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K Archana
Soil Science and Agricultural
Chemistry, College of Agriculture,
PJTAU, Rajendranagar,
Telangana, India

R Uma Reddy
Regional Agricultural Research
Station, Warangal, Telangana,
India

A Krishna Chaitanya
Regional Sugarcane and Rice
Research Station, Rudrur,
Telangana, India

K Indudhar Reddy
Krishi Vignan Kendra, Rudrur,
Telangana, India

Corresponding Author:
K Archana
Soil Science and Agricultural
Chemistry, College of Agriculture,
PJTAU, Rajendranagar,
Telangana, India

Effect of paddy straw incorporation along with nitrogen and phosphorus levels on yield and yield attributes in *Rabi* maize

K Archana, R Uma Reddy, A Krishna Chaitanya and K Indudhar Reddy

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Abstract

A field experiment was conducted at the Regional Agricultural Research Station, Warangal, during the Rabi season of 2024-25, to study the effect of Paddy Straw with nitrogen and phosphorus levels on yield and yield attributes in maize. The experimental design was executed in a Factorial RBD comprised of 12 treatments replicated thrice. The results obtained that grain yield and Stover yield were significantly affected by both nitrogen and phosphorus management options, with the highest being found in the incorporation of crop residue along with 125% Recommended dosage of Nitrogen (30% basal, 30%15DAS, 35%Knee high stage, 30% tasselling stage) and 100% RDP (Basal). Yield attributes like number of cobs per plant, number of rows per kernel, cob girth, cob length, Test weight (gms) were also highest in incorporation of crop residue along 125% recommended dosage of Nitrogen (30% basal, 30%15DAS, 35% Knee high stage, 30% tasselling stage) and 100% RDP (Basal).

Keywords: Paddy straw, incorporation, maize, yield

1. Introduction

Maize (*Zea mays* L.) is one of the major cereal crops cultivated worldwide. Among the maize-growing countries, India ranks 4th in area and 7th in production, representing around 4% of the world's maize area and 2% of the total output (iimr.icar.gov.in). During 2023-24 in India, the maize area reached 11.24 mha (Agriculture statistics at glance 2023). During 1950-51, India used to produce 1.73 million MT of maize, which has increased to 37.67 million MT by 2023-24, recording a close to 19 times increase in production average productivity increased 6.12 times from 547 kg ha⁻¹ to 3351 kg ha⁻¹, while the area increased nearly three times. Though India's productivity is almost half the world's average, the productivity of Indian maize is at par with many leading maize-producing countries (ICAR-Indian Institute of Maize Research). The important maize-growing states are Madhya Pradesh, Karnataka, Rajasthan, Uttar Pradesh, Tamil Nadu, Maharashtra, and Telangana. Maize is the third most important cultivated crop in Telangana. The Maize area is gaining momentum in Telangana, due to the favourable climate and reliable irrigation facilities, which have enhanced crop yields. In Telangana, Rabi maize is grown in an area of 2.64 lakh ha with a production of 17.19 lakh tonnes and a productivity of 6511 kg ha⁻¹. Total maize area in Telangana is 5.15 lakh ha with a production of 28.62 lakh tonnes and productivity of 5557 kg ha⁻¹ during 2022-23 (India Statistics, 2024).

India is the second largest producer of Rice after China. Rice's area, production and productivity in India is about 47.82 mha, 137.83 million tones and 2882 kg ha⁻¹ respectively. In India, rice-growing major states are West Bengal, Punjab, Uttar Pradesh, Tamil Nadu, Andhra Pradesh, Telangana, Bihar, Odisha, etc. The area and production of Rice in Telangana is 3 million hectares and 258 LMTs respectively. The area under rice cultivation in the state has increased to 3 mha (2022-23) as against 1.9 mha in 2013-14 and also production increased in leaps and bounds from 5.7mt in 2013-14 to 258 LMTs in 2022-23 (Directorate of Economics and Statistics, Government of India, Socio Economic Outlook, 2024). Rice is the most residue-producing crop in Asia (826 million tons), contributing 84% of the total world product.

