



Enhancing Physiochemical Properties and Quality of Maize Through Integrated Nutrient Management

Lomada Vasudha¹, Amandeep Kaur¹, Shailja Sharma¹, Kavita Bhadu²

10.18805/ag.D-6114

ABSTRACT

Background: Maize (*Zea mays* L.) is a staple crop widely cultivated around the world, playing a crucial role in global food security. However, the sustained productivity of maize is threatened by declining soil health and quality due to intensive farming practices and improper nutrient management. Integrated nutrient management (INM) is a judicious use of organic and inorganic sources of nutrient to crop fields for sustaining and maintaining soil productivity. However, the use of appropriate and conjunctive use of application of suitable nutrients through organic and inorganic solely or in combination can provide the solutions to the problems such as increase in the price of inorganic fertilizers and deterioration effect of soil fertility and productivity. Hence, judicious application of these combinations can sustain the soil fertility and productivity.

Methods: A field experiment comprising of 12 treatments was carried out in the *kharif* season of 2022 at the research farm of the Department of Agronomy, School of Agriculture, LPU, Phagwara. Aim of this research was to optimize nutrient availability and enhance soil fertility. Addressing these challenges, the present investigation entitled, enhancing physio chemical properties and nutrient content of maize through integrated nutrient management

Result: Application of 100% RDN+ mixed biofertilizers + FYM+ 1% spray of ZnSO₄ + resulted in showed the highest protein content (10.15%), starch content (60.4%) and ash content (1.19%) in maize grains, followed by 75% RDN + Mixed Biofertilizers + FYM + 1% spray ZnSO₄ and T₁₁. Additionally, T₁₂ showed the highest available zinc status in the soil with 1.5 kg/ha and the highest available zinc content in grains and straw after harvest with 325.6 mg/kg and 27.3 mg/kg, respectively. These findings highlight the importance of combining various nutrient sources to optimize maize growth and enhance its productivity.

Key words: Integrated nutrient management, Maize, Quality, Soil fertility.

INTRODUCTION

Maize (*Zea mays* L.) holds great importance as a major cereal crop and serves as a staple food for over 900 million people in developing nations. It is a versatile crop that provides raw materials to produce food sweeteners, alcoholic beverages, protein, oil, starch and fuel. Compared to other cereal crops, maize has a higher potential for genetic yield. Maize grain is composed of around 10% protein, 70% carbohydrates, 4.1% oil and 2.3% crude fiber. Its exceptional yield potential has earned it the nickname of 'miracle crop' and the title of 'queen of cereals' (Sudhakar and Kuppusamy, 2007). In India, maize is considered a promising crop for diversifying agriculture in upland areas due to its high production potential and increasing market value in both irrigated and rainfed conditions. Global maize production covers an extensive area of nearly 207.25 million hectares, yielding 5.87 metric tonnes with productivity of 5754.7 kg/ha (USDA, 2023).

Considering its genetic potential of yield and fast growth habits, maize is a highly demanding crop in terms of nutrient requirements. Maize necessitates higher amounts of nitrogen (N) and phosphorus (P) compared to other essential elements throughout its growth stages. To achieve optimal yields and maintain soil fertility, it is crucial to supply the necessary nutrient elements in appropriate quantities. The integration of organic and inorganic fertilizers, with a balanced approach to plant nutrient

¹Department of Agronomy, Lovely Professional University, Phagwara-144 411, Punjab, India.

²Department of Agronomy, Rajasthan Agricultural Research Institute, Durgapura-302 018, Rajasthan, India.

Corresponding Author: Amandeep Kaur, Department of Agronomy, Lovely professional University, Phagwara-144 411, Punjab, India. Email: amugorsian@gmail.com

How to cite this article: Vasudha, L., Kaur, A., Sharma, S. and Bhadu, K. (2025). Enhancing Physiochemical Properties and Quality of Maize Through Integrated Nutrient Management. Agricultural Science Digest. 1-6. doi: 10.18805/ag.D-6114.

