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Impact of site specific nutrient omission technique on growth, yield and quality of QPM

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Abstract

Maize holds immense importance as the most widely cultivated crop on a global scale. It exhibits remarkable responsiveness to the external application of fertilizers and the optimal doses of nutrients are essential to augment the growth as well as yield characteristics of maize. Therefore, to investigate the nutrient omission impact on crop growth and yield of quality protein maize (LQMH-1 hybrid) under SSNM application of nutrients, a study was performed at an Agricultural Research Farm, FoA, Wadura, SKUAST Kashmir, India, during Kharif season 2021. The experiment comprised of eight treatments *viz*., absolute control (T_1), NPK (T_2), NPKZnS (T_3), PKZnS (-N) (T_4), NKZnS (-P) (T_5), NPZnS (-K) (T_6), NPKS (-Zn) (T_7) and NPKZn5 (-S) (T_8) in RCBD experimental design with three replications. The application of NPKZnS led to a substantial increase in yield metrics, including cob length, cob diameter, ear height, grain rows per cob, and seed index. The treatment (T_3) attained a significantly higher leaf area index of 5.82 at 60 DAS with CGR of 2.78g m^{-2} day^{-1} at 60-90 DAS and RGR of 52.74 mg g^{-1} day^{-1} between 30-60 DAS and also recorded maximum protein content (9.5%). Among the omission of nutrients, nitrogen was found to be the most limiting nutrient that drastically reduced LAI, CGR, RGR, yield characters, and protein content of maize which was trailed by P omission and K omission. However, the omission of Zn and S had the least significant impact on the performance of the QPM hybrid.

Keywords crop growth rate, leaf area index, nutrient omission, quality protein maize, seed index

Introduction

Maize holds a crucial position as a major grain crop globally to feed humans and livestock. Due to its remarkable genetic yield potential and significant role in both human and animal diets, it is known as the "Queen of Cereals". It is cultivated on an area of about 140 million hectares in a variety of climates with India accounting for about 9.47 million hectares of cultivation. The country's production and yields are 28.64 million tonnes and 29.45 q ha^{-1}, respectively [1]. In Jammu and Kashmir, an area of 2.6 lakh ha is occupied by maize [1]. Increased demand for meat and poultry thrust on further importance for maize as feed for both poultry and sheep. Conventional types of maize are deficient in the amino acids lysine and tryptophan, which are necessary to make proteins, and they contain their niacin (vitamin B_3) in an indigestible complex [2]. People who eat maize as their main source of food have an abundance of energy, but their bodies suffer from a protein deficiency [3]. The low protein and imbalanced amino acid content in maize causes protein deficiency diseases like kwashiorkor and malnutrition in the poor class people who have maize as their principal dietary source. In this regard, the genetic improvement of cereal grains like maize is essential while focusing on their nutritional value [2]. Quality Protein Maize (QPM), developed at CIMMYT has the same yield potential or looks and tastes like regular maize, but it has roughly twice as much lysine and tryptophan, which are deficient in normal maize. Low fertilizer efficiency, inadequate fertilizer recommendations, lack of knowledge about nutrients besides N, P, and K, and steadily declining soil quality all contribute to the productivity of maize being constrained. Fertilizer, which accounts for 50–60% of additional agricultural production among other agricultural inputs, has been and will continue to be the key input in meeting the nation's food production goals. The response of main cereals to fertilizer treatments is frequently much below the potential yields, yield enhancements are likely to come by fine-tuning crop management. Presently, the average maize yield indicates great chances through precise nutrient and crop management specifically based on crop need, soil nutrient values, and target production to further boost productivity when compared to the potential yield for a particular genotype and climate [4]. Due to its substantial biomass accumulation, the maize crop demands higher amounts of nutrients particularly NPK [5]. The primary nutrient that affects plant production is nitrogen, and protein content and its insufficiency significantly lowers maize yield. Since nitrogen is crucial for agricultural productivity, it is essential for generating high yields and the best possible economic return [6-7]. Insufficient nitrogen availability limits the yield producing ability of the crop and the addition of nitrogenous fertilizers can significantly boost the yield and total dry matter of maize [8]. With a quantitative change in biomass, plant growth analysis is a quantitative method used to characterize and understand the performance of the entire plant system developed under natural, semi-natural, or managed settings [9]. The easiest and most accurate way to assess the role that various physiological processes play in plant development is growth analysis. The physiological indices like biomass accumulation, LAI, and crop growth rates are impacted by various factors including genotype, plant population, climate, soil fertility, etc [10]. The leaf area index plays a prime role in influencing photosynthesis and the build-up of dry matter [11]. Leaf area index is used in plant physiological studies as a growth indicator for plants as well as for assessing assimilation, estimating photosynthesis, transpiration rates, and dry matter build-up [12]. The partitioning of dry matter in plants is shown by the degree of plant growth, which is differentiated physiologically per unit area. The quantity of light intercepted that a crop absorbs directly affects the rate of crop growth [13]. Two parameters are measured in order to quantify growth *viz*., leaf area and the dry weight of the plant. From these two measurements, further quantities are derived. Growth analysis is an exact tool for assessing the role that various physiological processes play in plant development. Therefore, the principle aim of this research endeavor was to evaluate the effect of nutrient omission on crop growth indices, dry matter accumulation, and yield of QPM.