Traditionally, rice straw is removed from fields for use as cattle feed and other purposes in South Asia. Rice crop remainders average contain 0.7 N, 0.23 P, and 1.75 K. Thus, the quantum of NPK contained in rice crop remainders produced is about 22.13×106 and 26.26×106 t year⁻¹ in Asia and the world, respectively (Goswami *et al.*, 2019) ^[11]. Bacterial and fungal populations are dropped directly and mainly in the top 2.5 cm of the soil because of residue burning. Water, nutrients, and microbial inoculum are demanded to promote crop residue decomposition under *in-situ* decomposition (Thakur *et al.*, 2019) ^[19].

During rice harvest, rice straw is removed and scattered across the field, with the amount varying based on whether harvesting is done manually or mechanically. The ratio of straw to paddy generally falls between 0.7 and 1.4, depending on the rice variety and its growth conditions. Due to the shorter turnaround times needed for intensive rice cropping. However, incorporating straw into the soil as fertilizer is not feasible in such systems, as two to three cropping cycles per year leave insufficient time for decomposition. This results in poor soil fertility and weak crop establishment. With limited alternatives, open-field straw burning has risen sharply over the past decade (Bhuvaneshwari *et al.*, 2019) ^[5]. For many farmers, burning rice straw appears to be the most practical option for disposal, as it is both inexpensive and effectively controls pests (John, 2013) ^[14]. However, stubble burning contributes significantly to air pollution and leads to the loss of valuable biomass, including organic carbon and essential plant nutrients. Nearly all carbon, about 80-90% of nitrogen, 25% of phosphorus, 20% of potassium, and 50% of sulfur contained in the residues are released into the atmosphere as gases and particulates, thereby worsening air quality and contributing to global warming (Kaur *et al.*, 2019) ^[15]. Hence, there is a need to explore sustainable alternatives and technologies that can reduce environmental damage while improving the profitability of rice production systems (Hung *et al.*, 2020) ^[12]. Incorporating rice straw into the soil helps reduce nutrient loss and air pollution while enriching the soil with carbon and nutrients. However, due to its high C: N ratio, rice straw decomposes slowly, temporarily reducing nutrient availability and hindering the growth of succeeding crops like maize. To overcome this, straw is often incorporated along with additional nutrient sources. Despite such practices, India's average productivity (2.43 t ha⁻¹) remains below the global average of 4.92 t ha⁻¹.

2. Materials and Methods

2.1 Experimental Site

The field experiment was conducted at the Regional Agricultural Research Station in Warangal, during the Rabi of 2024-25. The experimental site is located between 15°. 5' N latitude and

79°.28' E longitude at an altitude of 268.5 m above mean sea level (MSL). During the entire crop growth duration the weekly mean maximum temperature ranged from 28.8 °C to 38.4 °C during the crop growth. The mean minimum temperature for the corresponding period ranged from 14.5 °C to 24.8 °C, with an average of 19.1 °C. In comparison, the average maximum and minimum temperatures during the same period were 33.2 °C and 17.7 °C, with an average of 33.07 °C, respectively. The weekly mean evaporation ranged from 0.3 mm to 7.4 mm, averaging 3.77mm day⁻¹ during the crop growth period. Sunshine fluctuated between 2.1 and 9.3 hours with an average of 6.16 hours day⁻¹.

The weekly morning sunshine hours fluctuated between 50.1 percent and 94.4 percent, averaging 80.03 percent. The weekly mean afternoon relative humidity fluctuated between 44.6 percent and 78.1 percent, averaging 59.1 percent.

The soil of the experimental field was sandy loam with a neutral pH (7.27), EC (0.34dS m⁻¹), low in organic carbon (3.6 g kg⁻¹) and available N (165.5 kg ha⁻¹), medium in available P2O5 (37.14 kg ha⁻¹) and medium in available K2O (228 kg ha⁻¹).