Submitted: 07-07-2024 **Accepted:** 18-01-2025 **Online:** 07-05-2025

application, has been proven effective in boosting maize productivity and preserving soil fertility. By combining different sources of organic manures with inorganic fertilizers in varying proportions, the integrated application approach offers significant advantages, including increased maize yield, enhanced nutrient uptake by plants and the preservation of soil nutrient levels in maize-based cropping systems. Integrated nutrient management (INM) is a valuable technique that promotes sustainable agricultural production while safeguarding the environment for future generations. INM involves the implementation of soil fertility management practices that optimize the

efficiency of both fertilizer and organic resource usage to enhance crop production. This approach encompasses the judicious utilization of appropriate chemical fertilizers and organic resources, ensuring a well-rounded and sustainable approach to nutrient management in maize cultivation.

Ravi *et al.* (2012) conducted a study that demonstrated the positive effects of specific fertilizer applications on various growth parameters and yield characteristics of maize. The application of 10 t/ha of FYM in combination with 100 percent of the RDF (150:75:37.5 kg NPK/ha + 25 kg ZnSO₄/ha) resulted in higher plant height (187.8 cm), LAI (4.7), total DMP (309.4 g/plant), weight per cob (122.2 g), cob length (15.8 cm), cob girth (11.52 cm) and seed index (29.1 g). Biofertilizers, a type of organic fertilizer, offer an environmentally friendly approach to fertilization. Commonly utilized microorganisms such as *Azospirillum*, PSB and VAM act as biofertilizers. These biofertilizers play a significant role in enhancing soil fertility by fixing atmospheric nitrogen, solubilizing insoluble forms of phosphorus, potash and mobilizing otherwise immobile nutrients in the soil. To maximize the benefits of both organic and inorganic fertilizers in maize cultivation, it is recommended to integrate FYM, *Azospirillum* and PSB with inorganic fertilizers such as urea, single superphosphate and muriate of potash at the recommended doses (Sivamurugan *et al.*, 2018). Maize is a crop that responds positively to zinc application, which leads to improved yields and substantial net returns for farmers. Many researchers observed that the application of zinc has shown positive effects on growth parameters, yield parameters, nutrient uptake, yield, quality and economic aspects of maize. Considering the current circumstances, it is essential to conduct further research to identify the most effective combination of organic components, varying doses of nitrogen and foliar spray of ZnSO₄ for optimal growth and production of maize.

MATERIALS AND METHODS

A field experiment comprising of 12 treatments was carried out in the *kharif* season of 2022 at the research farm of the Department of Agronomy, School of Agriculture, LPU, Phagwara. The research farm was situated at Latitude 31.24, Longitude 75.67, with an elevation of 252 meters above sea level. The soil of the experimental field had a sandy loam texture, a slightly alkaline pH of 7.80 and a moderate level of available nitrogen (280.6 kg/ha) and phosphorus (20.5 kg/ha), along with a high level of available potassium (295.0 kg/ha). Meteorological data were collected from May to September 2022, revealing that the maximum temperature ranged from 32.4°C to 42.4°C, the minimum temperature ranged from 25.4°C to 32.57°C and the average RH ranged from 30.5% to 71.2% throughout the crop's growth cycle. The total evaporation recorded during the crop season amounted to 142.9 mm, while the total rainfall received during the same period was 52.36 mm.

