**Response of rice to graded levels of nitrogen and sulphur in temperate Kashmir**

**Abstract**

A field experiment entitled ~~as~~ **“Response of rice to graded levels of nitrogen and sulphur in temperate Kashmir”** was conducted at the Crop Research Farm, Division of Agronomy, Faculty of Agriculture, Sher-e- Kashmir University of Agricultural Sciences and Technology of Kashmir during *Kharif*, 2021. The soil of the experimental field was silt clay loam with neutral pH, low in available nitrogen, medium in phosphorous, potassium, and organic carbon, and sufficient in sulphur. The experiment consisted of two factors: Factor A being Nitrogen Levels (kg ha-1) as Control, N60, N80, N120 and Factor B being Sulphur Levels (kg ha-1) as Control, S15, S30, S45 laid out in Factorial Randomized Complete Block Design with three replications. Significant variations in dry matter accumulation, tiller count, N and S uptake by crop, agronomic efficiency, protein content of grain and protein productivity were recorded among different levels of nitrogen and sulphur management practices. Higher dry matter accumulation, and tiller count, were recorded under the 120 kg ha-1 level of nitrogen and 45 kg ha-1 level of sulphur. However N80 was at par with N120. Significant interaction was also seen between nitrogen (80kg N ha-1) and sulphur (30kg S ha-1) on agronomic efficiency.

***Keywords*:** Dry matter accumulation, tiller count, nitrogen, Sulphur, interaction.

**Introduction**

Rice (*Oryza sativa* L**.)** is one of the important staple food crops for the world population. More than 90% of the world’s rice is produced and consumed in Asia. Out of 782 million tonnes of global rice production from 167.1 million hectares, India produced 116.42 million tonnes in 44.5 million hectares (FAO, 2020). In Jammu and Kashmir, rice is grown from time immemorial and stands as the principal staple food crop. The total rice area of the UT of Jammu and Kashmir is around 0.28 million hectares with a production and productivity of 0.55 million tonnes and 2.1 tonnes per hectare, respectively (DES, 2018).

Rice is a nutritional staple food that provides instant energy, as its most important component is carbohydrate (starch). It provides about 700 calories per day per person for about 3 billion people living mostly in developing countries (USDA 2020). It is also used in the manufacturing of paper pulp and livestock bedding. The per capita food intake in India is 2234 calories per day, of which 30 percent comes from rice only. Its protein is highly digestible with excellent biological values and protein efficiency ratio owing to the presence of a higher concentration (4%) of lysine (Oko *et al*., 2012). Nitrogen and Sulphur are both involved in plant protein synthesis, a process that determines the crop yields. Nitrogen is the main factor to improve the rice grain nutritional quality, which positively affects the protein fraction of glutelin rich in essential amino acids (Mingotte *et al.,* 2012) and is also involved in productivity (Fageria *et al.,* 2010). Sulphur fertilization improves the nutrient uptake and fertilizer use efficiency of N, P, K and Zn because of the synergistic relationship of sulphur with these nutrients. Sulphur tends to increase the yield in cereals up to certain limit (Ying- xing *et al*., 2017). Nitrogen is considered as the most yield-limiting nutrient in irrigated rice production around the world (Samonte *et al*., 2006). Nitrogen is the most limiting nutrient for rice crop growth and yield which is required in higher amounts compared to other nutrients (Djaman *et al*., [2018](https://www.tandfonline.com/doi/full/10.1080/24749508.2020.1742509)).

Nitrogen is one of the most important plant nutrients and plays a vital role in plant photosynthesis and biomass production. Increasing panicle numbers in per unit area is the main factor of yield increment as a result of nitrogen application (Bindra *et al.,* 2000; Laroo and Shivay, 2011). Nitrogen influences rice yield by playing major role in the photosynthesis, biomass accumulation and spikelets formation (Yoshida *et al*., 2006). Furthermore, excessive use of high analysis fertilizers in the recent past for improved cultivars has led to nutrient imbalance in soil, particularly to the deficiency of secondary nutrients like sulphur. After N, P, and K, sulphur has long been acknowledged as the fourth most important nutrient for plants. According to Prasad (2004), sulphur is moving up from fourth to third on the list of essential nutrients in India. Both inorganic and organic forms of sulphur are found in soils, with organic sulphur accounting for more than 93% of all sulphur in soils from humid and semi-humid locations. However, depending on the kind of soil and sampling depth, there are significant differences in the percentage of inorganic and organic sulphur in a soil sample. Sulfate-S is continuously present in soil solution at very low concentrations, depending on the balance of S plant uptake, fertilizer input, immobilization, and mineralization at any given time (Balik *et al.,* 2009).

