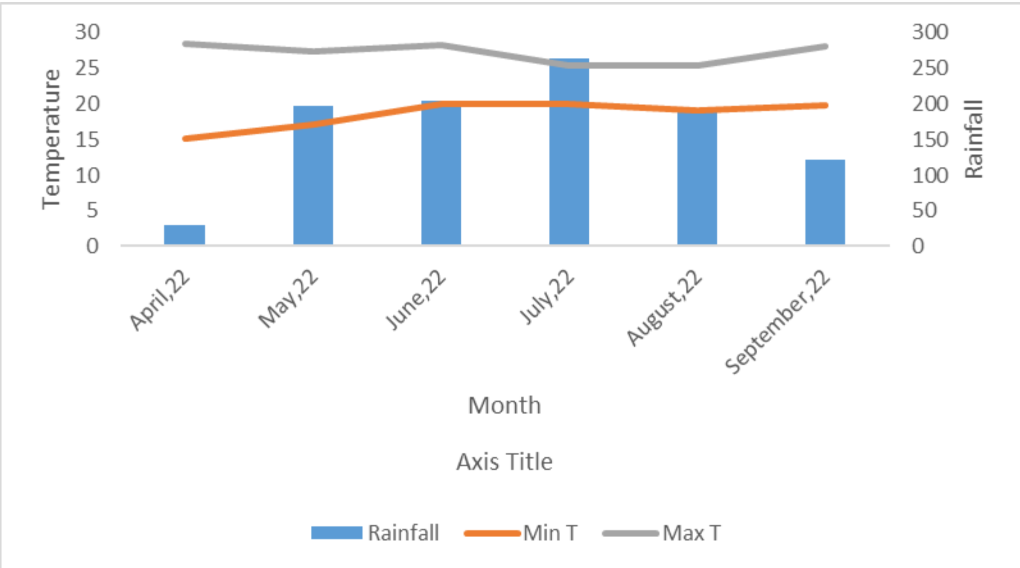

Fig 1. Monthly total rainfall, mean maximum and minimum temperatures during the experiment (2022/23)

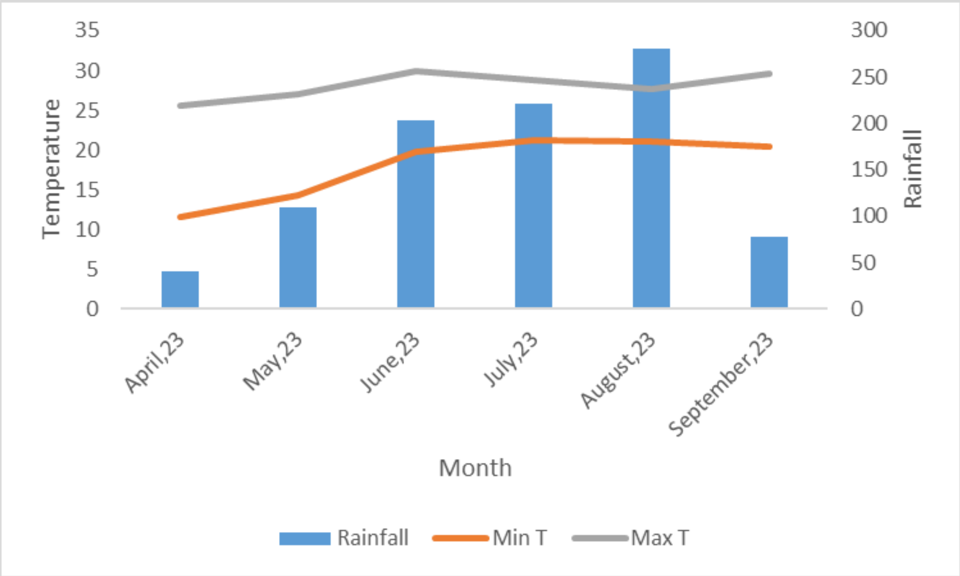

Fig 2: Monthly total rainfall, mean maximum and minimum temperatures during the experiment (2023/24)

Chemical properties of soil (0-15cm) at the experimental site

Composite soil samples was taken randomly from three different spots of each replication from 0-15cm soil depth using tube auger and the samples was air dried, grounded and sieved through 2mm sieve and sent to laboratory for testing before planting. Total N was determined by Kjeldahl Digestion method, total phosphorous by Vanadomolybdate method, total potassium by flame photometric method, soil PH by Potentiometric (1:2.5) metric method, soil organic matter by Walkley and Black method and sand, silt, clay percentage by hydrometer method.