The treatments include T₁. Control, T₂. Mixed biofertilizers (*Azospirillum* @ 20 ml/kg of seed and phosphate solubilising bacteria @ 20 gm/kg of seed), T₃. FYM (@15 t/ha with NPK 0.5:1.2:1.2%), T₄. 75% recommended dose of nitrogen (RDN) + mixed biofertilizers, T₅. 75% RDN + FYM, T₆. 75% RDN + mixed biofertilizers + FYM, T₇. 75% RDN + mixed biofertilizers + FYM + 1% spray ZnSO₄, T₈. 100% RDN, T₉. 100% RDN + mixed biofertilizers, T₁₀. 100% RDN + FYM, T₁₁. 100% RDN + mixed biofertilizers + FYM, T₁₂. 100% RDN + mixed biofertilizers + FYM + 1% spray ZnSO₄. The experimental field was organized in a randomized block design (RBD) consisting of three replications. The total area of the field was 833 m², while the net field area, excluding the borders, was 733 m². Before land preparation, well-decomposed FYM was applied to the experimental plots. Prior to sowing, the seeds underwent treatment with biofertilizers and a foliar spray of 1% ZnSO₄ was conducted at 60 DAS, according to the respective treatments. For the nutrient application, the complete dose of phosphorus and potassium, along with one-third dose of the N, was applied as a basal dose. The remaining N was split into two equal applications at the knee-high stage and pre-tasselling stage. Nitrogen was supplied through urea, phosphorus through single superphosphate and potassium through muriate of potash. The maize variety used for sowing was PMH-13, with seeds planted at a depth of 3-5 cm and a spacing of 60 cm × 25 cm. All cultural practices were carried out in adherence to the recommended guidelines for maize cultivation. Morphological characteristics were recorded from five randomly selected plants, while maize grain yield and straw yield were measured at the plot level. The collected data was subjected to appropriate statistical analysis methods as recommended by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Growth characters

Plant stand was recorded after 30 DAS and at harvest and is presented in Table 1. This observation was recorded to determine the impact of various integrated nutrition sources on plant stand, which in turn may affect the grain production of the crop. The data showed that the combination of different integrated nutrient sources influenced the plant stand at 30 DAS and at harvest. Significantly higher plant stand was observed with the application of 100% RDN+ Mixed biofertilizers + FYM +1% spray of ZnSO₄ but it was statistically at par with 100% RDN+ Mixed biofertilizers + FYM and 100% RDN + FYM treatments. Dry matter accumulation (DMA) is a crucial factor that significantly affects the final yield of a crop. Achieving optimal dry matter accumulation, along with proper distribution of nutrients to developing plant parts, is essential for realizing the crop's maximum yield potential. The results indicated a continuous increase in DMA as the crop ages, with the highest values observed at 90 DAS. The rate of increase is more rapid between 30 and 60 DAS, corresponding to the crop's grand growth phase. The

data showed that different integrated nutrient sources had a significant influence on the dry matter accumulation at all the time intervals. Significantly higher dry matter accumulation was seen at 30, 60 and 90 DAS of 14, 95.9, 161.1 g per plant, respectively was observed with 100% RDN+ Mixed biofertilizers + FYM +1% spray of ZnSO_4 treatments followed by the remaining treatments. The results indicated that integration of organic and inorganic sources of nutrient application having favourable effect on the dry matter accumulation of maize. Shakoor *et al.*, (2015) concluded that treatment received 20% FYM had the highest dry weight, in comparison to control. Similarly, Buriro *et al.* (2014), Ravi *et al.* (2012) and Bezboruah and Dutta (2021) confirmed these observations for using organic sources of nutrient application for enhancing maize dry matter production.

Crop phenology

The results presented in Table 1 indicated that various integrated nutrient sources had a significant effect on the number of days taken to 50% tasselling, 50% silking and physiological maturity. The control treatment *i.e.*, in which no nutrient sources were added had the maximum number of days taken to 50% tasselling (65.6 days) were recorded. The number of days decreased with the application of different integrated nutrient sources. The minimum number of days taken to 50% tasselling (60.6) was recorded under 100% RDN+ Mixed biofertilizers + FYM +1% spray of ZnSO_4 treatment which showed that tasselling was 6 days earlier as compared to the control. Results stated that treatments 100% RDN+ Mixed biofertilizers + FYM +1% spray of ZnSO_4 and 100% RDN+ Mixed biofertilizers + FYM were significantly better as the days taken for 50% tasselling was lesser followed by rest of the treatments. Likewise, the number of