Realizing the importance of sulphur and nitrogen on the performance of rice a study entitled **““Response of rice to graded levels of nitrogen and sulphur in temperate Kashmir”** was conducted during 2021.

**Materials and methods**

The present investigation, entitled **“Response of rice to graded levels of nitrogen and sulphur in temperate Kashmir”** wasconducted at the Faculty of Agriculture, Wadura (Sopore), Sher-e-Kashmir University of Agricultural Sciences & Technologyof Kashmir during *kharif* season of2021. The experimental site is situated in the temperate zone between 34o35/ N latitude and 74o40/ E longitude at an altitude of 1584 meters above mean sea level. Climatically the experimental site was in a mid-altitude temperate zone characterized by hot summers and very cold winters with an average annual precipitation of 812 mm (average of the past 20 years) most of which is received from December to April in the form of snow and rain. The soil of the experimental site was silty clay loam, medium in available P, K, S and organic carbon; however it was low in available N.

Five hills were cut from the base of the middle row randomly from each treatment at 15 day intervals and were sun dried for 3-4 days. The plant samples were then oven-dried at 60- 650C for 48 hours to a constant value. The dry weight was recorded in grams and then converted into q ha-1. Tiller count was recorded from 15 DAT till harvest at 15-day intervals from 5 randomly tagged hills of each plot and subsequently the number was transformed to tillers per m-2. For the plant nutrient studies, plant samples collected at harvest were sun dried and then packed in labeled long paper bags. These samples were put in an electric oven dried for 36 hours at 60-65oC temperature till constant weight was obtained. The oven-dried plant samples were grinded with the help of Yarco grinder. The ground samples were put in labelled bags for chemical analysis. Nitrogen content was estimated by digesting 0.5 g sample with 10 ml concentrated sulphuric acid and digestion mixture. Total nitrogen was determined by micro Kjeldahls method. N uptake by straw and grain of crop were calculated by multiplying dry matter production with corresponding values of their content and was expressed as kg ha-1. Sulphur content was estimated by turbidimetric method outlined by. S uptake by straw and grain of crop were calculated by multiplying dry matter production with corresponding values of their content and was expressed as kg ha-1. Protein content of grain was calculated by multiplying nitrogen content of grain with the factor 6.25. It was expressed in terms of percent. Agronomic efficiency was calculated as kg of grain per kg of nutrient applied. Protein productivity was calculated by the following formula:

|  |  |
| --- | --- |
| Protein productivity= | Protein content x yield (grams) |
| 100 |

**Results and discussion**

**Dry matter accumulation (q ha-1)**

Dry matter accumulation is an important index to express the growth and metabolic efficiency of a plant, which ultimately influences the yield and yield attributes, periodic dry matter production increased with the increase in crop age. The present data as presented in Table 1 revealed that there was a significant increase in dry matter accumulation with the application of higher levels of nitrogen (80 kg N/ha and 120 kg N/ha). At harvest, application of 120 kg ha -1 produced maximum dry matter accumulation in the plant which was on par with 80 kg ha -1. This improvement was due to more assimilation and utilization of available nitrogen by the growing plants during the entire grand growth period. As the result of this, more dry matter accumulated in the roots, stems, leaves, and grains which favored increasing the dry weight production. The results are in close conformity to the findings of Pandey *et al*. (2001) and Meena *et al*. (2003).Among different Sulphur (S) levels, significantly higher dry matter production was recorded with the application of 45 kg S ha-1 than all other levels of sulphur except with application of 30 kg S ha-1 as it was at par with 45 kg S ha-1. The results agree with the findings by Amano *et al.* (1993), Cassman *et al.* (1998) and Jifengying *et al.* (1998) who reported that the higher yield of modern rice cultivars was due to higher biomass production.