2.2 Experimental Details

The experiment was conducted in a Factorial Randomized Block Design (RBD) during the Rabi season of 2024-25, consisting of twelve treatments replicated thrice, having a gross plot size of 6 m × 4.2 m = 25.2 m2. Maize variety NK-6802 was sown in sandy loam soil at 60 cm x 20 cm spacing. The experiment was conducted using rice grown as a kharif crop. Paddy straw was uniformly spread and burnt in situ in a specific plot. Soon after burning, the burnt area was flooded with water to avoid ash flying; later, ash was incorporated into the soil. Paddy straw (5.5 t ha⁻¹) was spread uniformly, a week before the land preparation consortium, and Pusa decomposer was sprayed. A week after its spray, paddy straw was incorporated with the help of shredder cum mulcher equipment drawn by a 55 HP tractor for incorporation treatments. The maize crop was ploughed and levelled with a rotavator, and line sowing was adopted.

A microbial consortium developed by Professor Jayashankar Telangana Agricultural University, Rajendranagar, Hyderabad, was used in the present study for incorporation treatments. Microbial consortium is a combination of *Trichoderma viridae*, *Phanerochaete*, *Chrysosporium*, and *Aspergillus Niger*, and it was sprayed @ 2 % on paddy straw and stubble. PJTAU University consortium: *Aspergillus*, *Trichoderma*, and *Phanerochaete* University consortium and Pusa decomposer will be sprayed after harvest, and the residue will be incorporated into the soil for land preparation. RDF for Rabi Maize (240-80-80 N-P-K kg ha⁻¹).

Treatment details of the experiment

Factor	Treatment No	Treatment Description
Factor 1: Nitrogen management options	1	Burning + 100% RDN (33.3% at basal, 33.3% at knee-high stage (30 DAS) and 33.3% at tasseling stage (60 DAS))
	2	Incorporation + 100% RDN (33.3% at basal, 33.3% at knee-high stage (30 DAS) and 33.3% at tasseling stage (60 DAS))
	3	Incorporation + 125% RDN (30% at basal, 30% at 15 DAS, 35% at knee-high stage (30 DAS) and 30% at tasseling stage (60 DAS))
	4	Incorporation + Spraying of University Consortium + 100% RDN (33.3% at basal, 33.3% at knee-high stage (30 DAS) and 33.3% at tasseling stage (60 DAS))
	5	Incorporation + Spraying of University Consortium + 100% RDN (20% at basal, 20% at 15 DAS, 30% at knee-high stage (30 DAS) and 30% at tasseling stage (60 DAS))
	6	Incorporation + Spraying of Pusa Decomposer + 100% RDN (20% at basal, 20% at 15 DAS, 30% at knee-high stage (30 DAS) and 30% at tasseling stage (60 DAS))
Factor 2: Phosphorus management options	1	100% RDP (Basal)
	2	75% RDP (Basal) + PSB @ 5 kg ha ⁻¹

Yield and yield attributes

Number of cobs per plant

The total number of cobs counted from each plot was divided by the number of plants in that plot to obtain the number of cobs per plant.

$$\text{Number of cobs per plant} = \frac{\text{Total number of cobs per plot}}{\text{Total number of plants per plot} \times 100}$$

Cob length (cm)

After harvesting, five cobs were selected randomly from each of the plots. After dehusking, the length of the cobs was measured from the base to the tip of the cob. An average value was obtained from these readings, which was expressed in cm in the final data.

Cob girth (cm)

Five cobs randomly selected for measuring cob length were also measured for cob girth with a measuring tape put around their circumference. An average value was obtained from the readings, which was expressed in cm in the final data.

Number of grains per cob

The samples taken for cob length were shelled, and the grains

were counted. An average value was worked out from that data.

100-grain weight (g)

From the grain stock of each net plot, 100 grains were taken to form a representative sample. After drying and cleaning, the weight of these 100 grains was recorded and expressed in grams.