days taken to 50% silking was also significantly influenced by various integrated nutrient sources. Significantly more number of days (69) were taken to 50% silking in control meanwhile in 100% RDN+ Mixed biofertilizers + FYM +1% spray of ZnSO_4 treatment 65.6 days were taken. Results stated that treatments 100% RDN+ Mixed biofertilizers + FYM +1% spray of ZnSO_4 and 100% RDN+ Mixed biofertilizers + FYM were significantly best as the days taken for 50% silking was lesser followed by rest of the treatments. It was observed that the control plot took the longest time, with a maximum of 92.7 days to reach physiological maturity. In comparison, plot with 100% recommended dose of nitrogen + Mixed biofertilizers + Farmyard manure+ 1% spray of ZnSO_4 reached physiological maturity in 90.7 days. Similarly, application of 100% recommended dose of nitrogen (RDN) + Mixed biofertilizers, 100% recommended dose of nitrogen + Mixed biofertilizers + farmyard manure and 100% recommended dose of nitrogen + Mixed biofertilizers + farmyard manure were found to be at par with 100% RDN + Mixed biofertilizers + Farmyard manure+ 1% spray of ZnSO_4 regarding the time taken for physiological maturity and showed significant 2-3 days earliness as compared to control. The findings suggest that reduction in the number of days taken for 50% tasselling, 50% silking and days taken for physiological maturity in maize, when using various integrated nutrient sources, may be attributed to higher LA and DMA. This leads to an increase in energy levels in plants, which in turn promotes tasselling, silking and physiological maturity. Sharma *et al.* (2016) also observed that using different rates of Farmyard manure (FYM) and nitrogen application led to earlier tasselling, silking and physiological maturity.

Table 1: Effect of integrated nutrient sources on growth and phenological stages of maize.

Treatments	Plant stand (no. of plants per plot)		Dry matter accumulation (g)			Days taken to		
	30 DAS	At harvest	30 DAS	60 DAS	90 DAS	50% Tasselling	50% Silking	Physiological maturity
Control	83.3	83.3	2.2	18.6	64.7	65.6	69.0	92.6
Mixed biofertilizers (<i>Azospirillum</i> + PSB)	84.7	84.7	2.6	28.8	73.0	65.3	67.0	92.3
FYM (Farmyard manure)	87.7	87.7	2.9	32.4	78.8	65.0	67.3	92.3
75% RDN + Mixed biofertilizers	87.0	87.0	4.1	38.6	81.6	63.6	68.6	92.3
75% RDN + FYM	97.0	97.0	6.6	42.3	85.3	63.6	68.3	92.6
75% RDN + Mixed biofertilizers + FYM	103.3	103.3	6.8	44.7	88.7	64.0	67.3	93.0
75% RDN + Mixed biofertilizers + FYM + 1% spray of ZnSO_4	111.0	111.0	7.5	50.9	92.0	64.0	68.0	92.6
100% RDN	111.7	111.7	8.5	54.0	93.2	63.6	67.6	92.3
100% RDN + Mixed biofertilizers	111.7	111.7	9.5	58.8	109.3	62.3	65.3	91.0
100% RDN + FYM	113.7	113.7	11.4	61.9	125.0	62.6	65.3	91.0
100% RDN+ Mixed biofertilizers + FYM	114.3	114.3	12.7	70.2	145.6	60.6	65.6	91.0
100% RDN+ Mixed biofertilizers + FYM +1% spray of ZnSO_4	115.0	115.0	14.0	95.9	161.1	60.6	65.6	90.6
SE $\pm$	1.14	1.14	0.2	0.5	2.0	0.7	1.4	1.4
CD (p=0.05)	2.36	2.36	0.4	1.0	4.2	1.5	3.0	2.96

Table 2: Effect of integrated nutrient sources on quality and soil nutrient status parameters in maize.