Chemical properties of the experimental field revealed that soil pH was moderately acidic with medium organic matter content. Total nitrogen content and total available potassium was medium while soil was high in total available phosphorous with loam soil type. Farmyard manure (FYM) applied in experimental plot was slightly acidic with pH 6.35, high in nitrogen 1.39% , high in potassium content 1.70% and low in phosphorous 0.41%.

Table 1. Physio-checmical properties of the soil

Physical properties	**Content (kg ha^{-1})**	**Category**
Sand%	36.16	
Silt%	49.88	
Clay%	13.96	Loam
Chemical properties	**Content (kg ha^{-1})**	**Category**
Soil organic matter%	2.53	Medium
Total Nitrogen %	0.23	Medium
Available Phosphorous (P_2O_5 kg ha^{-1})	568.6	High
Available Potassium (K_2O kg ha^{-1})	212.02	Medium

Experimental details and cultural practices

The experiment was carried out in randomized block design with four replication in 2022/23 and 2023/24. The plot size was of 4.8m×3m and sowing was done on 11th May, in both growing season with a crop geometry of 60cm*20cm. Popcorn variety used was Lumle yellow. Seed rate was applied @12 kg ha^{-1}. Chemical fertilizer was used @150:75:50 N:P_2o_5:K_2o kg/ha i.e 25 % above state recommended dose 120:60:40 N:P_2O_5:K_2O kg ha^{-1} . Single super phosphate was used as source of phosphorous. Half dose of N was applied as basal, remaining half N was splitted twice (one at knee height stage and remaining N at tasseling stage). Treatment comprised of FYM @ 6 t ha^{-1}, (unfertilized/control/farmer practice), N omitted (-N,+PK) 75kg P_2O_5+50 kg K_2O, P omitted (-P,+NK) 150kg N+50 kg K_2O, K omitted (-K,+NP), 150kg N+75 kg P_2O_5, NPK applied (+NPK) 150 Kg N+75kg P_2O_5 +50 kg K_2O. All the recommended agronomic practices were carried out as when required.

Data collection

Data was taken from 10 randomly selected plants from net plot area (middle 4 rows i.e 7.2m^2 area) for measuring plant height, final plant stand, no grains/cob, cob length, 1000 grain weight. Grain yield and straw dry matter were calculated from the net plot. 50 gm of grain sample and two plants were randomly selected from each plot and air dried and sent for analysis for nutrient uptake calculation. Field specific nutrient (NPK) was calculated considering the nutrient demand, indigenous nutrient supply of soil and recovery efficiency. Data was analyzed using Gene stat statistical package at 5% level of significance.

RESULTS AND DISCUSSION

In 2022/23 the results of the experiment (Table 2a,b) revealed a significant difference in plant height in popcorn upon nutrient omission. Nitrogen omission (-N,+PK) resulted in significant reduction in plant population, yield attributes, yield and shelling percentage and similar trend was observed for other parameters and increment in all these mentioned traits were recorded in +NPK applied treatment. Days to 50% tasseling was earliest in nitrogen omitted and FYM applied treatment and late most in full dose of +NPK applied plot. Nitrogen dose increased nitrogen uptake, and hence the days for the different phenological stages increased.

Table 2a: Effect of nutrient omission on growth, yield attributes and yield of popcorn in Khumaltar, 2022/23

Treatments	Plant height(cm)	Cob length (cm)	No of grains/cob	Final plant stand	Thousand grain weight (gm)	Sterility%	Days to 50% tasseling
FYM	237.0^{cd}	16.46^{a}	235^{b}	50^{b}	136.40^{c}	8.94^{ab}	55^{b}
-N,+PK	234.5^{d}	12.11^{b}	191^{b}	47^{b}	132.0^{c}	10.17^{a}	54^{b}
-P,+NK	247.1^{bc}	17.33^{a}	374^{a}	58^{a}	166.30^{ab}	8.12^{b}	61^{a}
-K,+NP	257.3^{b}	17.67^{a}	366^{a}	58^{a}	160.80^{b}	8.15^{b}	60^{a}
+ NPK (+25% RDF)	269.1^{a}	17.06^{a}	390^{a}	59^{a}	175.40^{a}	7.14^{b}	62^{a}
Grand mean	249.0	16.12	311.20	54.40	154.20	8.5	58.75
F test	*	*	*	*	*	*	*
LSD (0.05)	11.75	2.41	83.22	3.35	11	1.71	5.33
CV%	3.1	9.7	17.4	4	4.6	13.1	5.9

