Effect of nutrient management on growth, productivity and economics in rice based cropping system in lateritic soil of West Bengal

Tanmoy Shankar, Mahua Banerjee, GC Malik and Sudarshan Dutta

DOI: https://doi.org/10.22271/chemi.2020.v8.i2a0.9156

Abstract
The experiment was conducted during 2014-2015 and 2015-2016 at farmers’ field situated at Binuria village (23°40’N and 87°37’E) of Birbhum district of West Bengal under the red and lateritic belt of West Bengal. The experiment was laid out in Randomized Block Design with three replication and twelve treatments in both during kharif and boro season. The plot size was 5m x 4m and the treatment combinations are T1-N0P0K0Zn0S0, T2-N0P0K0Zn2S0, T3-N0P0K0Zn2S20, T4-N0P2K0Zn2S20, T5-N0P2K0Zn2S40, T6-N0P2K0Zn2S60, T7-N0P2K0Zn2S80, T8-N0P2K0Zn2S100, T9-N0P2K0Zn2S120, T10-N0P2K0Zn2S140 and T11-N0P2K0Zn2S160 and T12 -Control where as in boro season the treatment combinations are T1-N20P0K0Zn0S0, T2-N0P0K0Zn2S0, T3-N0P0K0Zn2S20, T4-N0P0K0Zn2S40, T5-N0P0K0Zn2S60, T6-N0P0K0Zn2S80, T7-N0P0K0Zn2S100, T8-N0P0K0Zn2S120, T9-N0P0K0Zn2S140 and T10-N0P0K0Zn2S160 and T11-N0P0K0Zn2S180 and T12 - Control. The high yielding varieties (HYV) rice during Kharif season was MTU 7029 (Swarna) and hybrid variety used in Boro season was Azirize 6444 GOLD. The study concludes that application of N20P0K0Zn2S20 (T1) during kharif and N20P0K0Zn2S20 (T1) in boro season during the two season of experimentation was essential for improving growth attributes, yield components and productivity of high yielding variety (HYV) and hybrid rice. The treatments positively influenced the crop efficiency factors, improved physico-chemical properties and fertility status of the soil and paid highest gross and net returns from the rice cultivation. The study suggests the application of ample dose of fertilizer for better growth, higher productivity, profit and sustainability of rice in the lateritic soil of west Bengal.