Treatments	Quality parameters				Available			N uptake			Zinc	
	Protein (%)	Starch (%)	Ash (%)	N (kg/ha)	P (kg/ha)	K (kg/ha)	Grain (kg/ha)	Stover (kg/ha)	Grain (mg/kg)	Straw (mg/kg)	Soil (kg/ha)	
Control	5.52	55.1	0.29	258.5	12.17	78.21	108.9	37.7	259.6	18.8	0.7	
Mixed biofertilizers (<i>Azospirillum</i> + PSB)	5.85	55.7	0.34	266.8	14.22	78.73	117.6	39.6	266.8	19.7	0.8	
FYM (Farmyard manure)	6.25	55.8	0.31	277.6	14.94	75.24	118.7	41.1	276.0	20.5	1.0	
75% RDN + Mixed biofertilizers	6.81	55.5	0.34	300.1	15.62	72.13	121.8	41.2	300.1	22.0	1.1	
75% RDN + FYM	7.19	56.4	0.35	301.4	18.47	68.05	121.9	41.5	301.4	23.6	1.1	
75% RDN + Mixed biofertilizers + FYM	7.71	56.5	0.64	307.6	22.29	62.34	124.3	42.4	307.6	21.6	1.2	
75% RDN + Mixed biofertilizers + FYM	10.04	57.3	0.62	318.6	24.47	56.18	126.5	42.2	319.9	28.2	1.5	
+ 1% spray of ZnSO ₄												
100% RDN	8.00	58.6	0.63	320.4	24.40	54.04	126.0	42.3	313.4	25.5	1.3	
100% RDN + Mixed biofertilizers	8.27	59.4	0.68	324.5	25.15	55.48	127.5	42.4	315.6	26.6	1.3	
100% RDN + FYM	8.63	59.5	0.83	328.3	26.00	52.62	128.5	43.3	317.1	26.7	1.3	
100% RDN+ Mixed biofertilizers + FYM	9.51	60.3	1.08	339.6	26.92	48.20	129.1	43.5	317.4	27.3	1.4	
100% RDN+ Mixed biofertilizers + FYM	10.15	60.4	1.19	342.0	27.81	46.12	130.9	44.7	325.6	29.5	1.5	
+1% spray of ZnSO ₄												
SE _{ent}	0.31	0.2	0.0	1.9	0.50	0.51	1.9	1.1	1.2	0.8	0.06	
CD (p=0.05)	0.64	0.5	0.1	3.9	1.04	1.06	4.0	2.3	2.5	1.6	0.13	

Quality parameters

Maximum and significantly higher protein content (10.15 %) was observed with the application of 100% RDN+ Mixed biofertilizers + FYM +1% spray ZnSO_4 as compared to all other treatments, but it was statistically at par with application of 75% RDN + Mixed biofertilizers + FYM + 1% spray ZnSO_4 and 100% RDN+ Mixed biofertilizers + FYM with protein content of 10.04% and 9.51% respectively. The increase in protein content was observed due to spray of ZnSO_4 as it helps in binding the amino acid chain which resulted in protein synthesis. Significantly higher starch content (60.4%) was observed in 100% RDN+ Mixed biofertilizers + FYM +1% spray ZnSO_4 treatment and it was statistically at par with only 100% RDN+ Mixed biofertilizers + FYM) with 60.3% starch content, followed by 100% RDN + FYM and T₉ 100% RDN + Mixed biofertilizers by 59.5% and 59.4% respectively. Deswal and Pandurangam. (2018), Kalra and Sharma (2015), Kumar *et al.* (2020), Manzeke *et al.* (2014) and Ariraman *et al.* (2022). Significantly higher ash content *i.e.*, 1.19% was observed in 100% RDN+ Mixed biofertilizers + FYM +1% spray ZnSO_4 treatment and it was followed by 100% RDN+ Mixed biofertilizers + FYM with 1.08% followed by 100% RDN + FYM with by 0.83% ash content. The rise could potentially be attributed to the combined impact of nitrogen on a variety of other minerals, as well as its indirect influence through the expansion of root surface area. In simpler terms, applying nitrogen seems to enhance the accessibility and absorption of other essential nutrients, possibly through an interconnected effect. Sharma *et al.* (2016) observed that application of farmyard manure @ 25 t/ha significantly improved quality components such as ash content compared to the untreated and control plots. Kumar *et al.* (2020) reported that the treatment with 100% RDK+PGPR + FYM (6 t/ha) + two-time spray of 0.5% ZnSO_4 resulted in the increased ash content.

Soil nutrient status after harvesting of maize

The utilisation of several integrated nutrition sources had a significantly influenced the available nitrogen and phosphorus status in the soil after harvesting maize. The data given in Table 2 showed that the available nitrogen (342.0 kg/ha) and phosphorus status (27.81 kg/ha) was increased by 24.4 and 56.2%, respectively. in the soil at a depth of 0-15 cm in 100% RDN+ Mixed biofertilizers + FYM +1% spray ZnSO_4 treatment which was statistically similar with 100% RDN+ Mixed biofertilizers + FYM. Lowest value of available nitrogen status was recorded under control. The findings indicate that that application of FYM along with RDF increases overall land productivity than sole use of inorganic fertilizer as well as show that integration of organic and inorganic sources of nutrient improved soil fertility status.

