

Balanced Nutrient Management on Rice (*Oryza sativa*) in Red and Lateritic Soils of West Bengal

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ABSTRACT

A field experiment was conducted on rice during kharif season of 2015 using different doses of nitrogen, phosphorus, potassium as per recommended practices along with FYM @ 5 tha^{-1} , and micronutrients viz. boron and zinc using black gram as the test crop. All samples are processed and chemical analysis of plant and seed samples as well as protein content are done by using the standard protocol. The experiment was conducted using four levels of potassium viz., 0, 20, 40 and 60 $kg\ ha^{-1}$, four levels of sulphur viz., 0, 10, 20 and 30 $kg\ ha^{-1}$, three levels of phosphorus viz., 0, 20, 40 $kg\ ha^{-1}$, nitrogen in a single dose @ 80 $kg\ ha^{-1}$ and the residual effect of micronutrients from the previous crop using rice as the test crop. The results revealed that highest significant grain, straw and biological yield (8.43, 11.28 and 19.71 $t\ ha^{-1}$ respectively) recorded when the crop received all the nutrients (N, P, K, S, B and Zn). Protein content ranged between 14.35 to 17.97%. Combined application of all the nutrients increased nutrient accumulation and uptake. Among the micro and secondary nutrients, deletion of B greatly affect the N, P and K uptake as compared to Zn and S. Balanced application of N, P and K with S, B and Zn recorded highest grain yield response.

Keywords: Rice, Balanced Nutrient Management, Yield, Uptake, Protein content.

INTRODUCTION

Rice is a nutritional staple food which provides instant energy as its most important component is carbohydrate (starch). In husked rice, protein content ranges in between 7 per cent to 12 per cent. The use of nitrogen

fertilizers increases the percentage content of some amino acids. In India rice is grown under widely varying conditions of altitude and climate. There are three seasons for growing rice in India viz. autumn, winter and summer.

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The main rice growing season in the country is the 'Kharif'. About 84 percent of the country's rice crop is grown in this season and generally, medium to long duration varieties are grown in this season.

Zinc (Zn) is one of the most important micronutrients essential for plant growth especially for rice grown under submerged condition. Zinc deficiency continues to be one of the key factors in determining rice production in several parts of the country (Muthukumararaja & Sriramachandrasekharan, 2012). Zn deficiency is the most widespread micronutrient disorder in lowland rice and application of Zn along with NPK fertilizer increases the grain yield dramatically in most cases (Fageria et al., 2011 & Singh et al., 2011). Apart from major nutrients zinc is very much responsive to highly intensive cereal-based cropping system. Zinc is required in a large number of enzymes and plays an essential role in DNA transcription. Adequate availability of zinc to young and developing plants is certain promise for sufficient growth and development. Zinc plays a greater role during reproductive phase especially during fertilization. Reduction in yield of rice is often blamed to zinc sulphur deficiency. Zn deficiency is the most widespread micronutrient disorder in lowland rice and application of Zn along with NPK fertilizer increases the grain yield dramatically in most cases (Rahman et al., 2008 & Chaudhary et al., 2007).

Boron (B) is responsible for better pollination, seed setting and grain formation in different rice varieties (Aslam et al., 2002 & Rehman et al., 2012), making it more important during the reproductive stage as compared to the vegetative stage of the crop. Balanced nutrition based on soil test value is the key to sustain rice productivity and to improve soil productivity. A suitable combination of secondary and micronutrients is the most important single factor that affects the productivity of the crops. With this information, the present study was undertaken to evaluate the integrated effect of N, P and K with S, Zn and B on productivity and nutrient uptake by rice.