Keywords: Ample dose, grain yield, rice, nutrient management

Introduction
Rice is a main staple in more than 100 countries worldwide. Rice is most closely associated with South, Southeast, and East Asia, where 90% of the world's rice is produced. Asia’s hot and humid climate during the long and heavy monsoon season, and the fertile land along the river basins of the major deltas that are regularly flooded, provide the most favourable agro-ecological environment for rice cultivation. Amongst the rice growing countries, rice cultivation is the most important agricultural operation in India, not only in term of food security but also in term of livelihood. It plays a major part in the diet, economy, employment, culture and history of India. Ninety percent of rice produced is consumed within the country. India ranks number one globally in paddy area with 42.75 million hectares and with production of 105.24 million tonnes (Anonymous, 2014) [1] stands next only to China. While there has been no net increase in the area of rice cultivation in the last 30 years, rice contributes nearly 15 percent of India’s annual gross domestic product (GDP) and provides 31 percent of the total calorie supply. India needs to produce 120 million tonnes by 2030 to feed its one and a half billion plus population by then. A real-time analysis of this scenario provides sufficient justification for strengthening, intensifying and introducing cutting edge science and technology for increasing rice productivity in India. In West Bengal, the area and production under food grains during 2012-13 were 5.44 million hectares and 15.02 million tonnes respectively (Gupta et al., 2012 and Das et al., 2014) [7,5]. Rice grows in the state in 3 different seasons viz., Aus (autumn rice), Aman (winter rice) and Boro (summer rice). There are three seasons for growing rice in West Bengal viz. - autumn, winter and summer. These three seasons are named according to the season of harvest of the crop.
Autumn or pre-kharif rice is known as Aus in West Bengal. The pre-monsoon Aus, covers April to July in the northern region and May to September in the southern region of the state and accounts for only 5% of total rice area and with the expansion of irrigation facilities, the area under this crop has gradually been declining. At present, more than 99% of the total area is covered with high yielding varieties during Aus season. The winter or monsoon rice, known as Aman, is grown from June to December. It accounted for 69% of the total rice area and is grown under rainfed conditions in the semi-deep, deep and flooded land (mostly indigenous improved and traditional varieties) and under irrigated conditions in the flood-free medium and shallow lowlands (mostly modern high yielding varieties). During Aman cultivation, farmers still grow some traditional or local ice varieties having special features and it covers nearly about 12% of the total rice area cultivated during Aman. The remaining 26% of the rice area is covered by the summer or dry season rice popularly known asboro. The nutrient mining issues concern the nutrients that are less mobile in soils and have higher potential of staying in the soil. For example, nitrogen (N) is highly mobile in the soil and has the highest probability, among the major nutrients, to be lost from the soil system through volatilization and leaching, among others. The Indian soils, being in the sub-tropical region coupled with the preponderance of tillage practices, are rarely sufficient in N. Nitrogen is generally applied in adequate quantities to the crops, and “nitrogen mining” is not frequently discussed as crop production relies more on adequate external application through fertilizer/manure sources rather than on the native soil reserve of N. The input-output balance calculations for N, at the regional or the national scale, generally show positive balance in soils (Sanyal, 2014) [13]. The total fertilizer N needed by rice to achieve a profitable yield target is determined from the anticipated crop response to applied fertilizer N and a targeted efficiency of fertilizer N use. Fertilizer N is supplied at critical growth stages, especially active tillering and panicle initiation, to match the crop needs for supplemental N. Fertilizer P and K are applied in sufficient amounts to overcome deficiencies and sustain soil fertility. (Buresh, 2009) [3] Nitrogen management requires special attention in its use so that the large losses can be minimized and the efficiency maximized. Site-specific nutrient management (SSNM) (Banayo et al., 2018) [2] has been found especially useful to achieve the goals of improved productivity and higher N use efficiency (NUE) (Kumar et al., 2018) [8].

Materials and Methods
The experiment was conducted during 2014-2015 and 2015-2016 at farmers’ field situated at Binuria village (23°40’N and 87°37’E) of Birbhum district of West Bengal under the red and lateritic belt of West Bengal. The experiment was laid out in Randomized Block Design with three replication and twelve treatments in both kharif and boro season. The plot size was 5 m x 4 m and the treatment combinations are T1-N120P120K60Zn25S20, T2-N120P0K0Zn0S0, T3-N120P0K0Zn25S25, T4-N60P20K0Zn0S0, T5-N120P0K60Zn25S20, T6-N120P0K60Zn25S25, T7-N120P60K0Zn25S20, T8-N120P0K60Zn12.5S20, T9-N120P60K0Zn12.5S20, T10-N120P60K60Zn25S20, T11-N120P0K0Zn12.5S20 and T12- Control. The ample dose of nutrients was 80:40:40:25:20 and 120:60:60:25:20 kg/ha of N: P2O5: K2O: Zn:S in kharif and boro season rice respectively. The high yielding varieties (HYV) rice during kharif season was MTU 7029 (Swarna). The Hybrid variety used in boro season was Arize 6444 GOLD. The data were statistically analyzed applying the techniques of analysis of variance and the significance of different sources of variations were tested by error mean square of Fisher Snedecor’s ‘F’ test at probability level 0.05 (Cochran and Cox, 1977) [9].

Results and Discussion

Growth Attributes
The plant height of kharif season rice record highest with application ample dose of nutrients (i.e. T1:N120P120K60Zn25S20) caused significant increase in height of the rice plants over control (i.e. T12: No fertilizer) in the pooled data analysis. The treatment T1 (N120P0K0Zn25S25) was significantly superior to control and all the treatments produced and statistically at par with T2(N120P0K0Zn25S20), T3 (N120P0K60Zn25S20), T5 (N120P0K60Zn25S25), T6 (N120P60K0Zn25S20), T8 (N120P60K0Zn25S25), T9 (N120P60K0Zn12.5S20) and T10 (N120P0K0Zn12.5S0). The plant height of boro season rice also produce similar type of observations as recorded in kharif season rice. T1 remained statistically at par with all other treatment except the treatments T3 and control (T12) remained statistically at par in enhancement of the plant height at the same stage. The dry matter accumulation of kharif and boro rice which was reflected on pooled data of two years of experiment and observed similar trend was noted in dry matter where T1 produced significantly higher dry matter than T3 and control. Moreover, T1 remained statistically at par with other treatments except T3, and T12. The control treatment shows lowest dry matter during the growth stage among all other the treatment (Shankar et al., 2014) [10].