Methodology

Climate and soil of experimental site

A study entitled "Site Specific Rational Nutrient Management in Quality Protein Maize" was carried out at FoA, Wadura, SKUAST Kashmir, India in the year 2021, to evaluate the effect of nutrient omission on crop growth indices, yield and protein content of QPM hybrid (LQMH-1). The weather data during *Kharif* season of 2021 recorded at the Meteorological Observatory located at Wadura, revealed that the minimum and the maximum temperature varied from 9.50 to 18.91 °C and 26 to 32 °C respectively on a weekly basis. Precipitation of 184.60 mm was recorded during the entire crop growing period. Furthermore, the average relative humidity ranged from 48.07 to 75.98 percent. The experimental field indicated silty clay loam texture analyzed by hydrometer meter method [14] with neutral pH and medium in organic carbon (0.69 %) that was estimated with Walkley and Black's rapid titration method [15], normal in EC (0.28 dSm^{-1}) estimated by solu-bridge conductivity meter, [16], medium in available N, P, K, S (304.20, 16.42, 178.63, 17.30 kg ha^{-1}, respectively) but deficient in available Zn.

Experimental setup

The present experiment was tested using eight treatments viz., absolute control (T_1), NPK (T_2), NPKZnS (T_3), PKZnS (T_4), NKZnS (T_5), NPZnS (T_6), NPKS (T_7) and NPKZn (T_8), replicated thrice in RCBD. The fertilizers used for supplying the nutrients were urea, DAP, potassium sulphate, and zinc oxide. For the omission of nitrogen in the case of T_4, rock phosphorus was used instead of DAP and for omission of potassium (T_6) gypsum was used instead of potassium sulphate. Nitrogen was given in split doses with three splits. Economics was calculated through prevailing prices of inputs and outputs.

Data compilation

For functional leaves, at 30 days interval of sowing up to harvest, the total number of green, healthy, active, and fully expanded leaves were tallied from the tagged plants of each treatment. The average value was calculated and recorded. To compute the leaf area length and width of each healthy and active leaf of the tagged plants were measured. This was multiplied by a correction factor of 0.75 to get the leaf area of the plant. The LAI was taken as the average of the tagged plants.

$$\text{LAI} = \frac{\text{Leaf area } (cm^2)}{\text{Ground area } (cm^2)}$$

$$\text{CGR} = \frac{W_2 - W_1}{T_2 - T_1} \ldots\ldots\ldots\ldots\ldots\ldots[17]$$

$$\text{RGR} = \frac{\ln W_2 - \ln W_1}{T_2 - T_1} \ldots\ldots\ldots\ldots\ldots\ldots[18]$$

Where W_1: dry matter per m^2 at time T_1 and W_2: dry matter per m^2 at time T_2

T_2-T_1 = Time interval of sampling in days

L_n = natural logarithm

For cobs per plant, enumeration of cob counts was performed on five tagged plants during the harvest phase. Subsequently, the mean for each individual plant within the experimental unit was figured. The harvested cobs of five tagged plants were used for measuring cob length spanning from the base to the tip of each cob. The cob diameter was determined through the computation of cob girth, achieved by measuring the circumference of observed cobs. This measured value was then divided by 3.14, the averaged results represented the cob diameter. Ear height, in centimeters, was determined by measuring the distance from the base of the observational plants up to the 1/4th portion of the topmost cob. The average value of the results represented the ear height. The number of kernel rows per cob was determined by taking the average of the rows of cobs under observation. In each treatment, 100 sundried grains were collected from the shelled cobs of observational plants. These grains were then weighed to determine the seed index in grams (g). The nitrogen content of grain was multiplied by a factor of 5.98 to estimate its protein content.

Statistical analysis

In order to analyze the impact of nutrient omission on crop growth indices of QPM statistically, the ANOVA was carried out on experimental data using RCBD as a standard statistical procedure. Least square difference (LSD) was used to assess the significance of treatment means at a 5% level of significance. SPSS software version 27.0 was used to perform the data analysis.