MATERIALS AND METHODS

A field experiment was conducted on rice during kharif season of 2015 in red and lateritic soils of West Bengal at the Agricultural Farm of Palli Siksha Bhavana (Institute of Agriculture), Visva-Bharati, Sriniketan. The experimental farm was situated at 23°39' N latitude and 87°42' E longitude with an average altitude of 58.9 m above the mean sea level under sub humid semi-arid region of West Bengal. The experiment was laid out in randomized block design (RBD) with three replication and seventeen treatments. The soil was sandy loam in texture, low in organic carbon, nitrogen, potassium and sulphur and medium in phosphorus with pH 5.67 and EC 0.11 dSm⁻¹. After harvesting the crop, representative soil samples were collected to determine the effect of fertilizer doses on the nutrient status of the experimental field from a soil depth of 0-15 cm. The soil samples were dried under shade and ground with a pestle-mortar and then sieved through 2 mm sieve and stored for further analysis. The physicochemical properties of the soil were determined according to standard methods (Page, 1982; Jackson, 1973 & Bingham et al., 1982). All the recommended package and practices were followed for raising a healthy crop. The final plant samples were collected at harvest from each plot, cleaned, oven dried at 60°C and ground in a steel grinder. The nutrients like N, P and K content in seed and stover were determined by modified Kjeldahl method, vanadomolibdophosphoric yellow colour method and flame photometer, respectively (Jackson 1973). Available sulphur and boron were determined turbidimetrically (Chesnin & Yien, 1950) and in hot water (Jackson, 1973), respectively. Micronutrients were determined by methods of Lindsay and Norvell (1978). The representative dry samples of seed and stover were analyzed for ascertaining the nutrient (N, P, K and S) content. Seed and stover samples were digested in H₂SO₄ for determination of nitrogen (AOAC, 1995) and in di-acid mixture (HNO₃: HClO₄, 9:4 v/v) for phosphorus and potassium estimation

(Bhargava & Raghupathi, 1984). The nutrients uptake by seed and stover were calculated by multiplying nutrient content with seed and stover yield (kg ha^{-1}). Crude protein content was determined by multiplying percentage of nitrogen content in grain of rice with a factor of 6.25 and expressed in percentage. The nutrient uptake (%), yield parameters and protein content were subjected to statistical analysis by using the method of Gomez and Gomez (1984).

RESULT AND DISCUSSION

Response of balanced fertilization on soil nutrient status after harvest of rice

Postharvest soil available nutrient status (N, P, K, B, Zn) after the harvest of rice was significantly influenced by graded nutrient levels (table 1). Slightly improvement was notice in case of NPK build-up. Significant build-ups in the soils were notice in case of sulphur, boron and zinc which was initially low, become sufficient due to continuous addition to the soil. Improvement in fertility status leads to improvement in productivity status of the experimental plot (Saha et al., 2007; Muthukumararaja & Sriramachandrasekharan, 2012 & Singh et al., 2011).

The organic carbon content varied between 0.34% in plots receiving zinc as fertilizer @ 40 kg ha^{-1} along with nitrogen, phosphorus and potassium @ $80, 40$ and 20 kg ha^{-1} respectively and 0.50% in plots receiving dose of nitrogen, phosphorus and potassium @

$80, 40$ and 40 kg ha^{-1} respectively. Treatment effect was found to be significant. Available nitrogen content in soils after harvesting of rice ranged between 142.17 to $242.52 \text{ kg ha}^{-1}$. The lowest value was recorded where no fertilizer was applied (control) and the maximum was recorded in plots receiving zinc @ 4 kg ha^{-1} along with nitrogen, phosphorus and potassium @ $80, 40$ and 20 kg ha^{-1} respectively. There is no treatment effect was found to be significant in altering available nitrogen content in soil. The values of available phosphorus varied from 5.77 to 21.35 kg ha^{-1} . Maximum value was obtained in plots receiving zinc @ 6 kgha^{-1} along with nitrogen phosphorus and potassium @ $80, 40$ and 20 kgha^{-1} respectively and the minimum value got in plots receiving where there no fertilizer was applied (control). Treatment effect was found to be significant. Available potassium content in soils (table 1) ranged from 58.46 to 99.64 kg ha^{-1} . Highest potassium availability was found in T_7 whereas minimum availability resulted in without application of fertilizers (control). Treatment effect was found to be significant. Data on the available sulphur content in soils after harvesting of rice varied between 6.72 and 32.34 kg ha^{-1} . The minimum value was recorded in plots receiving no fertilizers (control). The maximum value of available sulphur was recorded with application of maximum dose of sulphur @ 30 kg ha^{-1} . Treatment effect was found to be significant.