The number of tillers per m² harvested were statistically analyzed and presented in Table 1 and 2. The data reflect that most of the treatments recorded higher number of tillers per m² during the two years of experimentation. The resulting showed that the rapid increase in number of tillers was observed during both the years of the experiment when application of 100% of recommended dose of fertilizers (T1:N120P120K60Zn25S20) gave maximum number of tiller per m² was recorded which was statistically at par with the treatments having T2-N60P20K0Zn25S20, T3-N60P0K0Zn25S20, T4-N60P0K60Zn25S20, T5-N120P60K0Zn25S25 and T9-N120P0K0Zn12.5S20 in kharif season but during boro rice the pooled data analysis, also produce similar trend and the effect of nutrient management observed that T1: N120P0K0Zn25S20 gave higher tillers per plant over T12 (control). T1(N120P60K0Zn25S25) was significantly superior over T3(N120P0K60Zn25S20), T5(N120P0K0Zn25S25), T6(N120P60K0Zn25S25), T7(N120P0K60Zn25S25), T8(N120P0K60Zn12.5S20), T9(N120P0K0Zn12.5S20) and T12- Control which was statistically at par with T3-N120P0K0Zn25S25, T5-N120P0K60Zn25S20, T6-N120P0K60Zn25S25, T7-N120P0K60Zn25S20, T8-N120P0K60Zn12.5S20, T9-N120P0K0Zn12.5S20 and T12-N120P0K0Zn25S20. The lowest number of tillers per m² was recorded in T3, T5, T9, T11 and control which was due to omission of different nutrients gave less growth attribute compared to ample dose of nutrients which follow similar trend in pooled data analysis during both years of experimentation (Nanjappa et al., 2013) [10].
**Yield Attributes**

During *kharif* and *boro* season of 2014-15 and 2015-16. The yield attributes like number of panicles m⁻², panicle length, number of spikelets panicle⁻¹ and number of filled grains panicle⁻¹ recorded at maturity were presented in the Table 1 & 2. The effect of higher doses of nitrogen, phosphorus, potassium, zinc and sulphur revealed that number of panicles m⁻², increased with the 100% application to rice pooled data analysis of *kharif* season. The control show least among all other the treatments. The number of panicles per m² was maximum in the treatment T₁ (N₀P₀K₀Zn₂S₀) was applied with ample dose of nutrient compared to omission and control treatment and it was statistically at par with (T₂) N₀P₀K₀Zn₂S₂₀, (T₄) N₀P₀K₀Zn₂S₂₀, (T₆) N₀P₀K₀Zn₂S₂₀, (T₈)N₀P₀K₀Zn₁₂S₂₀ and (T₁₀). This was closely followed by T₅ all the treatments. The pooled data of S showed the lowest number of filled grains per panicle among T₄ P₀K₀Zn₁₂S₂₀, T₆ N₀P₀K₀Zn₂S₂₀, T₀₁ N₀P₀K₀Zn₁₂S₂₀ and T₀₈ N₀P₀K₀Zn₂S₁₀. This was significantly and appreciably the treatment combination with 100% of RDF gave maximum value among all the treatment and the lowest number of spikelets per panicle observed in control (no fertilizer) (Ray et al., 2015 and Shankar et al., 2018) [12, 14, 15].