Results

Growth attributes

The maximum number of functional leaves were recorded with (T_3) $N_{120}P_{75}K_{40}Zn_5S_{10}$ throughout the crop growth period from 30 DAS (8.93) to harvest (6.00) and the lowest with control (Figure 1). Also, the maximum accumulation of dry matter was observed under the application of $N_{120}P_{75}K_{40}Zn_5S_{10}$ throughout the growing stages with a maximum of 157.56 q ha^{-1} at harvest. Among nutrient omission treatments, the number of functional leaves as well as dry matter accumulation were registered minimum with nitrogen omission followed by the P omission and K omission. The data showed that the leaf area index was initially lowest at 30 DAS and increased with increasing plant age, and the values spiked at later stages. The treatment $N_{120}P_{75}K_{40}Zn_5S_{10}$ acquired significantly highest LAI values at all growth stages among all other treatments *viz.*, 30 DAS (1.87), 60 DAS (5.82), 90 DAS (4.39) and at harvest (1.90) respectively (Figure 2).

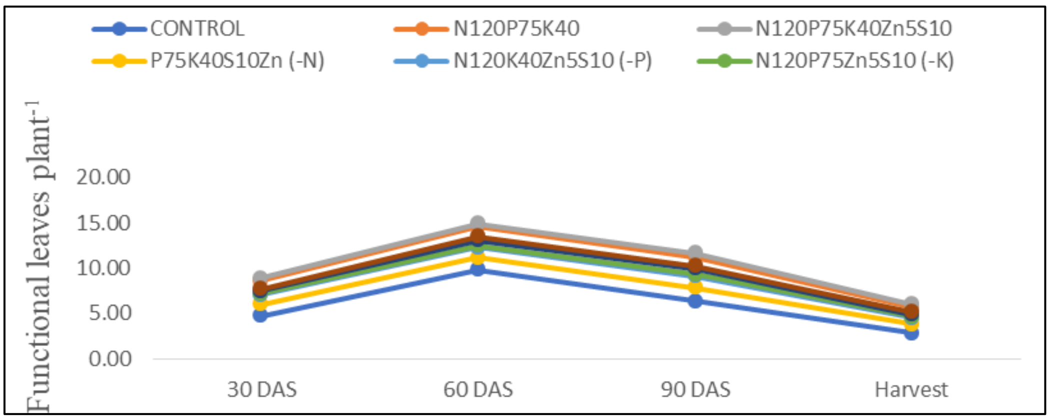

Figure 1. Nutrient omissions impact on number of functional leaves per plant of QPM

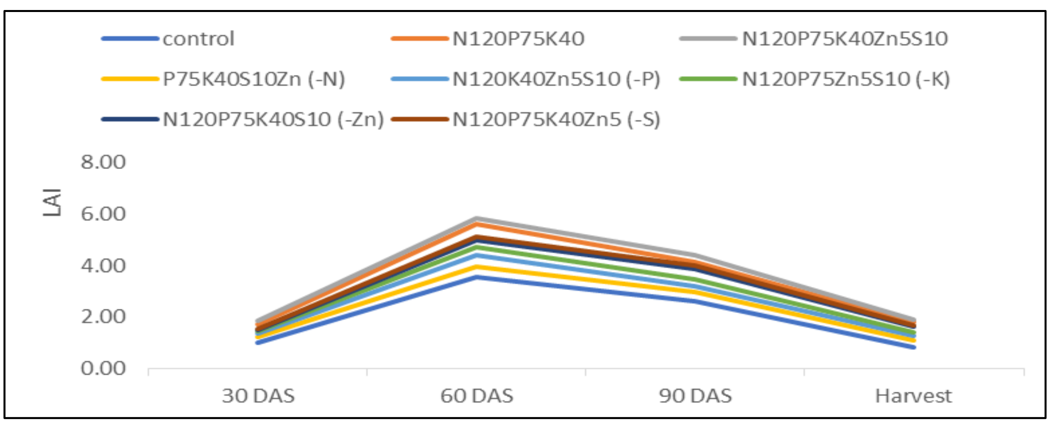

Figure 2. Nutrient omissions impact on leaf area index of QPM

A significant impact of nutrient omission was observed on the crop growth rate at different periodic intervals. The application of $N_{120}P_{75}K_{40}Zn_5S_{10}$ led to significantly higher CGR at 60-30 DAS interval (2.44 g m^{-2} day^{-1}), 90-60 DAS interval (2.78 g m^{-2} day^{-1}) and the interval between harvest-90 DAS (0.20 g m^{-2} day^{-1}) (Table 1), respectively and attained significantly higher RGR at 60-30 DAS interval (52.74 mg g^{-1} day^{-1}) (Table 2 and Figure 3). The omission of N reduced the LAI, CGR as well RGR significantly which was trailed by P omission and K omission.