**Tiller count (m-2)**

The effect of nitrogen on the number of tillers at different stages of crop was found to be significant (Table 2). The number of tillers m-2 responded to nitrogen fertilization at all the periodical stages. The higher doses of nitrogen (120 kg N ha-1 and 80 kg N ha-1) exhibited the maximum tillers m-2, while the lowest number of tillers m-2 were noted with no application of nitrogen. The increasing number of tillers with increasing levels of nitrogen may be attributed to the fact that nitrogen seems to have played a vital role in the formation of new tissues, which are dependent on the protoplasmic structure, cell division and cell elongation. The results agree with those of Pandey *et al*. (2001) and Meena *et al*. (2003). Sulphur levels had a significant effect on number of tillers m-2 of and the data indicated that the application of 45 kg S ha-1 resulted in a significantly high number of tillers plant-1 and was observed to be on par with the application of 30 kg S ha-1.

**N and S concentration (%) and uptake (kg ha-1) by grain and straw**

N concentration of grain and straw was significantly affected by N levels as well as S levels (Table 3). N concentration in grain and straw was found to be significantly higher in N120 however, it was at par with N80 while ~~as,~~ N0 recorded the lowest N concentration in grain and straw. Under different sulphur levels N concentration of grain was recorded significantly higher in S45 however it was at par with S30 while as it was recorded lowest under S0 treatment. N concentration in straw was found to be higher in S45 however, different S levels were at par with each other (Table 3). The nitrogen levels had a significant effect of N uptake in grain and straw (Table 3). The nitrogen uptake by grain and straw was increased significantly with increasing levels of nitrogen up to 120 kg ha–1. Highest N uptake in grain and straw was recorded in treatment 120 kg ha–1. This was mainly due to a significant increase on nitrogen content in grain and straw as well as their respective yields with increasing levels of nitrogen. The higher uptake of N might also be due to better established roots and better plant growth under increased N levels. Similar findings were also reported by Rao *et al.* (2014). S levels had a significant effect on N uptake by grain and straw and the highest N uptake was recorded by application of 45 kg S ha-1 which significantly increased N-uptake by plant. The results are in conformity with the findings of. The significant increase of nitrogen uptake by grain and straw with application of sulphur might be attributed to the synergistic uptake mechanism of nitrogen and sulphur. The increase could also be attributed to the increase in yield and higher nutrient demand for plant growth. S concentration of grain and straw was significant affected by N levels as well as S levels (Table 4). Sulphur concentration in grain was significantly affected. Higher in N120 while as, N0 recorded the lowest S concentration in grain. S concentration in straw was found significantly higher in N120,however it was at par with N80, while as, it was recorded lowest in N0 treatment. Among different S levels higher S concentration in grain and straw was found significantly higher in S45 whereas, it was recorded lowest in S0 treatment (Table 4). The nitrogen levels had a significant effect on S uptake in grain and straw. The S uptake by grain and straw was increased significantly with increasing levels of nitrogen. Application of 120 kg N ha-1 significantly increased the S uptake however, N120 was at par with N80 with respect to N uptake by grain. Control treatment (N0) recorded lowest S uptake by grain and straw. Among different S levels S uptake by grain and straw was found significantly higher under S45 which was at par with S30, however S0 recorded lowest s uptake by grain and straw. This could be attributed due to better nutrition which resulted in better growth and yield which ultimately led to higher uptake of Sulphur. The result is in conformity with the findings of Singh and Meena, (2004).

**Protein content of grain and protein productivity (g m-2)**

The data presented Table 5 revealed that the significantly highest protein content was found in treatments N120 and S45 having value of 6.71 and 6.28. Similarly, in the case of protein productivity significantly higher productivity was found in treatments N120 and S45 which is 52.73 g m-2 and 47.83 g m-2 respectively. The treatments N120 and S45 was found to be at par with treatments N80 and S30 in both cases. A significant increase in protein content of the rice plant with increasing N rates was similarly reported by Mandana *et al*. (2011) and Shiferaw *et al*. (2012). The increase in protein content and protein productivity was attributed to the increase in seed yield.

**Agronomic efficiency (kg of grain/kg of nutrient applied)**

The data presented in Table 6 indicate that the agronomic use efficiency of rice was found to be superior in treatment N80 and S30 having a value of 53.12. The estimation of nutrient use efficiency (NUE) in crop plants is crucially needed to assess the fate of applied nutrients and their role in improving maximum economic yield through efficient absorption utilization by the plant. The substantial improvement in the NUE components of the rice crop when N is fertilized with S could be due to the synergistic effect of S on N uptake and utilization that facilitates the biosynthesis of proteins, a vital process that determines yield. The results are in conformity with the findings of Habtegebrial *et al.* (2013).