Grain yield (kg ha⁻¹)

After detaching from the stover, the cobs were dehusked manually and exposed to the sun for drying. The sun-dried cobs from each experimental plot were put into a power-operated maize sheller. The grains and cob cores thus obtained were weighed separately. The final grain yield was expressed as kg ha⁻¹.

Stover yield (kg ha⁻¹)

The plots of maize were harvested and sun-dried. After that, they were weighed for biological yield. Then the cobs were plucked away, leaving the Stover and husk behind. The weight of the cobs was recorded and subtracted from the biological yield to obtain the Stover yield values, which were expressed as kg ha⁻¹.

Results and Discussion

Table 1: Yield attributes of maize influenced by nitrogen and phosphorus management options

Treatments	Cob length (cm)	Cob girth (cm)	Number of cobs per plant	Number of rows per kernel	100 seed weight (gms)
Nitrogen management options (F1)					
N1	20.22	15.96	1.00	27.45	28.14
N2	20.60	16.19	1.00	28.13	28.30
N3	23.92	17.37	1.10	29.55	29.90
N4	21.65	16.26	1.00	28.40	28.40
N5	23.20	16.95	1.10	29.25	29.17
N6	22.70	16.67	1.10	29.13	28.74
SE(m)±	0.59	0.32	0.03	0.95	0.95
CD (P=0.05)	1.74	0.94	NS	NS	NS
Phosphorus management options(F2)					
P1-100% RDP (Basal)	22.56	16.91	1.07	28.66	28.88
P2-75%RDP (Basal) + PSB @ 5 kg ha ⁻¹	21.54	16.22	1.03	28.65	28.67
SE(m)±	0.34	0.19	0.02	0.55	0.55
CD (P=0.05)	1.01	0.55	NS	NS	NS
Interactions (F1x F2)					
SE(m)±	0.84	0.46	0.05	1.34	1.35
CD (P=0.05)	NS	NS	NS	NS	NS

N1-Burning + 100% RDN (33.3% at basal, 33.3% at KHS and 33.3% at TS), N2-Incorporation +100% RDN (33.3% at basal, 33.3% at KHS +33.3% at TS), N3-Incorporation+125% RDN (30% at basal, 30% at 15 DAS, 35% at KHS and 30% TS), N4-Incorporation + Spraying of University Consortium + 100% RDN (33.3% at basal, 33.3% at KHS and 33.3% at TS), N5-Incorporation + Spraying of University consortium + 100% RDN (20% at basal, 20% at 15DAS, 30% at KHS and 30% at TS), N6-Incorporation + Spraying of Pusa decomposer + 100% RDN (20% at basal, 20% at 15 DAS, 30% at KHS and 30% at TS)

Cob length (cm)

Both nitrogen and phosphorus management options significantly influenced the cob length (cm) in maize, and the interaction had no significant effect.

Among the different nitrogen management options, the significantly highest cob length was reported in with N3-I+125%N (30:30:35:30) with 23.92 cm on par with N5-I+UC+100% N (20:20:30:30) with 23.2, N6-I+PD+100% N (20:20:30:30) with 22.7, and least was observed in N1-B+100% N (33:33:33) with the value of 20.22cm.

Among the Phosphorus management options, the significantly highest cob length (cm) was obtained in 100% RDP (Basal) with 22.56, and the lowest was reported in 75% RDP (Basal) + PSB

@ 5kg ha⁻¹, i.e., 21.54 cm.

Cob girth (cm)

Both nitrogen and phosphorus management options significantly influence cob girth and there was no significant interaction between the two factors.

Among the nitrogen management factors, the highest cob girth was observed in N3-N3-I+125%N (30:30:35:30), i.e., 17.37, which was comparable with N5-I+UC+100% N (20:20:30:30), i.e., 16.95, N6-I+PD+100% N (20:20:30:30), with 16.67.and the least was observed in N1-B+100% N (33:33:33) with the value of 15.96 cm. Among the Phosphorus management options higher cob girth was obtained in 100% RDP (Basal) with 16.91

cm, least was reported in 75% RDP (Basal) + PSB @ 5 kg ha⁻¹ with 16.2.