Table 2b: Effect of nutrient omission on growth, yield attributes and yield of popcorn in Khumaltar, 2022/23

Treatments	Days to 50% silking	Days to 50% maturity	Yield (t/ha)	Stover yield (t/ha)	Harvest index (HI)	Barrenness%	Shelling%
FYM	63^{a}	94^{b}	1.90^{c}	4.79^{b}	0.29^{b}	17.86^{a}	50.05^{b}
-N,+PK	62^{a}	93^{b}	1.69^{c}	4.33^{b}	0.28^{b}	18.61^{a}	45.89^{b}
-P,+NK	70^{a}	101^{a}	3.51^{ab}	6.35^{a}	0.40^{a}	9.90^{b}	77.21^{a}
-K,+NP	69^{a}	100^{a}	3.25^{b}	5.92^{a}	0.37^{a}	10.64^{b}	75.23^{a}
+ NPK (+25% RDF)	71^{a}	102^{a}	3.67^{a}	6.40^{a}	0.40^{a}	8.64^{b}	82.28^{a}
Grand mean	67.6	98.1	2.8	5.56	0.33	13.13	66.1
F test	*	*	*	*	*	*	*
LSD(0.05)	6.16	4.83	0.3	0.79	0.04	6.14	24.2
CV%	5.9	3.2	6.8	9.2	9.20	30.40	23.8

Note FYM=Farmyard manure, N=Nitrogen,P=Phosphorous,K=Potassium

An increase in nitrogen and other nutrient like phosphorous and potassium might have increased the rate of photosynthesis in the plant that resulted in leaf durability and delayed the phenological characteristics (Gungula et al 2003). Early flowering and maturity of N omitted plots was ascribed to hampered amino-acid and protein production leading poor growth that finally resulted in early development (Kamrunnahar et al 2017). Sterility and barrenness percent was highest when nitrogen was omitted and only FYM applied plot. In 2023/24 (Table 3a,b) plant height was significantly influenced by nutrient omission. Plant height was highest in +NPK applied treatment and lowest in N omitted (-N,+PK) plot which was satistically at par with only FYM applied treatment. The increment in plant height might be due to increase in cell elongation and more vegetative growth attributed to balanced application, especially of primary nutrients N, P and K. On the other hand, the shortest plant in unfertilized plots might have been due to insufficiency of indigenous nutrients supplied by the soil to support plant growth. Phosphorus is required for shoot and root development where metabolism is high and cell division is rapid while K is required for stomata regulation and hence entry of raw materials of photosynthesis and water regulation (Hasanuzzanman et al 2018).

Table 3a: Effect of nutrient omission on growth, yield attributes and yield of popcorn in Khumaltar, in 2023/24

Treatments	Plant height(cm)	Cob length (cm)	No of grains/cob	Final plant stand	Thousand grain weight (gm)	Sterility%	Days to 50% tasseling
FYM	238.5^{bc}	11.93^{b}	206^{b}	44^{c}	118.20^{c}	12.01^{a}	56^{b}
-N,+PK	227.20^{c}	11.46^{b}	169^{b}	43^{c}	116.20^{c}	12.38^{a}	54^{b}
-P,+NK	269.3^{a}	16.48^{a}	404^{a}	52^{ab}	160.90^{ab}	7.83^{b}	67^{a}
-K,+NP	257.9^{ab}	16.06^{a}	387^{a}	49^{b}	159.20^{b}	8.66^{ab}	66^{a}
+NPK	271.9^{a}	18.0^{a}	417^{a}	56^{a}	143.43	6.78^{b}	68^{a}
Grand mean	253	14.79	317	49.2	143.43	9.54	62.15
F test	*	*	*	*	*	*	*
LSD (0.05)	23.36	3.96	54.38	4.35	2.61	3.7	2.27
CV%	6	17.4	11.1	5.7	1.2	25.2	2.4

Table 3b: Effect of nutrient omission on growth, yield attributes and yield of popcorn in Khumaltar, in 2023/24