Table 1. Nutrient omissions impact on crop growth rate (g m^{-2}day^{-1}) of QPM

Treatments	60-30 DAS	90-60 DAS	Harvest-90 DAS
T_1: Control	0.82	1.70	0.14
T_2: $N_{120}P_{75}K_{40}$	2.09	2.90	0.11
T_3: $N_{120}P_{75}K_{40}Zn_5S_{10}$	2.44	2.78	0.20
T_4: $P_{75}K_{40}S_{10}Zn_5$ (-N)	1.10	2.37	0.34
T_5: $N_{120}K_{40}Zn_5S_{10}$ (-P)	1.28	2.61	0.24
T_6: $N_{120}P_{75}Zn_5S_{10}$ (-K)	1.45	2.80	0.10
T_7: $N_{120}P_{75}K_{40}S_{10}$ (-Zn)	1.69	2.85	0.13
T_8: $N_{120}P_{75}K_{40}Zn_5$ (-S)	1.81	2.88	0.11
Sem±	**0.06**	**0.07**	**0.02**
CD(p≤0.05)	**0.16**	**0.21**	**0.06**

Table 2. Nutrient omissions impact on relative growth rate (mg g^{-1} day^{-1}) of QPM

Treatments	60-30 DAS	90-60 DAS	Harvest-90 DAS
T_1: Control	39.91	29.92	1.59
T_2: $N_{120}P_{75}K_{40}$	50.03	24.41	0.67
T_3: $N_{120}P_{75}K_{40}Zn_5S_{10}$	52.74	21.53	1.14
T_4: $P_{75}K_{40}S_{10}Zn_5$ (-N)	38.32	30.06	2.71
T_5: $N_{120}K_{40}Zn_5S_{10}$ (-P)	40.91	29.76	1.74
T_6: $N_{120}P_{75}Zn_5S_{10}$ (-K)	43.21	29.21	0.71
T_7: $N_{120}P_{75}K_{40}S_{10}$ (-Zn)	46.43	27.32	0.82
T_8: $N_{120}P_{75}K_{40}Zn_5$ (-S)	47.66	26.50	0.69
Sem±	**0.72**	**0.17**	**0.26**
CD(p≤0.05)	**2.14**	**0.54**	**0.76**

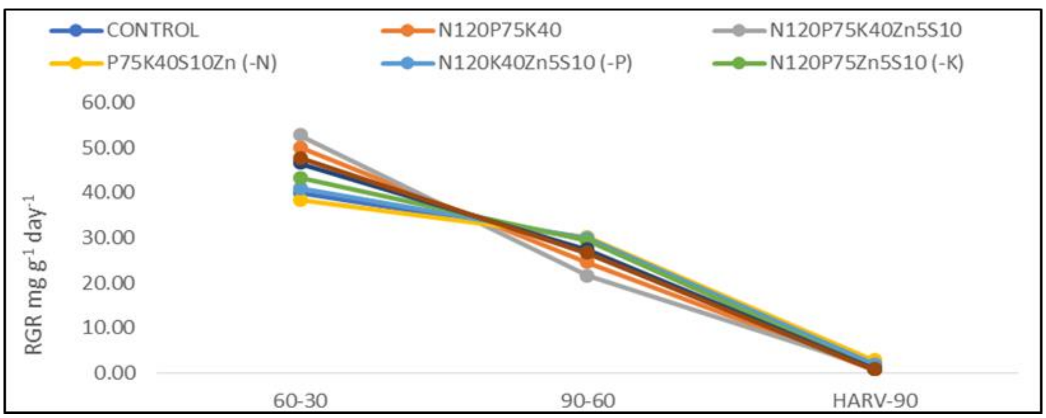

Figure 3. Nutrient omissions impact on RGR of QPM

Yield attributes

The data in Tables 3 and 4 revealed that varied nutrient omission treatments had no significant impact on the number of cobs per plant but recorded a significant impact on different yield attributes. The treatment NPKZnS numerically produced higher cobs per plant. Absolute control and the nitrogen omitted treatment, however, produced the lowest number of cobs per plant. Furthermore, omission of nutrients NPKZn and S didn't affect the number of cobs per plant. The treatment NPKZnS resulted in taller ears (107.433 cm) but was statistically at par with $N_{120}P_{75}K_{40}$. With a value of 86.767 cm, absolute control recorded the lowest ear height. The omission of nutrients NPKZn and S resulted in a considerable reduction in ear height. However, the impact of omission of NPK on the reduction of ear height was more pronounced than the omission of Zn and S. The treatment (T_3) $N_{120}P_{75}K_{40}Zn_5S_{10}$ resulted in considerably more kernel rows per cob (14.50) but was statistically at par with $N_{120}P_{75}K_{40}$ (Table 3). Absolute control recorded the lowest number of kernel rows per cob (10.90). The treatment (T_3) NPKZnS resulted in significantly maximum cob length with husk (23.19 cm) and without husk (19.80 cm), highest cob diameter with husk (7.22 cm) and without husk (6.02 cm) (Table 4). Absolute control yielded the shortest cobs of 14.83 cm and 11.43 cm, with and without husk respectively, and the smallest cob diameter of (3.04 cm) and (1.84 cm) with and without husk, respectively. The cob length and diameter reported considerable reduction under the influence of nutrient omission of NPKZn and S, but NPK omission had even more pronounced effect than omission of Zn and S. Omission of nitrogen (-N) demonstrated the lowest cob diameter (3.53 cm and 2.33 cm, with and without husk, respectively), that was statistically significant followed by omission of phosphorus (-P) (4.14 cm and 2.94 cm, with and without husk and potassium (-K) (4.93 cm and 3.73 cm, with and without husk, respectively). The exclusion of nutrients resulted in a significant reduction in kernel rows per cob. The lowest kernel rows per cob (11.87) were observed under