Table 1: Response of balanced fertilization on soil nutrient status after harvest of rice

Treatments	Org C	Available N	Available P	Available K	Available S	Available Zn	Available B
	%	kg ha^{-1}				(mg kg^{-1})	
T_1 - $N_{80}+P_{40}+K_{20}$	0.39	167.25	16.66	82.47	18.48	1.42	0.59
T_2 - $N_{80}+P_{40}+K_{20}+S_{10}$	0.42	150.53	15.59	86.80	20.16	1.2	0.65
T_3 - $N_{80}+P_{40}+K_{20}+S_{20}$	0.41	158.89	18.58	91.73	27.72	1.43	0.71
T_4 - $N_{80}+P_{40}+K_{20}+S_{30}$	0.42	175.62	14.73	77.65	32.34	1.56	0.76
T_5 - $N_{80}+P_{20}+K_{40}$	0.35	209.07	13.88	78.06	19.32	1.11	0.71
T_6 - $N_{80}+P_{40}+K_{40}$	0.34	158.89	13.45	87.02	29.82	1.32	0.75
T_7 - $N_{80}+P_{20}+K_{60}$	0.48	183.98	17.72	99.64	24.78	1.75	0.78
T_8 - $N_{80}+P_{40}+K_{60}$	0.35	175.62	20.50	88.82	29.82	1.27	0.61

T ₉ - N ₈₀ +P ₄₀ +K ₂₀ +Zn ₂	0.47	217.43	14.52	70.00	27.30	1.78	0.66
T ₁₀ - N ₈₀ +P ₄₀ +K ₂₀ +Zn ₄	0.5	242.52	12.81	77.62	23.52	2.38	0.75
T ₁₁ - N ₈₀ +P ₄₀ +K ₂₀ +Zn ₆	0.44	183.98	21.35	81.13	24.36	2.95	0.76
T ₁₂ - N ₈₀ +P ₄₀ +K ₂₀ +B _{0.5}	0.26	175.62	12.60	91.32	18.90	1.72	0.88
T ₁₃ - N ₈₀ +P ₄₀ +K ₂₀ +B ₁	0.48	192.34	12.39	67.87	19.74	1.42	1.07
T ₁₄ - N ₈₀ +P ₄₀ +K ₂₀ +B _{1.5}	0.47	183.98	13.24	72.91	25.20	1.24	1.28
T ₁₅ - N ₈₀ +P ₄₀ +K ₂₀ +S ₁₀ + Zn ₂ + B _{0.5}	0.48	200.70	17.30	78.44	26.46	1.75	0.95
T ₁₆ - N ₈₀ +P ₄₀ +K ₂₀ +S ₂₀ + Zn ₄ +B ₁	0.46	225.79	18.58	81.05	30.24	1.96	1.15
T ₁₇ - Control	0.43	142.17	5.45	58.46	6.72	1.08	0.51
CD(P=0.05)	0.09	66.503	3.325	9.320	7.213	0.03	0.02
CV	12.12	20.21	12.23	6.49	17.02	1.356	1.81

The value of available zinc varied between 1.08 and 2.95 mg kg⁻¹. The minimum value was recorded in plots receiving no fertilizers (control). The maximum value of available zinc was recorded in T₁₁ with application of maximum dose of zinc @ 6 kg ha⁻¹ along with NPK followed by T₁₀. Treatment effect was found to be significant. Data on the available boron content in soils varied between 0.51 and 1.28 mg kg⁻¹. The minimum value was recorded in plots receiving no fertilizers (control). The maximum value of available zinc was recorded in T₁₄ with application of maximum dose of boron @ 1.5 kg ha⁻¹ along with NPK followed by T₁₆. Treatment effect was found to be significant.

Response of balanced fertilization on yield and protein content of rice

With balanced application of N, P, K and S, B, Zn, the grain yield of rice increased

significantly shown in table 2. The grain yield of rice ranged from 5.95 t ha⁻¹ to 8.43 t ha⁻¹. Minimum grain yield was obtained in plots receiving no fertilizers (control). Grain yield of rice was found to increase with the integrated application of micro nutrients along with major and secondary nutrients. The maximum yield was observed in plots receiving the dose of sulphur application @ 20 kg ha⁻¹ along with application of zinc and boron @ 4 and 1 kg ha⁻¹ respectively. The response of sulphur was more pronounced in grain yield in plots treated with nitrogen @ 40 kg ha⁻¹. Increase in number of panicles and dry matter yield could be as a result of nitrogen being involved in carbohydrate and protein metabolism that promotes cell division and enlargement resulting in more productive panicles and dry matter yields.