Number of cobs per plant

The number of cobs per plant depicted in Table 1 significantly influenced by neither nitrogen nor phosphorus management options. Among nitrogen management and phosphorus management options, it ranged from 1.00 to 1.10.

Number of rows per kernel

Both nitrogen and phosphorus management options had no significant influence on the number of rows per kernel in maize, and there was no significant interaction between the two factors, as depicted in Table 1.

Among nitrogen management options, it varied from 29.55 to 27.45. Among the phosphorus management options, the highest was obtained in 100% RDP (Basal) with 29.22, followed by 75% RDP (Basal) + PSB @ 5 kg ha⁻¹ with 28.1.

Hundred seed weight (g)

Both nitrogen and phosphorus management options had no significant influence on the 100-seed weight (g) of maize, and there was no significant interaction between the two factors, as depicted in Table 1.

Among nitrogen management options, the highest was observed in N3-I+125%N (30:30:35:30) with the value of 29.9, and the least was observed in N1-B+100% N (33:33:33) with the value of 28.14 cm.

In phosphorus management options, the highest was observed in 100%RDP (Basal) 28.88, and the least was reported in 75% RDP (Basal) + PSB @ 5kg ha⁻¹, i.e., 28.60.

The results indicated that cob length and girth were markedly higher under straw incorporation than when burning residue. This could be attributed to the fact that straw incorporation enhances the soil's physical, chemical, and biological conditions by enriching it with organic matter, whereas burning depletes these properties. Similar findings were also reported by Singh *et al.* (2019) [17]. The lowest yield attributes recorded under the N1-Burning+100% RDN treatment could be attributed to nutrient losses caused by paddy straw burning, which in turn might have reduced soil fertility (Dobermann and Fairhurst, 2002) [8]. A considerable portion of nitrogen was applied during the early growth stages, but much of it may have been lost from the soil, resulting in reduced grain yield. This reduction can also be linked to the lack of synchronization between nitrogen supply and the crop's nutrient demand at critical growth stages, which is essential for achieving higher yields (Chaudhary *et al.*, 2013) [6]. Significantly greater cob length of maize was observed under the treatments N3, N5, and N6 as compared to the other residue management practices. This superiority can be ascribed to the delayed nitrogen application and more splits, which likely sustained leaf chlorophyll content and photosynthetic activity over an extended period. The prolonged greenness of the crop facilitated greater synthesis of photosynthates and their efficient translocation towards the reproductive organs, thereby contributing to enhanced cob development.

Table 2: Effect of Nitrogen and phosphorus management options on grain yield and Stover yield

Treatments	Grain yield (kg ha ⁻¹)	Stover yield (kg ha ⁻¹)
Nitrogen management options (F1)		
N1	7456.57	8667.50
N2	7865.46	9065.67
N3	8735.83	9480
N4	7985.33	9194.5
N5	8629.77	9470.08
N6	8100.00	9325.17
SE(m)±	238.61	89.86
CD (P=0.05)	699.71	263.51
Phosphorus management options (F2)		
P1-100%RDP(Basal)	8341.78	9410.94
P2-75%RDP+PSB@5 kg ha-1	7915.88	8990.03
SE(m)±	137.76	51.88
CD (P=0.05)	403.98	152.14
Interactions (F1xF2)		
SE(m)±	337.44	127.08
CD (P=0.05)	NS	NS

N1-Burning + 100% RDN (33.3% at basal, 33.3% at KHS and 33.3% at TS), N2-Incorporation +100% RDN (33.3% at basal, 33.3% at KHS +33.3% at TS), N3-Incorporation+125% RDN (30% at basal, 30% at 15 DAS, 35% at KHS and 30% TS), N4-Incorporation + Spraying of University Consortium + 100% RDN (33.3% at basal, 33.3% at KHS and 33.3% at TS), N5-Incorporation+ Spraying of University consortium + 100% RDN (20% at basal, 20% at 15DAS, 30% at KHS and 30% at TS), N6-Incorporation + Spraying of Pusa decomposer + 100% RDN (20% at basal, 20% at 15 DAS, 30% at KHS and 30% at TS).