**Yield (t ha⁻¹)**

The Grain and straw yield (t ha⁻¹) observed that the highest grain yield (5.6 t ha⁻¹) and straw yield (7.5 t ha⁻¹) of *kharif* rice (Table 1 & 2), in the pooled data which shows that the grain yield has increased significantly due to application of ample dose of nutrient T₁(N₀P₀K₀Zn₂S₀) compared to the control and Application of fertilizer to rice-riese based cropping system has resulted significantly and appreciably higher grain yield of rice in both the season. Which was statistically at par with all other treatment except T₁ and T₁₂. The maximum grain and straw yield of rice was recorded in T₁ (N₀P₀K₀Zn₂S₀). The pooled of *boro* season (2015 & 2016), the highest grain and straw yield (6.60 & 8.52 t ha⁻¹) was achieved T₁ (N₀P₀K₀Zn₂S₀) applied with ample dose of nutrients which was statistically at par with T₁(N₀P₀K₀Zn₂S₀),T₅(N₀P₀K₀Zn₁₂S₁₀),T₇(N₀P₀K₀Zn₁₂S₂₀),T₈(N₀P₀K₀Zn₂S₁₀) and T₁₀(N₀P₀K₀Zn₁₂S₁₀) with compared to control treatment. The treatment combination with 100% recommended dose of fertilizers has brought about significant improvement in yield of *kharif* and *boro* rice over control treatments. The ample dose of nutrients (T₁) has proved appreciably and significantly superior to all other the treatments (Kumar et al. 2018) [8]. Which resulted the maximum yield of rice-riese cropping system and the lowest straw yield has been recorded in the control plot in both years of the experiment (Shankar et al., 2014) [16].

Table 1: Effect of nutrient management on growth and yield attributes of *Kharif* rice (pooled data over two years)

| Treatment          | Plant height (cm) | Dry matter Accumulation (g) | Tiller m⁻² | Number of panicles/m² | Number of filled grains/panicle | Number of Spikelets/panicle | Grain yield (t ha⁻¹) | Straw yield (t ha⁻¹) |
|--------------------|-------------------|-----------------------------|------------|-----------------------|-------------------------------|-----------------------------|---------------------|--------------------|
| T₁(N₀P₀K₀Zn₂S₀)   | 119.6             | 1308.3                      | 312.1      | 248                   | 132.1                         | 149.6                      | 5.56                | 7.59               |
| T₂(N₀P₀K₀Zn₂S₀)   | 111.1             | 1252.7                      | 296.9      | 243                   | 127.6                         | 146.4                      | 4.82                | 7.1                |
| T₄(N₀P₀K₀Zn₂S₀)   | 95.4              | 661.7                       | 258.4      | 209.9                 | 110.3                         | 132.5                      | 3.32                | 5.18               |
| T₆(N₀P₀K₀Zn₂S₀)   | 117               | 1242.6                      | 295.9      | 245.4                 | 122.3                         | 145.5                      | 5.26                | 7.45               |
| T₈(N₀P₀K₀Zn₂S₀)   | 108.5             | 1213.2                      | 277.2      | 239.3                 | 113.1                         | 135.8                      | 5.03                | 7.55               |
| T₁₀(N₀P₀K₀Zn₂S₀)  | 115.1             | 1332.2                      | 303.3      | 234.6                 | 126.9                         | 149.2                      | 5.18                | 7.46               |
| T₁₂(Control)      | 103.6             | 1209.4                      | 274.5      | 226.3                 | 112.4                         | 136.3                      | 5.07                | 7.29               |
| T₇(N₀P₀K₀Zn₁₂S₁₀) | 114.2             | 1237.7                      | 302.7      | 246                   | 124.9                         | 148                         | 5.21                | 7.52               |
| T₉(N₀P₀K₀Zn₁₂S₂₀) | 100.8             | 1206.4                      | 274.4      | 217.2                 | 113.6                         | 135.6                      | 5.02                | 7.47               |
| T₁₀(N₀P₀K₀Zn₁₂S₂₀)| 114.2             | 1222.8                      | 290.2      | 245                   | 118.2                         | 145.5                      | 5.32                | 7.53               |
| T₁₁(N₀P₀K₀Zn₂S₁₀) | 96                | 1244                        | 273.2      | 220.4                 | 113                           | 133.8                      | 5.28                | 7.50               |
| SEm (±)            | 6.5               | 64.6                        | 9.6        | 7.2                   | 5.9                            | 4                          | 0.25                | 0.33               |
| CD (p=0.05)        | 19                | 189.3                       | 28.2       | 21.2                  | 17.2                           | 11.7                       | 0.74                | 0.98               |
| CV(%)              | 10.4              | 11.1                        | 6          | 5.3                   | 8.8                            | 4                          | 4.8                 | 8.3                |
Table 2: Effect of nutrient management on growth and yield attributes of Boro rice (pooled data over two years)