Table 3. Nutrient omissions impact on yield attributes of QPM

Treatments	Cobs plant^{-1}	Ear height (cm)	Rows per cob	Seed index (g)
T_1: Control	1.30	86.76	10.90	19.70
T_2: $N_{120}P_{75}K_{40}$	1.40	107.20	13.97	21.52
T_3: $N_{120}P_{75}K_{40}Zn_5S_{10}$	1.40	107.43	14.50	21.70
T_4: $P_{75}K_{40}S_{10}Zn_5$ (-N)	1.30	91.60	11.87	20.67
T_5: $N_{120}K_{40}Zn_5S_{10}$ (-P)	1.35	95.20	12.27	20.95
T_6: $N_{120}P_{75}Zn_5S_{10}$ (-K)	1.40	98.60	12.57	21.13
T_7: $N_{120}P_{75}K_{40}S_{10}$ (-Zn)	1.40	103.50	13.17	21.32
T_8: $N_{120}P_{75}K_{40}Zn_5$ (-S)	1.40	104.86	13.40	21.36
Sem±	**0.06**	**1.92**	**0.31**	**0.08**
CD(p≤0.05)	**NS**	**5.76**	**0.94**	**0.25**

Table 4. Nutrient Omissions impact on yield attributes and protein content of QPM

Treatments	Cob length(cm)		Cob diameter(cm)		Protein content (%)
	with husk	without husk	with husk	without husk	
T_1: Control	14.83	11.43	3.04	1.84	6.21
T_2: $N_{120}P_{75}K_{40}$	21.68	18.39	6.03	4.83	9.38
T_3: $N_{120}P_{75}K_{40}Zn_5S_{10}$	23.19	19.80	7.22	6.02	9.50
T_4: $P_{75}K_{40}S_{10}Zn_5$ (-N)	16.08	13.02	3.53	2.33	7.59
T_5: $N_{120}K_{40}Zn_5S_{10}$ (-P)	17.64	14.44	4.14	2.94	8.49
T_6: $N_{120}P_{75}Zn_5S_{10}$ (-K)	18.47	15.92	4.93	3.73	8.61
T_7: $N_{120}P_{75}K_{40}S_{10}$ (-Zn)	19.89	17.40	5.43	4.23	8.73
T_8: $N_{120}P_{75}K_{40}Zn_5$ (-S)	20.13	17.66	5.73	4.53	8.79
Sem±	**0.48**	**0.46**	**0.191**	**0.61**	**0.03**
CD(p≤0.05)	**1.44**	**1.36**	**0.59**	**0.471**	**0.08**

nitrogen (-N) omission, which was statistically significant, followed by phosphorus (-P) (12.27) and potassium omission (-K) (12.57). The treatment (T_3) $N_{120}P_{75}K_{40}Zn_5S_{10}$ yielded the highest seed index (21.70 g), among all other treatments. Absolute control, on the other hand, recorded the lowest seed index of 19.70 g. Among the omission of nutrients, omission of N had the most significant effect on the seed index reduction.

Quality parameter

The treatment N120P75K40Zn5S10 recorded significantly higher values of protein content (9.50 %) in comparison to other treatments (Table 4). However, absolute control recorded the lowest protein content (6.21 %). The protein content was decreased significantly with the omission of -NPKZn and S. The lowest protein content was registered (7.59%) with nitrogen omission treatment, which was statistically significant, followed by phosphorus (-P) and potassium omission (-K). However, in comparison to –N, –P, and –K, zinc omission and sulfur omission showed the minimum effect on protein content.