Grain and Stover yield (kg ha⁻¹)

Both nitrogen and phosphorus management options significantly influenced the Grain and Stover yield, and there was no significant interaction between the two factors, which was presented in Table 2.

Among the various nitrogen treatments, the highest grain and Stover yields were recorded in N3-Incorporation + 125% RDN (30:30:35:30) with 8735.83kg ha⁻¹ and 9480 kg ha⁻¹ this was comparable to N5-I+UC+100% N (20:20:30:30), yielding 8629 kg ha⁻¹ and 9470 kg ha⁻¹, respectively. And N6-Incorporation + Spraying of Pusa decomposer + 100% RDN (20:20:30:30) with

8100 kg ha⁻¹ and 9325.17 kg ha⁻¹ conversely, the lowest yield observed was in N1-Burning + 100% RDN (33.3: 33.3: 33.3), 7456.57 kg ha⁻¹ and 8667.5 kg ha⁻¹, respectively.

Under phosphorus management options, significantly higher grain and Stover yield was recorded in 100% RDP (Basal) i.e., 8341.78 kg ha⁻¹ and 9410.94 kg ha⁻¹, the lowest was observed in the treatment with paddy straw incorporation with 75% RDP along with PSB @5 kg ha⁻¹ with the value of 7915.88 kg ha⁻¹ and 8990 kg ha⁻¹. The results conform with the results of EI-Sobsky (2017), that increasing P significantly increased grain yield. Similar results were reported by Surekha *et al.* (2006) [18].

The enhancement in yield from straw incorporation is due to the substantial return of nutrients to the soil, benefiting plant growth. Moreover, incorporating straw improves the soil's organic matter content, enhancing its physical, chemical, and biological properties, boosting soil health and increasing grain yields (Zhang *et al.*, 2016) ^[20]. Higher nitrogen levels also improved chlorophyll content and enhanced photosynthesis, creating more photosynthetic area for increased dry matter (DM) production and, in turn, higher maize grain yields (Gao *et al.*, 2023) ^[10]. Burning paddy straw may have resulted in the loss of soil nutrients, potentially decreasing soil fertility (Dobermann and Fairhurst, 2002) ^[8]. The results are corroborated by Latha *et al.* (2022) ^[16] and Anil *et al.* (2018) ^[4], who stated that applying nitrogen with 4 splits resulted in better yield attributes contributing to higher grain yield. Which might explain the lower yields observed in the N1-burning+100% RDN (33.3,

33.3, and 33.3) treatment.

An interactive effect between nitrogen and phosphorus management options was found to be non-significant.

Conclusion

The residue incorporation and 125% recommended dosage of nitrogen with four splits of significantly enhanced yield parameters like cob length and girth, no. of cobs per plant, number of rows per kernel, test weight, grain yield, and straw yield. As nitrogen is prone to losses through leaching, denitrification, and volatilization, to prevent these, providing 25% extra RDN with bhuvafour splits of nitrogen to the crop, which receives a synchronized supply, also reduces the environmental hazards created by burning treatment. Hence, it is recommended for reducing environmental risks and increasing yield.