Treatments	Days to 50% silking	Days to 50% maturity	Yield (t ha^{-1})	Sover yield (t ha^{-1})	Harvest index (HI)	Barrenness%	Shelling%
FYM	63^{b}	96^{b}	1.96^{c}	4.50^{b}	0.30b	16.45^{a}	42.88^{b}
-N, +PK	63^{b}	95^{b}	1.73^{c}	4.21^{b}	0.29b	17.90^{a}	47.02^{b}
-P,+NK	79^{a}	102^{a}	3.22^{ab}	5.88^{a}	0.40^{a}	9.57^{b}	74.21^{a}
-K,+NP	77^{a}	100^{a}	3.08^{b}	5.86^{a}	0.34^{a}	11.71^{b}	72.94^{a}
+NPK	80^{a}	103^{a}	3.40^{a}	6.17^{a}	0.40^{a}	7.54^{b}	75.59^{a}
Grand mean	72.4	99.7	2.68	2.68	0.33	12.64	65.23
F test	*	*	*	*	*	*	*
LSD (0.05)	5.5	3.39	0.28	0.28	0.03	4.52	4.36
CV%	4.9	2.2	6.7	6.7	6.5	9.2	4.5

Note FYM=Farmyard manure, N=Nitrogen,P=Phosphorous,K=Potassium

Highest no grains/cob, final plant stand, thousand grain weight, harvest index, stover yield and shelling percentage was recorded in +NPK applied treatment which was statically at par with P ommitted (-P,+NK) and K omitted (-K,+NP) treatment and lowest grain number, final plant stand,1000 grain weight, harvest index and yield was recorded in N omitted (-N,+PK) followed by only FYM applied treatment. Statistically similar grain yield among –P,+NK, -K,+NP, and +NPK applied treatment, was observed where ample of N was applied but lowest in N omitted (-N,+PK) plot indicating that N application cannot be substituted and has highest contribution in maize yield. It could be due to high effect of N on chlorophyll formation, photosynthesis and assimilate production because nitrogen stress reduces crop photosynthesis by reducing leaf area development and leaf photosynthesis rate by accelerating the leaf senescence (Diallo et al 1996). Moreover, under N deficiencies, a considerably large proportion of dry matter is partitioned to roots than shoots, leading to reduced shoot/root dry weight ratio (Rufty et al 1988) and consequently grain yield.

The pooled analysis almost follows the same trend as 2022/23 and 2023/24 (Table 4a,b). Significantly highest plant height was recorded in +NPK applied treatment followed by –P,+NK(P omitted) and –K, +NP (K omitted) treatment which were statistically at par with each other and lowest in –N,+PK treatment over year. A significant difference in yield parameter was observed in pooled analysis as compare to first and second year. Here, significantly highest yield was recorded in +NPK applied treatment which was at par with –P, +NK (P omitted) treatment over the year. -K,+NP treatment (K omitted) recorded lower yield than these two treatment unlike first and second year where all these three treatment resulted in statistically similar result. Significantly lowest yield was recorded N omitted (-N,+PK) plot followed by only FYM applied treatment. +NPK application resulted in significant increment in days to tasseling, silking, maturity, no of grains/cob, final plant stand, thousand grain weight, harvest index, stover and shelling percentage where reduction of either one of the nutrient either P or K also seemed to show statistically similar result over year but N reduction and only FYM applied plot resulted in drastic reduction in all these traits thus severly reducing yield and increasing barrenness, sterility% in plant. From this result; it can be concluded that by adequate nitrogen supply sterility could be reduced. Stover yield from only FYM applied and N omitted treatments were significantly lower as compared to other treatments. It could be suggested that absence of nitrogen increases sterility and ultimately limits the optimum growth of crop resulting low grain yield and biomass production. Stover yield is strongly correlated with K supply and was low in –K,+NP treatment due to its omission in comparison to +NPK and –P,+NK applied treatment though they were statistically similar. When NPK was applied it promoted photosynthetic activity, potassium increases cell expansion by regulating solute potential that may increase the rate of leaf expansion and the leaf area (Yahiya et al 1996).

Table 4a: Effect of nutrient omission on growth yield attributes and yield of popcorn in Khumaltar, in 2022/23 and 2023/24