Discussion

The presence of ample and balanced nutrients is fundamental in promoting the luxuriant growth of leaves, which greatly enhances the photosynthetic efficiency of plants. The greater leaf count leads to the development of a larger canopy, optimizing the intake, absorption, and utilization of light. This leads to a notable increase in the leaf area index (LAI), providing more leaf area exposed to sunlight and thereby boosting photosynthetic activity substantially. The consequential effect is a significant rise in biomass production, leading to notable improvements in both crop growth as well as relative growth rate [19-20]. The adoption of a balanced nutrient prescription within the framework of SSNM has a positive impact on crop plants by promoting the development of more chlorophyll. This leads to the expansion of functional photosynthetic areas, resulting in higher NDVI and SPAD values, as observed in a study conducted by Kumar et al., [21]. As a consequence, a significant increment in leaf area index was experienced. The provision of all nutrients in appropriate amounts creates a favorable environment, enhancing the photosynthetic activity of the plant and facilitating greater dry matter accumulation, thereby contributing to the overall increase in crop growth indices [22]. Nitrogen being the key constituent of chlorophyll of plants and therefore its concentration is directly related with the photosynthetic areas of the plant. The absence of nitrogen adversely affects the crop's vegetative phase, resulting in a decline in the number and area of photosynthetically active leaves. This reduction in vegetative growth has a profound impact on various crop growth indices, ultimately leading to decreased dry matter accumulation [23].

A significant impact on the yield attributes was observed under different nutrient omission treatments. The best results were observed when all nutrients were applied at their optimal doses. Particularly, the application of $N_{120}P_{75}K_{40}Zn_5S_{10}$ led to a substantial increase in yield metrics, including cob length, cob diameter, ear height, grain rows per cob, and seed index. On the other hand, the absolute control, where no nutrients were applied, showed the greatest reduction in yield attributes. Among the various treatments, omitting nitrogen (N) had the most severe effect on the yield attributes of QPM (Quality Protein Maize), depicting that nitrogen has the most significant impact on yield attributes in comparison to the omission of other nutrients under investigation.

The strategic adoption of SSNM, coupled with the precise application of nutrients at $N_{120}P_{75}K_{40}Zn_5S_{10}$ levels, provided maize plants with superior nutrient availability. This, in turn, led to notable improvements in plant height, green leaf development, and dry matter content, culminating in a substantial boost in all yield parameters [24]. The favourable growth traits observed, characterized by notable increments in leaf area, LAI, and stem dry matter accumulation, had a significant positive impact on the intricate processes governing the transfer, partitioning, and assimilation of photosynthates. This, in turn, led to a substantial improvement in the source-sink relations of the plants, ultimately influencing various essential yield characteristics. Notably, an higher grain rows in a cob were observed, and the seed index experienced significant enhancement. The availability of higher levels of mineral nutrition played a crucial role in stimulating increased source activity, particularly attributable to the development of a larger leaf area. This mechanism facilitated an optimized supply of photosynthates, consequently enhancing the overall growth and development of the plants [25]. The achievement of an optimal nutrient intake level during the reproductive organ development stage had a profound impact on dry matter production, leading to a substantial enhancement of various yield qualities [26]. Additionally, the application of zinc played a pivotal role in this context, significantly enhancing the chlorophyll content. This boost in chlorophyll content had far-reaching implications, positively affecting critical factors like photosynthetic activity, the production of essential metabolites and growth regulators, as well as various oxidative and metabolic activities. Consequently, these combined effects played a key role in promoting robust crop growth and development, ultimately resulting in a notable increase in yield qualities [27]. The enhanced availability of photosynthates is hypothesized to have significantly influenced the proliferation of flowers, ultimately leading to improved fertilization and subsequent development. As a consequence, a higher number of yield factors were observed [28]. However, it is noteworthy that the various nutrient omission treatments did not yield any statistically significant impact on cobs per plant, emphasizing the varietal nature of this particular trait. The findings indicated that nitrogen omission had the most negative impact on the performance of maize, followed by the omission of phosphorus and potassium. This nutrient deficiency scenario likely hindered the optimal vegetative growth of the plants and led to reduced biomass accumulation, particularly during the crucial early growth phases. Consequently, the inadequate partitioning of photosynthates towards the reproductive organs significantly contributed to the observed reduction in the overall yield attributes of the maize crop [29]. The exclusion of essential nutrients resulted in reduced availability of NP and K which in turn, led to poor nutrient uptake by the maize crop, ultimately adversely affecting its yield characteristics. On the other hand, the omission of zinc and sulphur had a less significant impact on the reduction of yield attributes of maize. This observation can be attributed to the adequate availability of zinc and sulphur from the soil reserves, which mitigated their negative impact on crop yield [30].

The SSNM based fertilizer application of $N_{120}P_{75}K_{40}Zn_5S_{10}$ significantly resulted in higher protein content of maize and ranged from 6-10% under various nutrient omission treatments. This might be due to the optimized dose of N coupled with P, K, Zn, and S, which led to better growth, biomass yields, photosynthetic rate, and protein content in the plant tissues of maize. The role of zinc in the synthesis of IAA, chlorophyll formation, carbohydrate, and auxin metabolism may be associated with higher protein content of hybrid [31]. The least N uptake and unavailability of N during grain filling stage under controlled conditions resulted in the lowest protein content of QPM. Nitrogen is responsible for the amino acid composition of protein and has an impact on the nutritional value of protein. Therefore, the omission of nitrogen significantly reduces the protein content in maize followed by the omission of phosphorus and potassium. Phosphorus facilitates widespread root development in plants, which improves N uptake and indirectly influences the protein content and potassium also contributes significantly to protein synthesis, assimilate translocation, and N absorption. The synergetic effect of P and K toward N uptake improved the protein content of maize [32]. The significant impact of nutrient omissions was also reported by [33]. Rehman et al., [34] highlighted the positive impact of NPK on protein content as a consequence of the existence of a close relationship between N content and protein content.