Table 2: Response of balanced fertilization on yield and protein content of rice

Treatments	Grain Yield	Straw Yield	Biological Yield	Harvest Index	Protein content
	(t ha ⁻¹)				(%)
T ₁ - N ₈₀ +P ₄₀ +K ₂₀	7.87	8.29	16.16	42.82	15.40
T ₂ - N ₈₀ +P ₄₀ +K ₂₀ +S ₁₀	6.77	8.83	15.60	43.26	17.38
T ₃ - N ₈₀ +P ₄₀ +K ₂₀ +S ₂₀	7.55	10.16	17.71	44.78	16.10
T ₄ - N ₈₀ +P ₄₀ +K ₂₀ +S ₃₀	7.60	10.56	18.16	44.69	16.57
T ₅ - N ₈₀ +P ₂₀ +K ₄₀	7.47	9.57	17.04	44.12	14.70
T ₆ - N ₈₀ +P ₄₀ +K ₄₀	7.52	9.33	16.85	44.82	16.80
T ₇ - N ₈₀ +P ₂₀ +K ₆₀	7.41	9.04	16.45	44.97	15.87
T ₈ - N ₈₀ +P ₄₀ +K ₆₀	7.97	9.31	17.28	45.85	15.63
T ₉ - N ₈₀ +P ₄₀ +K ₂₀ +Zn ₂	6.88	10.05	16.93	41.19	17.97
T ₁₀ - N ₈₀ +P ₄₀ +K ₂₀ +Zn ₄	7.28	11.01	18.29	40.02	15.17
T ₁₁ - N ₈₀ +P ₄₀ +K ₂₀ +Zn ₆	7.97	9.01	16.99	46.94	15.75
T ₁₂ - N ₈₀ +P ₄₀ +K ₂₀ +B _{0.5}	7.63	10.59	18.21	42.07	17.38

T ₁₃ - N ₈₀ +P ₄₀ +K ₂₀ +B ₁	7.52	9.68	17.20	43.91	16.33
T ₁₄ - N ₈₀ +P ₄₀ +K ₂₀ +B _{1.5}	7.17	8.80	15.97	46.21	16.10
T ₁₅ - N ₈₀ +P ₄₀ +K ₂₀ +S ₁₀ + Zn ₂ + B _{0.5}	8.24	10.53	18.77	44.10	16.10
T ₁₆ - N ₈₀ +P ₄₀ +K ₂₀ +S ₂₀ + Zn ₄ +B ₁	8.43	11.28	19.71	48.95	15.52
T ₁₇ - Control	5.95	7.87	13.81	36.69	14.35
CD(P=0.05)	2.200	3.153	3.782	11.076	1.369
CV	16.52	18.38	12.41	14.20	4.79

More or less similar trend was observed in case of straw yield and total biological yield (table 2). Straw yield ranged from 7.87 t ha⁻¹ to 11.28 t ha⁻¹. The maximum yield was recorded with the dose of sulphur application @20 kg ha⁻¹ along with application of zinc and boron @ 4 and 1 kg ha⁻¹ respectively. Minimum yield was obtained in plots receiving no fertilizers (control). The increase in yield due to application of sulphur may be due to better metabolism and increased efficiency of other nutrients. Similarly, the biological yield shows the same result as before observed in grain and straw. Biological yield ranged from 13.81 t ha⁻¹ to 19.71 t ha⁻¹. The maximum yield was recorded with the dose of sulphur application @20 kg ha⁻¹ along with application of zinc and boron @ 4 and 1 kg ha⁻¹ respectively. Minimum yield was obtained in plots receiving no fertilizers (control). The increase in yield due to application of sulphur may be due to better metabolism and increased efficiency of other nutrients. The HI (harvest index) of rice ranged from 40.02 to 48.95. Minimum HI was obtained in control plots and the maximum HI was observed in plots receiving the dose of nitrogen, phosphorus, potassium and sulphur fertilizers @ 80, 40, 20 and 20 kg ha⁻¹ along with zinc and boron application @ 4 and 1 kg ha⁻¹.