Nitrogen uptake by the crop

Nitrogen uptake by the plant was significantly affected by different integrated nutrient sources. The data reported in

Table 2 indicated that significantly higher N uptake in grains (130.9 kg/ha) and stover (44.7 kg/ ha) was recorded with the application of 100% RDN+ Mixed biofertilizers + FYM +1% spray of ZnSO_4 but it was statistically at par with 100% RDN+ Mixed biofertilizers + FYM, 100% RDN + FYM and 100% RDN+ Mixed biofertilizers + FYM treatments but was significantly higher as compared to all other treatments. Buriro *et al.* (2014) using a combination of inorganic N and organic N sources (FYM) yielded better results than the unfertilized treatment. The results indicated that Nitrogen uptake improved significantly with the addition of FYM, N concentration in maize were superior with the combined use of organic and chemical fertilizers this was shown through improvements in N uptake by plants and green fodder yield of maize. Similar results were found by Singh *et al.* (2013) and Kalra *et al.* (2015).

Zinc status after harvesting of maize

Zinc content in grain, straw and soil

Significantly higher available zinc content in grains (325.6 mg/kg) after harvest of maize was recorded with the application of 100% RDN+ Mixed biofertilizers + FYM +1% spray ZnSO_4 as compared to all other treatments and it was followed by 75% RDN + Mixed biofertilizers + FYM + 1% spray ZnSO_4 treatment by 319.9 mg/kg. Manzeke *et al.* (2014) reported that the Zn-based treatments resulted in 67% increase in grain Zn concentration and 29% increase in yield, indicating that external Zn application not only improves yield but also enhances grain quality. Foliar spray of zinc has significantly influenced the available zinc content in straw and soil. Maximum available zinc content in straw after harvest (27.3 mg/kg) was recorded with 100% RDN+ Mixed biofertilizers + FYM +1% spray ZnSO_4 treatment which was statistically at par with 75% RDN + Mixed biofertilizers + FYM + 1% spray ZnSO_4 by 28.2 mg/kg and significantly higher than all other treatments. Significantly higher available zinc status in the soil at a depth of 15-30 cm (1.5 kg/ha) was recorded in 100% RDN+ Mixed biofertilizers + FYM +1% spray ZnSO_4 treatment which was statistically at par with 75% RDN + Mixed biofertilizers + FYM + 1% spray ZnSO_4 by 1.5 kg/ha and 100% RDN+ Mixed biofertilizers + FYM by 1.4 kg/ha and was better than all other treatments. The results showed that external Zn application not only improves yield but also enhances grain quality Manasa and Devaranavadagi, (2015) also observed higher zinc, iron and boron content in leaf with foliar application of ZnSO_4 @ 1.0 per cent in maize. Similar research findings were observed by Himanshu *et al.* (2018), Madhumati *et al.* (2019) and Tariq *et al.* (2015).

CONCLUSION

Application of 100% RDN+ Mixed biofertilizers + FYM +1% spray of ZnSO_4 resulted in significantly higher growth and yield attributes, grain yield and quality parameters. Therefore, it can be concluded that for getting higher productivity, profitability and quality, grow maize with 100%

RDN + mixed biofertilizers + farmyard manure + 1% spray of zinc $ZnSO_4$.

Conflict of interest

All authors declare that they have no conflict of interest.