Conclusion

The study indicated that in terms of growth and yield, the SSNM approach utilizing $N_{120}P_{75}K_{40}Zn_5S_{10}$ proved to be highly effective, as evidenced by significant improvements in key physiological growth indices such as functional leaves, LAI, CGR, RGR of QPM. The implementation of $N_{120}P_{75}K_{40}Zn_5S_{10}$ as a nutrient treatment resulted in substantial yield enhancements for maize. It notably increased the key yield metrics, including cob length, cob diameter, ear height, grain rows per cob, and seed index. Among the various nutrient omission treatments, nitrogen (N) stood out as the most prominent factor in affecting the performance of the crop. The omission of nitrogen had the most significant negative impact, followed by phosphorus (P) and potassium (K) omissions, respectively.

These results highlight the critical role of individual major nutrients in supporting plant growth and yield.

References

[1] DES **(2020)**. Agriculture statistics at glance, published by Directorate of Economics and Statistics. New Delhi.
[2] B. M. Prasanna, S. K. Vasal, B. Kassahum and N. N. Singh **(2001)**. Quality protein maize. Curr. Sci., **81:** 1308-1319.
[3] P. K. Kataki and S. C. Babu **(2002)**. Food systems for improved human nutrition: Linking agriculture, nutrition and productivity. 394. Binghamton: Food Products Press.
[4] G. W. Xu, G. L. Tan, Z. Q. Wang, L. J. Liu and J. C. Yang **(2009)**. Effects of wheat residue application and site-specific nitrogen management on growth and development in direct seeded rice. Acta Agron. Sin., **35:** 685-694.
[5] C. B. Chisanga, E. Phiri and V. R. N. Chinese **(2017)**. Assessing crop growth indices and yield parameters for maize (*Zea mays* L.) under irrigated condition in a subtropical environment of Zambia. Int. J. Multidisciplinary Res. Rev., Paper-ID : CFP/394/2017.
[6] K. B. Amanullah, Marwat, P. Shah, N. Maula and S. Arifullah **(2009)**. Nitrogen levels and its time of application influence leaf area, height and biomass of maize planted at low and high density. Pak. J. Bot., **41:** 761-768.
[7] M. S. Zeidan, A. Amany and M. F. Bahr El-Kramany **(2006)**. Effect of N fertilizer and plant density on yield and quality of maize in sandy soil. Res. J. Agric. Biol. Sci., **2:** 156-161.
[8] S. A. Valadabadi and H. A. Farahani **(2010)**. Effects of planting density and pattern on physiological growth indices in maize (*Zea mays* L.) under nitrogenous fertilizer application. J. Agric. Ext. Rural Dev., **2:** 40-47.
[9] W. A. Hoffmann and H. Poorter **(2002)**. Avoiding bias in calculations of relative growth rate. Ann. Bot., **90:** 37-42.
[10] S. Hokmalipour and M. H. Darbandi **(2011)**. Physiological growth indices in corn (*Zea mays* L.) cultivars as affected by nitrogen fertilizer levels. World Appl. Sci. J., **15:** 1800-1805.
[11] R. S. Sharifi, Y. Raei and W. Weisany **(2014)**. Study of physiological growth indices in maize (*Zea mays* L.) hybrids under different plant densities. Int. J. Biosci., **5:** 100-109.
[12] J. C. L. Lukeba, R. K. Vumilia, K. C. K. Nkongolo, M. L. Mwabila and M. Tsumbu **(2013)**. Growth and leaf area index simulation in maize (*Zea mays* L.) under small-scale farm conditions in a Sub-Saharan African region. Am. J. Plant Sci., **4:** 575–583.
[13] J. T. Edwards, L. C. Purcell and E. D. Vories **(2005)**. Light interception and yield potential of short-season maize (*Zea mays* L.) hybrids in the Midsouth. Agron. J., **97:** 225-234.
[14] G. J. Bouyoucos **(1962)**. Hydrometer method improved for making particle size analyses of soils. Agron. J., **54:** 464-465.
[15] A. J. Walkley and I. A. Black **(1934)**. Estimation of soil organic carbon by the chromic acid titration method. Soil Sci., **37:** 29-38.
[16] M. L. Jackson **(1962)**. Soil chemical analysis. Prentice Hall of India private limited, New Delhi, pp498.
[17] P. Redford **(1967)**. Growth Analysis formulae-their use and abuse. Crop Sci., **7:** 171-175.
[18] D. J. Watson **(1952)**.The physiological basis of variation in yield. Adv. Agron., **4:** 101-145.
[19] G. O. Kolawole, O. Eniola and Y. B. Oyeyiola **(2018)**. Effects of nutrients omission on maize growth and nutrient uptake in three dominant soil types of southwestern Nigeria. J. Plant Nutr., **41:** 1903-1915.
[20] M. A. A. Kumar, S. K. Gali and N. S. Hebsur **(2007)**. Effect of different levels of NPK on growth and yield parameters of sweet corn. Karnataka J. Agric. Sci., **20:** 41-43.