Role of micronutrients along with macro and secondary nutrients have a great impact in yield of rice. Zinc role is as multifaceted as the interface that reduces its availability. Physiologically its role in a plant is either as a metal constituent in an enzyme or as a functional co-factor of number of enzymes reactions. In general zinc deficient plant show signs of low levels of auxins such as indole acetic acid (IAA). Zinc plays a

greater role during reproductive phase especially during fertilization. Remarkably pollen grain contains zinc in very high quantity. At the time of fertilization most of zinc is diverted to seed only (Fageria et al., 2011). Reduction in yield of rice is often blamed to zinc sulphur deficiency. Zn deficiency is the most widespread micronutrient disorder in lowland rice and application of Zn along with NPK fertilizer increases the grain yield dramatically in most cases (Rahman et al., 2008 & Chaudhary et al., 2007). Boron is very much essential for flowering and grain formation in rice making it more important during the reproductive stage as compared to the vegetative stage of the crop.

Results revealed that levels of sulphur and other micro nutrients have significant effect on the protein content in rice (table 2). The protein content of rice seed increased over control with application of micronutrients irrespective of other nutrients. The protein content of rice ranged from 14.35 to 17.97 %. It is interesting to note that increased levels of S also increase the protein content in rice irrespective of other nutrients. However, the highest protein content (17.97 %) was observed in case of zinc @ 2 kg ha⁻¹. Boron is essential for all plant growth. It aids in the transfer of sugars and nutrients from leaves to reproductive organs, and increases pollination and seed development. According to Kolesnik (1962) B fertilization improves photosynthetic activity, enhances activity of enzymes and plays a significant role in protein and nucleic acid metabolism. Favourable effect of Zn on the yield of rice and increasing protein content and protein yield of rice may be attributed to its role in enzymatic activities, hormone

production, protein synthesis and seed production. These findings are in agreement with those reported by Varshney et al. (2008) and Prasad et al. (2010).

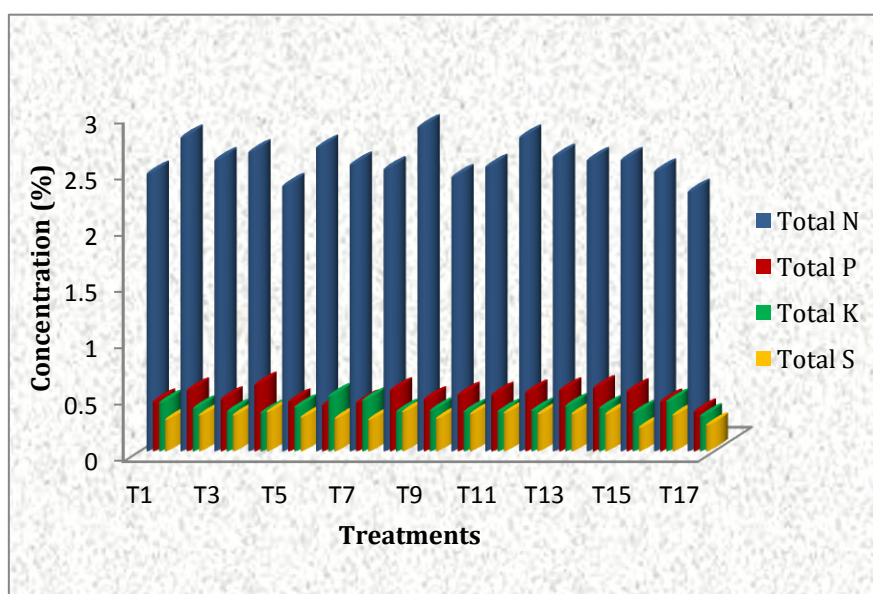
Response of balanced fertilization on nutrient concentration (%) in rice

Balanced application of fertilizer has a great role in uptake of nutrients in rice. Sulphur, zinc and boron had significantly influenced on concentration as they play important role in growth and development. Sulphur and zinc play identical role in case of nitrogen content and uptake. However, zinc take negative leads in case of phosphorus, moreover, sulphur plays vital role in potassium content and uptake zinc seems to be neutral. This is because of Zn and sulphur had equal role in nitrogen metabolism.