Treatments	Plant height(cm)	Cob length (cm)	No of grains/cob	Final plant stand	Thousand grain weight (gm)	Sterility%	Days to 50% tasseling
FYM	237.80^{c}	14.63^{b}	221^{b}	47^{c}	127.3^{c}	10.65^{a}	55^{b}
-N,+PK	230.90^{c}	11.79^{c}	180^{b}	42^{c}	124.1^{c}	11.09^{a}	54^{b}
-P,+NK	258.20^{b}	16.46^{ab}	389^{a}	55^{ab}	163.6^{b}	8.0^{b}	64^{a}
-K,+NP	257.6^{b}	16.86^{a}	377^{a}	54^{b}	160.0^{ab}	8.4^{b}	63^{a}
+ NPK (+25% RDF)	270.5^{a}	17.53^{a}	404^{a}	58^{a}	169.1^{a}	6.96^{b}	65^{a}
Grand mean	251	15.45	314.1	51.8	148.8	9.02	60.45
Treatments	*	*	*	*	*	*	*
Year	Ns	*	Ns	*	*	Ns	*
Treatments* Year	Ns	*	Ns	Ns	Ns	Ns	Ns
LSD (0.05)	11.94	2.09	46.68	2.65	5.33	2.03	2.66
CV%	4.6	13.2	14.4	5	3.5	21.9	4.3

Table 4b: Effect of nutrient omission on growth yield attributes and yield of popcorn in Khumaltar, in 2022/23 and 2023/24

Treatments	Days to 50% silking	Days to 50% maturity	Yield(t/ha)	Stover yield (t/ha)	Harvest index (HI)	Barrenness%	Shelling%
FYM	63^{b}	95^{b}	1.93^{c}	4.64^{b}	0.29^{b}	18.26^{a}	48.53^{b}
-N,+PK	62^{b}	94^{b}	1.71^{d}	4.27^{b}	0.30^{b}	17.16^{a}	44.38^{b}
-P,+NK	75^{a}	102^{a}	3.37^{a}	6.11^{a}	0.40^{a}	9.74^{b}	75.71^{a}
-K,+NP	73^{a}	100^{a}	3.17^{b}	5.89^{a}	0.35^{a}	11.18^{b}	74.09^{a}
+ NPK (+25% RDF)	76^{a}	103^{a}	3.54^{a}	6.29^{a}	0.40^{a}	8.09^{b}	78.93^{a}
Grand mean	70	98.9	2.74	5.44	0.33	12.88	64.3
Treatments	*	*	*	*	*	*	*
Year	*	Ns	*	Ns	Ns	Ns	Ns
Treatments*Year	Ns	Ns	Ns	Ns	Ns	Ns	Ns
LSD (0.05)	4.39	2.79	0.19	0.56	0.04	3.62	11.34
CV%	6.1	2.8	7	10.1	8.9	27.4	17.2

Note FYM=Farmyard manure, N=Nitrogen,P=Phosphorous,K=Potassium

The treatments that promoted better growth of the maize crop had a positive influence on harvest index (HI), presumably due to faster growth and partitioning of more carbohydrates into the grain. All treatments had higher HI compared to the control, reflecting poor plant growth in the control. The results suggest that an application of NPK supply is essential for optimized partitioning of dry matter between grain and other parts of the maize plant. The higher yield was due to more value of yield attributes viz., cob length, no of grains/cob, 100-grain weight. This could be justified by the positive linear correlation between grain yield and plant height (r= 0.98**), number of grains per cob (r= 0.99**) and thousand kernel weight (r= 0.99**) and negative correlation between grain yield and barrenness percentage (-0.98) in Table 5. However, variations in grain yield between two years may be attributed to weather conditions prevalent during crop season particularly rainfall that caused water logging in 2023/24 that affected on corn yield. The higher nutrient uptake from 25 percent above and full dose of fertilizer plot might be due to increase in balanced and surplus nutrient concentration with better plant growth. Nitrogen uptake in grain and stover could be enhanced with increased phosphorus applications and potassium application (Saifullah et al 2002). Nitrogen and phosphorus combination affected grain yield significantly. Amanullah and Khalil (2010) observed that increased level of phosphorus produced higher grain and stover yield that might be due to increase in yield and yield components.

Table 5. Correlation between, growth parameters, yield and yield attributes

Traits	Yield	Plant height	Grains/cob	1000 grain weight	Barrenness %	Grain N uptake	Harvest index
Yield							
Plant height	0.977**						
Grains/cob	0.977**	0.971**					
1000 grain weight	0.999**	0.977**	0.995**				
Barrenness %	-0.9804	-0.961*	-0.964*	-0.986			
Grain N uptake	0.995**	0.969**	0.998**	0.990**	-0.955*		
Harvest index	0.951**	0.917**	0.927**	0.951**	-0.973*	0.928**	

Omission of N (i.e. PK treatment) extraordinarily reduced recovery effeciency suggesting that P application in the absence of N cannot improve the recovery efficiency of P (Table 6 and Table 7). Negative value for P and K in FYM plot signifies that indigenous phosphorous supply (IPS) of soil was high as FYM was high in potassium also indigenous potassium supply (IKS) capacity of soil was medium so there was no need to apply ample P and K in FFP.