REFERENCES

- Airaman, R., Selvakumar, S., Mansingh, M., Karthikeyan, M. and Vasline, Y.A. (2022). Effect of zinc application on growth, yield parameters, nutrient uptake, yield and economics of maize. *Agricultural Reviews*. 43: 104-109. doi: 10.18805/ag.R-2098.
- Bezboruah, M. and Dutta, R. (2021). Effect of integrated nutrient management on growth and yield of summer maize (*Zea mays* L.). *International Journal of Chemical Studies*. 9: 677-680.
- Buriro, M., Oad, A., Nangraj, T. and Gandahi, A.W. (2014). Maize fodder yield and nitrogen uptake as influenced by farmyard manure and nitrogen rates. *European Academic Research*. 2: 11624-11637.
- Deswal, K. and Pandurangam, V. (2018). Morpho-physiological and biochemical studies on foliar application of zinc, iron and boron in maize (*Zea mays* L.). *Journal of Pharmacognosy and Phytochemistry*. 7: 3515-3518.
- Gomez, K.A. and Gomez, A.A. (1984). *Statistical Procedures for Agricultural Research with Emphasis on Rice*. pp 303.
- Himanshu, S., Virendra, S., Satyaban, S. and Richa, K. (2018). Response of maize (*Zea mays* L.) to foliar application of zinc and boron. *Indian Journal of Agronomy*. 65: 489-492.
- Kalra, V.P. and Sharma, P.K. (2015). Quality of fodder maize in relation to farmyard manure and nitrogen levels. *Forage Research*. 41: 63-67.
- Kumar, S., Singh, M., Meena, B.L., Meena, V.K., Onte, S. and Bhattacharjee, S. (2020). Yield and qualitative evaluation of fodder maize (*Zea mays* L.) under potassium and zinc based integrated nutrient management. *Indian Journal of Animal Nutrition*. 37: 235-241.
- Madhumati, S.Y., Khade, S.K. and Patil, V.A. (2019). Effect of biofertilizers on yield and yield components of maize (*Zea mays* L.) varieties Eco-92 and African tall. *International Journal of Current Research*. 11: 5149-5153.
- Manasa, L.P. and Devaranavadagi, S.B. (2015). Effect of foliar application of micronutrients on growth, yield and nutrient uptake of maize. *Karnataka Journal of Agricultural Sciences*. 28: 474-476.
- Manzeke, G.M., Mtambanengwe, F., Nezomba and Mapfumo, P. (2014). Zinc fertilization influence on maize productivity and grain nutritional quality under integrated soil fertility management in Zimbabwe. *Field Crops Research*. 166: 128-136.
- Ravi, N., Basavarajappa, R., Chandrashekar, C.P., Harlapur, S.I., Hosamani, M.H. and Manjunatha, M.V. (2012). Effect of integrated nutrient management on growth and yield of quality protein maize. *Karnataka Journal of Agriculture Science*. 25: 395-396.
- Shakoor, A., Ashraf, M., Shah, L., Ali, A., Khan, A. and Sher, A. (2015). Impact of farmyard manure and nitrogen, phosphorus and potassium on maize crop. *Academic Research Journal of Agricultural Science and Research*. 3: 219-223. doi: 10.18805/ag.R-2631.
- Sharma, P.K., Kalra, V.K. and Tiwana, U.S. (2016). Effect of farmyard manure and nitrogen levels on growth, quality and fodder yield of summer maize (*Zea mays* L.). *Agricultural Research Journal*. 53: 355-359.
- Singh, M.V., Kumar, N. and Mishra, B.N. (2013). Integrated use of nitrogen and FYM on yield, nutrient uptake and economics of maize in eastern Uttar Pradesh. *Annals of Plant and Soil Research*. 15: 128-130.
- Sivamurugan, A.P., Ravikesavan, R., Singh, A.K. and Jat, S.L. (2018). Effect of different levels of P and liquid biofertilizers on growth, yield attributes and yield of maize. *Chemical Science Review and Letters*. 7: 520-523.
- Sudhakar, P. and Kuppusamy, G. (2007). Evaluation of different organic manures in rice and their impact on succeeding crops. *Plant Archives*. 7: 439-441.
- Tariq, A., Anjum, S.A., Randhawa, M.A., Ullah, E., Naeem, M., Qamar, R. and Nadeem, M. (2015). Influence of zinc nutrition on growth and yield behaviour of maize (*Zea mays* L.) hybrids. *American Journal of Plant Sciences*. 5: 2646-2654.
- USDA. (2023) United States department of agriculture, World agricultural production, Foreign Agricultural Service.