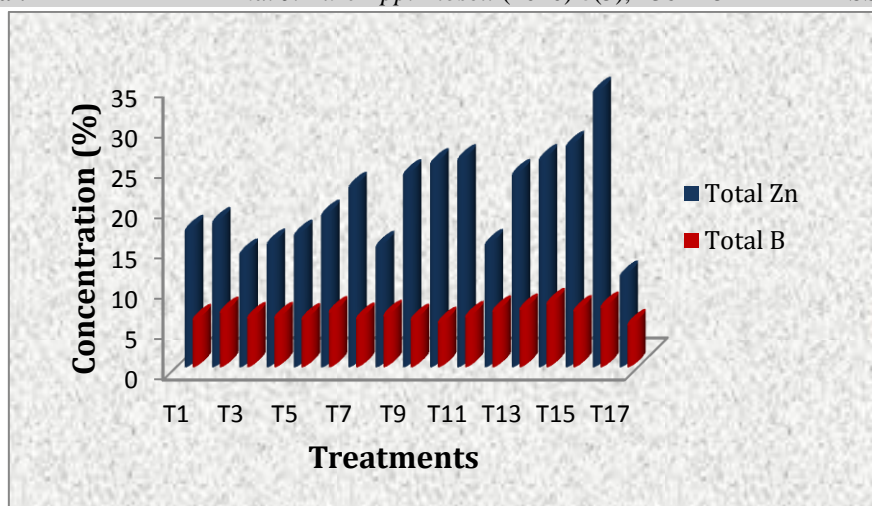
Accumulation of nutrient concentration (%) by rice grain

Accumulation of NPKS (%) in rice grain was depicted in figure 1. Grain nitrogen content ranged between 2.30% and 2.87%. Application of micronutrients increased nitrogen content in grains. Minimum result was obtained in plots receiving no fertilizers (control) and the maximum in plots receiving zinc @ 2 kg ha⁻¹.

Sulphur application also increased nitrogen content. Phosphorus content in rice grain varied from 0.35% to 0.59%. Minimum result was obtained in plots receiving no fertilizers (control) and the maximum in plots receiving sulphur @ 30 kg ha⁻¹. The values ranged from 0.31 to 0.49%. Minimum result was obtained in plots receiving no fertilizers (control). The maximum potassium content was recorded with potassium application @ 40 kg ha⁻¹. Sulphur content in grains ranged between 0.23 and 0.35 %. Application of Sulphur @ 30 kg ha⁻¹ gave significant result in sulphur content in grains. Minimum result was obtained in plots receiving no fertilizers (control). Zinc content in rice grain varies from 11.23% to 33.95% (fig.2). Minimum result was obtained in plots receiving no fertilizers (control) and the maximum in plots receiving zinc @ 4 mg kg⁻¹ along with NPK, sulphur and boron. Accumulation of boron content in grain varies between 5.21% to 7.82% (fig.2). Minimum result was obtained in plots receiving no fertilizers (control) and the maximum in T₁₄ with application of maximum dose of boron @ 1.5 kg ha⁻¹ along with NPK followed by T₁₆.



[Fig.1: Uptake of NPKS (%) by rice grain]

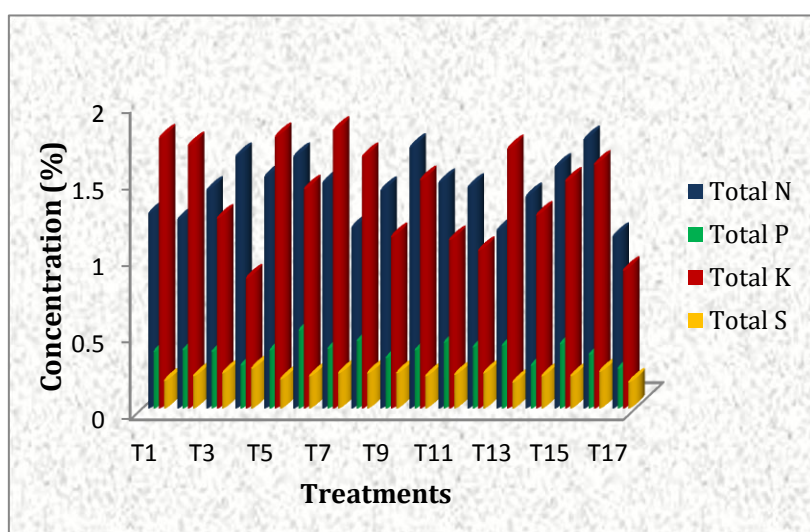


[Fig. 2: Uptake of B and Zn (%) by rice grain]