Fig 1: Treatment 3 during knee high stage

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References

1. Indian Institute of Maize Research. ICAR-IIMR [Internet]. Available from: <https://iimr.icar.gov.in/>
2. Ministry of Agriculture and Farmers Welfare. *Agriculture Statistics at a Glance 2023*. ICAR-Indian Institute of Maize Research; 2023.
3. Directorate of Economics and Statistics, Government of India. *Socio Economic Outlook 2024*. Government of India; 2024.
4. Anil K, Yakadri M, Jayasree G. Influence of nitrogen levels and times of application on growth parameters of aerobic rice. *Int J Curr Microbiol Appl Sci*. 2018;7(5):1525-1529.
5. Bhuvaneshwari S, Hettiarachchi H, Meegoda JN. Crop residue burning in India: policy challenges and potential solutions. *Int J Environ Res Public Health*. 2019;16(5):832.
6. Chaudhary A, Chhokar RS, Yadav DB, Sindhu VK, Ram H, Rawal S, *et al.* In-situ paddy straw management practices for higher resource use efficiency and crop productivity in Indo-Gangetic Plains (IGP) of India. *J Cereal Res*. 2019;11(3):172-198.
7. Dhar D, Datta A, Basak N, Paul N, Badole S, Thomas T. The effect of combinations of organic materials and biofertilizers on productivity, grain quality, nutrient uptake and economics in organic farming of wheat. *J Org Syst*. 2014;7(2):373-378.
8. Dobermann A, Fairhurst TH. Rice straw management. *Better Crops Int*. 2002;16(1):7-11.
9. El-Sobky E, El-Sayed EA. Effect of burned rice straw, phosphorus and nitrogen fertilization on wheat (*Triticum aestivum* L.). *Ann Agric Sci*. 2017;62(1):113-20.
10. Gao F, Khan R, Yang L, Chi YX, Wang Y, Zhou XB. Uncovering the potentials of long-term straw return and nitrogen supply on subtropical maize (*Zea mays* L.) photosynthesis and grain yield. *Field Crops Res*. 2023;302:109062.
11. Goswami SB, Mondal R, Mandi SK. Crop residue

- management options in rice-rice system: A review. Arch Agron Soil Sci. 2019;65(10):1476-87.
12. Hung N, Detras MMC, Migo MV, Quilloy R, Balingbing C, Chivenge P, Gummert M. Rice straw overview: availability, properties, and management practices. In: *Sustainable Rice Straw Management*. Springer; 2020, p. 1-13.
 13. Jin ZQ, Shah TR, Zhang L. Effect of straw returning on soil organic carbon in rice-wheat rotation system: a review. Food Energy Secur. 2020;9(2):13.
 14. John. Alternatives to open-field burning on paddy farms. Agricultural and Food Policy Studies Institute, Malaysia. 2013;18:1-5.
 15. Kaur R, Sharma S, Kaur N. Food security, nutrition and sustainable agriculture emerging technologies: heavy metals toxicity and the environment. J Pharmacogn Phytochem. 2019;1:247-249.
 16. Latha S, Prasad AJR, Trimurtulu N, Madhuvani P, Rao SV. Effect of incorporation of korra (*Setaria italica*) crop residue along with microbial consortia on soil enzyme activities, microbial population, growth and yield of chickpea (*Cicer arietinum*). Pharma Innov J. 2022;11(1):1089-1094.
 17. Singh RK, Sharma GK, Kumar P, Singh SK, Singh R. Effect of crop residue management on soil properties and crop productivity of rice-wheat system in inceptisols of Seemanchal region of Bihar. Curr J Appl Sci Technol. 2019;37(6):1-6.
 18. Surekha K, Reddy KPC, Padma Kumari AP, Sta Cruz PC. Effect of straw on yield components of rice (*Oryza sativa* L.) under rice-rice cropping system. J Agron Crop Sci. 2006;192(20):92-101.
 19. Thakur JK, Prajapathi S, Mandal A, Manna MC, Somasundram J. Crop residue burning consequences on soil microbes. Harit Dhara. 2019;2(2).
 20. Zhang P, Chen X, Wei T, Yang Z, Jia Z, Yang B, *et al.* Effects of straw incorporation on the soil nutrient contents, enzyme activities, and crop yield in a semiarid region of China. Soil Tillage Res. 2016;160:65-72.