| Treatment | Plant height (cm) | Dry matter Accumulation (g) | Tiller m⁻² | Number of panicles/m² | Number of filled grains/panicle | Number of Spikelets/panicle | Grain yield (t ha⁻¹) | Straw yield (t ha⁻¹) |
|-----------|-----------------|-----------------------------|------------|-----------------------|-------------------------------|----------------------------|-----------------------|----------------------|
| T₁(N₁₀P₅K₅Zn₂S₂) | 123.2 | 1417.2 | 360.8 | 281.6 | 142.7 | 157.3 | 6.60 | 5.82 |
| T₂(N₁₀P₅K₅Zn₂S₂) | 118.0 | 1397.7 | 360.9 | 275.1 | 134.5 | 151.6 | 7.88 | 6.06 |
| T₃(N₁₀P₅K₅Zn₂S₂) | 96.4 | 668.4 | 310.6 | 237.2 | 90.8 | 125.6 | 3.44 | 5.96 |
| T₄(N₁₀P₅K₅Zn₂S₂) | 117.4 | 1402.9 | 355.1 | 267.3 | 132.5 | 155.5 | 6.18 | 8.39 |
| T₅(N₁₀P₅K₅Zn₂S₂) | 114.9 | 1389.5 | 328.3 | 255.2 | 129.6 | 143.7 | 6.06 | 7.91 |
| T₆(N₁₀P₅K₅Zn₂S₂) | 119.2 | 1403.3 | 354.9 | 278.5 | 131.1 | 156.5 | 6.22 | 8.45 |
| T₇(N₁₀P₅K₅Zn₂S₂) | 112.7 | 1380.6 | 332.4 | 258.1 | 130.6 | 141.0 | 6.12 | 8.30 |
| T₈(N₁₀P₅K₅Zn₂S₂) | 121.5 | 1401.0 | 351.3 | 279.7 | 135.6 | 151.8 | 6.31 | 8.46 |
| T₉(N₁₀P₅K₅Zn₂S₂) | 120.2 | 1383.5 | 342.6 | 263.6 | 131.0 | 146.1 | 6.23 | 8.48 |
| T₁₀(N₁₀P₅K₅Zn₂S₂) | 117.2 | 1405.0 | 351.1 | 267.5 | 138.1 | 153.2 | 6.25 | 8.51 |
| T₁₁(N₁₀P₅K₅Zn₂S₂) | 118.1 | 1399.7 | 337.8 | 263.4 | 131.6 | 140.9 | 6.11 | 8.30 |

Economics

The gross return (Rs ha⁻¹) of high yielding rice and hybrid rice grown during kharif (2014 & 2015) and boro (2015 & 2016) season with different nutrient management practices was estimated on the basis of prevailing market price of different inputs and outputs. The data on gross return, net return in rice cultivation were analyzed statistically and presented in the Table 3. The pooled data of kharif and boro season rice for the gross return was found that the highest obtained in the ample dose (T₁₁:N₁₀P₅K₅Zn₂S₂). The gross return (Rs ha⁻¹) was significantly affected by nutrient application of ample dose of NPKZnS applied plot was significantly superior than the control plot. The application of 100% N+P+K+S dose increased yield components, which ultimately reflected on grain yield and straw yield. Due increased in yield which cause the higher gross return in T₁ and highest among all the treatment which was statistically at par with T₈ ([11]). The study indicates the need of ample dose of nutrition of hybrid rice for greater productivity along with higher profit. Whereas control (0.06) respond lesser compared to other treatments (Das et al., 2010 [6] and Mauriya et al., 2013 [9]).