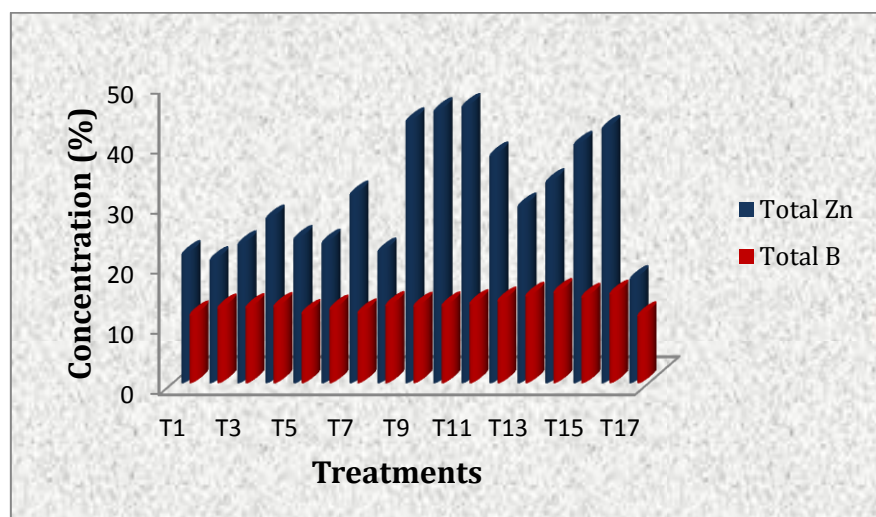
Accumulation of nutrient concentration (%) by rice straw

Accumulation of NPKS (%) in rice straw was depicted in figure 3. Nitrogen content in straw varied from 1.12 to 1.75%. Application of Zinc and Boron @ 4 and 1 kg ha⁻¹ respectively along with Sulphur application @ 20 kg ha⁻¹ increased nitrogen content in straw and resulted in the maximum value. The minimum value was observed in plots receiving where no fertilizer (control). Phosphorus content in straw varied from 0.26 to 0.51%. Maximum value was observed in plots receiving nitrogen, phosphorus and potassium @ 80, 40 and 40 kg ha⁻¹ respectively and the minimum value was recorded in plots received no fertilizer. Potassium content in straw varied between 0.90 to 1.81%. Potassium application @ 60 kg ha⁻¹ resulted in increased potassium

content in straw which is maximum. No fertilizer application (control) recorded the least potassium content in straw. Sulphur content in straw ranged between 0.17 and 0.26%. The maximum value was recorded in plots receiving sulphur @ 30 kg ha⁻¹ and the minimum S content was recorded in control. Zinc content in rice straw varies from 17.18% to 45.75% (fig.4). Minimum result was obtained in plots receiving no (control) and the maximum in T₁₁ receiving zinc @ 4 mg kg⁻¹ along with NPK followed by T₁₀. Accumulation of boron content in grain varies between 11.18% to 15.03% (fig.4). Minimum result was obtained in plots receiving no fertilizers (control) and the maximum in T₁₄ with application of maximum dose of boron @ 1.5 kg ha⁻¹ along with NPK followed by T₁₆.



[Fig. 3: Uptake of NPKS (%) by rice straw]



[Fig. 4: Uptake of B and Zn (%) by rice straw]

CONCLUSION

The result of the study revealed that combined application of NPK with S, B and Zn recorded higher yield, nutrient accumulation as well as uptake and maintained soil fertility. Balanced nutrient management is one of the important issues for increasing crop production sustainably. The balanced application of NPK with sulphur, boron and zinc recorded higher grain yield, total biological yield, crude protein content as well as protein yield, nutrient accumulation as well as uptake and maintained soil fertility. Combined application of sulphur, boron, and zinc increased the use efficiency of N, P and K. Balanced nutrient applications are more beneficial when the rate of the nutrient application is below the normal rate. It also improved the crop yields quality of the produce as well as improves the soil fertility, thus the overall profit of the farmers.

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