Table 6. Recovery efficiency of FYM and ample NPK plot, 2022/23

Recovery effeciency in FFP plot			Recovery effeciency in ample NPK plot		
Fertilizer	kg NPK/kg NPK	Percentage	Fertilizer	kg NPK/kg NPK	Percentage
Nitrogen	0.02	2.20	Nitrogen	0.25	24.90
Phosphorous	-0.40	-40.00	Phosphorous	0.14	13.87
Potassium	-0.08	-7.97	Potassium	0.18	17.78

Table 7. Recovery efficiency of FYM and ample NPK plot, 2023/24

Recovery effeciency in FFP plot			Recovery effeciency in ample NPK plot		
Fertilizer	kg NPK/kg NPK	Percentage	Fertilizer	kg NPK/kg NPK	Percentage
Nitrogen	0.03	3.40	Nitrogen	0.29	29.11
Phosphorous	-0.23	-23.33	Phosphorous	0.05	15.39
Potassium	-0.29	-28.58	Potassium	0.1	19.74

Grain N uptake was significantly influenced by nutrient omission (Table 8). Highest grain N uptake was recorded with +NPK applied treatment and lowest in nitrogen omitted treatment i.e –N,+PK. Total N P and K uptake was significantly influenced by nutrient omission. The highest total N, total P, total K uptake was recorded in +NPK applied treatment, and lowest total N uptake was recorded in N omitted plot, lowest total P uptake was recorded in N omitted and FYM applied plot followed by P omitted plot and lowest total K uptake was in N omitted and FYM applied plot followed by K omitted plot. The omission of nitrogen, phosphorous, potassium significantly decreased ($p < 0.05$) the respective nutrient content in both maize grains and their uptake compared to that with the ample fertilized plot. Moreover, luxury consumption of P in ample NPK plot indicates that the native supply of P was enough to support P requirement of popcorn and we may apply no or lower dose of P fertilizer.

Table 8. Effect of omission of nutrient on total nitrogen, phosphorous and potassium uptake

Treatment	Grain N uptake	Total N uptake	Total P uptake	Total K uptake
FYM	21.36^{c}	45.89^{c}	23.38^{c}	46.38^{c}
-N,+P	15.25^{d}	42.89^{c}	20.75^{c}	42.74^{c}
-P,+NK	40.14^{ab}	79.10^{ab}	37.05^{b}	60.52^{ab}
-K,+NP	37.47^{b}	77.70^{b}	39.59^{ab}	56.15^{b}
+NPK	41.17^{a}	82.99^{a}	41.77^{a}	63.04^{a}
Mean	31.08	65.63	32.51	53.77
Treatments	*	*	*	*
Year	*	Ns	*	*
Treatments*Year	Ns	Ns	Ns	Ns
LSD (0.05)	3.3	4.37	2.76	0.56
CV%	10.4	6.5	8.3	9.9

CONCLUSION

Khumaltar soil was rich in available phosphorous and rich in indigenous phosphorous supply and low in nitrogen supply than potassium supply although the soil indigenous nitrogen and potassium supply was medium. Taking into account in the indigenous nutrient supply capacity of soil NPK required for the experimental field was recorded to be 92.81 kg ha^{-1}N, 11.09 $kgha^{-1}$ P_2O_5, 52.81 $kgha^{-1}$ K_2O. Phosphorus requirement was found to be very much lesser because indigenous phosphorous supply (IPS) of soil was higher and lower amount of P fertilizer is required to meet the crop P requirement. Among various limitations, the low fertilizer use efficiency can be considered as a major limitation in achieving the desired yield. Quantification of indigenous nutrient supply capacity of soil for major nutrients NPK is a pre-requisite to increase nutrient use efficiency and yield. The results of two year data analysis illustrated that N was the most limiting nutrient followed by K and P in order. In order to maintain soil productivity and reach the same target yield of popcorn, there is a need to apply balance proportion of N, P_2O_5 and K_2O fertilizer.

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AUTHOR'S CONTRIBUTION

All authors contributed equally for conceptualization, design of experiment and its execution, data recording and analysis, preparing initial and final draft of this paper.

CONFLICT OF INTEREST

The authors declare no competing interests relevant to the content of this article.

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