[21] V. Kumar, A. K. Singh, S. L. Jat, C. M. Parihar, V. Pooniya, S. Sharma and B. Singh **(2014)**. Influence of site-specific nutrient management on growth and yield of maize (*Zea mays*) under conservation tillage. Indian J. Agron., **59:** 657-660.

[22] D. Jinger, S. Dhar, A. Dass, V. K. Sharma, L. Shukla, V. Paramesh and M. Parihar et al., **(2021)**. Growth indices, yield, nutrient uptake and soil enzyme activity of wheat as affected by residual effect of phosphorus and silicon. doi: 10.21203/rs.3.rs-930544/v1.

[23] M. R. Broadley, A. J. Escobar-Gutierrez, A. Burns and I. G. Burns **(2000)**. What are the effects of nitrogen deficiency on growth components of lettuce? New Phytol., **14:** 519-526.

[24] V. Sobhana, A. Kumar, L. K. Idnani, I. Singh and Shivadhar **(2012)**. Plant population and nutrient requirement for baby corn hybrids (*Zea mays*). Indian J. Agron., **57:** 294-296.

[25] E. Kolo, F. O. Takim and O. Fadayomi **(2012)**. Influence of planting date and weed management practices on weed emergence, growth and yield of maize (*Zea mays* L.) in Southern Guinea Savanna of Nigeria. J. Agr. Biodiv. Res., **1:** 33-42.

[26] R. K. Shivran, R. Kumar and A. Kumari **(2013)**. Influence of sulphur, phosphorus and farm yard manure on yield attributes and productivity of maize (*Zea mays* L.) in humid south eastern plains of Rajasthan. Agric. Sci. Digest., 33: 9-14.

[27] R. R. Meena, H. S. Purohit, M. L. Khatik and H. K. Sumeriya **(2013)**. Effect of site specific nutrient management on growth, productivity and macro nutrients in maize (*Zea mays* L.) under southern Rajasthan conditions. Annals Biol., **29:** 364-369.

[28] A. Asghar, A. Ali, W. H. Syed, M. Asif, T. Khaliq and A. A. Abid **(2010)**. Growth and yield of maize (*Zea mays* L.) cultivars affected by NPK application in different proportion. Pak. J. Sci., **62:** 211-216.

[29] C. Muthaura, M. Mucheru-Muna, S. Zingore, J. Kihara and J. Muthamia **(2017)**. Effect of application of different nutrients on growth and yield parameters of maize (*Zea mays*), case of Kandara Murang'a County. ARPN J. Agric. Biol. Sci., **12:** 19-33.

[30] H. M. O. Otieno, G. N. Chemining'wa and S. Zingore **(2018)**. Effect of farmyard manure, lime and inorganic fertilizer applications on soil pH, nutrients uptake, growth and nodulation of soybean in acid soils of western Kenya. J. Agric. Sci., **10:** 199-208.

[31] M. Lashkari, H. Madani, M. R. Ardakani, F. Golarardi and K. Zargari **(2011)**. Effect of plant density on yield and yield components of different corn (*Zea mays* L.) hybrids. American-Eurasian J. Agric. Environ. Sci., **10:** 450-457.

[32] M. R. Umesh, N. Manjunatha, M. A. Shankar, and N. Jagadeesha **(2014)**. Influence of nutrient supply levels on yield, nutrient uptake, grain quality and economics of corn (*Zea mays* L.) in *Alfisols* of Karnataka. Indian J. Dryland Agric. Res. Dev., **29:** 73-78.

[33] B. Jamsheed, T. A. Bhat, A. A. Saad, A. Nazir, S. Fayaz,S. M. Eldin and B. Jan et al., **(2023)**. Estimation of yield, phenology and agro-meteorological indices of quality protein maize (*Zea mays* L.) under different nutrient omissions in temperate ecology of Kashmir. J. King Saud Univ.–Sci., **35:** 102808. doi: 10.1016/j.jksus.2023.102808.

[34] A. Rehman, M. F. Saleem, M. E. Safdar, S. Hussain and N. Akhtar **(2011)**. Grain quality, nutrient use efficiency, and bioeconomics of maize under different sowing methods and NPK levels. Chil. J. Agric. Res., **71:** 586-593.