Agronomic efficiency (AE)

The NPKZnS level registered significant effect on agronomic efficiency (AE) during kharif and boro season. There was a strong negative relationship between agronomic efficiency (AE) and nutrient level. The decreased markedly as the NPKZnS level increased. Agronomic efficiency, which reflects the production per kg of nutrient applied, has varied appreciably due to different treatments and similar effect was observed in the pooled data analysis (Table 3). The fertilizer with 50% recommended dose of fertilizer was applied to kharif and boro rice has recorded higher agronomic efficiency than that of 100% recommended dose of fertilizer (T₁). Waiving the fertilizers application as T₂, T₃, T₄ and T₅ produced better effects on agronomic efficiency which has remarkably increased amongst all the treatments which was followed by 100% recommended fertilizer level (Ravisankar et al., 2014) [11].

Table 3: Effect of nutrient management on economics and Agronomic efficiency (AE) of kharif and Boro rice (pooled data over two years)

| Treatment | Gross Return (Rs ha⁻¹) | Net Return (Rs ha⁻¹) | B:C Ratio | Agronomic efficiency (AE) | Treatment | Gross Return (Rs ha⁻¹) | Net Return (Rs ha⁻¹) | B:C Ratio | Agronomic efficiency (AE) |
|-----------|-----------------------|---------------------|-----------|--------------------------|-----------|-----------------------|---------------------|-----------|--------------------------|
| T₁(N₁₀P₅K₅Zn₂S₂) | 93139.2 | 57408.3 | 1.62 | 30.7 | T₁(N₁₀P₅K₅Zn₂S₂) | 109754.5 | 67,491.4 | 1.60 | 37.8 |
| T₂(N₁₀P₅K₅Zn₂S₂) | 81453.0 | 46332.7 | 1.32 | 62.7 | T₂(N₁₀P₅K₅Zn₂S₂) | 98575.0 | 57,225.0 | 1.39 | 63.7 |
| T₃(N₁₀P₅K₅Zn₂S₂) | 56317.5 | 22003.9 | 0.64 | 0.0 | T₃(N₁₀P₅K₅Zn₂S₂) | 59455.8 | 19,018.7 | 0.47 | 0.0 |
| T₄(N₁₀P₅K₅Zn₂S₂) | 88473.4 | 53631.3 | 1.54 | 36.9 | T₄(N₁₀P₅K₅Zn₂S₂) | 103479.3 | 62,549.6 | 1.53 | 34.4 |
| T₅(N₁₀P₅K₅Zn₂S₂) | 81017.2 | 51063.9 | 1.50 | 34.0 | T₅(N₁₀P₅K₅Zn₂S₂) | 100856.6 | 61,360.1 | 1.55 | 33.4 |
| T₆(N₁₀P₅K₅Zn₂S₂) | 87383.2 | 52185.1 | 1.48 | 35.9 | T₆(N₁₀P₅K₅Zn₂S₂) | 104149.9 | 62,686.8 | 1.51 | 34.7 |
| T₇(N₁₀P₅K₅Zn₂S₂) | 85507.0 | 50841.7 | 1.47 | 34.5 | T₇(N₁₀P₅K₅Zn₂S₂) | 102407.2 | 61,744.1 | 1.52 | 33.8 |
| T₈(N₁₀P₅K₅Zn₂S₂) | 87841.3 | 52193.6 | 1.46 | 36.2 | T₈(N₁₀P₅K₅Zn₂S₂) | 105478.7 | 63,298.8 | 1.50 | 35.4 |
| T₉(N₁₀P₅K₅Zn₂S₂) | 85017.5 | 49453.0 | 1.39 | 33.9 | T₉(N₁₀P₅K₅Zn₂S₂) | 104286.5 | 62,189.8 | 1.48 | 34.7 |
| T₁₀(N₁₀P₅K₅Zn₂S₂) | 89530.9 | 54022.3 | 1.50 | 37.6 | T₁₀(N₁₀P₅K₅Zn₂S₂) | 104711.2 | 62,670.1 | 1.49 | 35.0 |

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Conclusion
Thus it may concluded that the nutrient management approach enhance the growth, productivity and nutrient use efficiency showed positive and significant relationships which in turn positively influenced by the application of ample dose of nutrients. The application of macro and micro nutrient from chemical fertilizers gave better result compared to omission and control treatments, which produced significantly better growth and productivity under rice-rice cropping system.

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