**Conclusion**

The results of the study indicated that the balanced application of nitrogen and sulphur improved rice growth, uptake of nutrients, agronomic efficiency, and protein content significantly. Nitrogen at 80 kg ha⁻¹ and sulphur at 30 kg ha⁻¹ proved most effective. Their combined use enhances productivity and nutrient use efficiency under temperate conditions in Kashmir.

**Table 1: Dry matter accumulation (q ha-1) as influenced by different graded levels of nitrogen and sulphur**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Treatments** | **15 DAT** | **30 DAT** | **45 DAT** | **60 DAT** | **75 DAT** | **90 DAT** | **105 DAT** | **Harvest** |
| **N0** | 0.95 | 4.88 | 38.24 | 99.29 | 110.83 | 114.67 | 116.15 | 116.47 |
| **N60** | 1.01 | 6.60 | 43.79 | 105.38 | 118.61 | 123.29 | 126.17 | 127.25 |
| **N80** | 1.12 | 7.70 | 52.05 | 113.28 | 128.01 | 138.16 | 141.70 | 142.32 |
| **N120** | 1.16 | 9.14 | 55.59 | 116.90 | 132.47 | 141.90 | 145.44 | 147.49 |
| **SE(m)±** | 0.02 | 0.63 | 1.68 | 2.23 | 2.70 | 3.36 | 2.80 | 3.40 |
| **CD(p≤0.05)** | **0.05** | **1.83** | **4.87** | **6.46** | **8.14** | **9.75** | **8.41** | **9.88** |
| **S0** | 0.95 | 5.31 | 39.91 | 101.98 | 111.97 | 116.73 | 118.02 | 119.18 |
| **S15** | 1.04 | 6.08 | 42.54 | 106.80 | 120.38 | 124.77 | 127.34 | 128.28 |
| **S30** | 1.09 | 7.13 | 50.89 | 111.88 | 126.39 | 134.37 | 138.70 | 140.55 |
| **S45** | 1.13 | 8.11 | 52.43 | 114.18 | 129.19 | 138.16 | 141.41 | 143.71 |
| **SE(m)±** | 0.02 | 0.63 | 1.68 | 2.23 | 2.70 | 3.36 | 2.80 | 3.30 |
| **CD(p≤0.05)** | **0.05** | **1.83** | **4.87** | **6.46** | **8.14** | **9.75** | **8.41** | **9.88** |

**Table 2: Tiller count (m-2) as influenced by different levels of nitrogen and sulphur**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Treatments** | **15 DAT** | **30 DAT** | **45 DAT** | **60 DAT** | **75 DAT** | **90 DAT** | **105 DAT** | **Harvest** |
| **N0** | 230.40 | 250.65 | 272.80 | 319.60 | 301.70 | 278.70 | 250.30 | 236.30 |
| **N60** | 243.70 | 266.60 | 290.30 | 346.20 | 330.50 | 312.80 | 285.20 | 272.70 |
| **N80** | 267.80 | 295.70 | 327.43 | 398.50 | 388.80 | 370.30 | 345.70 | 336.30 |
| **N120** | 280.30 | 308.50 | 342.50 | 416.80 | 409.40 | 389.60 | 358.50 | 350.10 |
| **SE(m)±** | 3.60 | 4.50 | 6.20 | 7.10 | 7.70 | 7.10 | 6.10 | 6.40 |
| **CD(p≤0.05)** | **10.40** | **13.80** | **18.90** | **21.80** | **22.50** | **20.30** | **17.60** | **19.30** |
| **S0** | 228.10 | 247.70 | 270.20 | 316.20 | 299.10 | 277.30 | 248.10 | 231.20 |
| **S15** | 240.20 | 264.80 | 286.20 | 341.20 | 327.40 | 311.20 | 282.60 | 268.40 |
| **S30** | 265.80 | 293.60 | 323.50 | 392.30 | 386.60 | 366.40 | 343.30 | 333.20 |
| **S45** | 272.80 | 300.20 | 336.20 | 409.10 | 401.20 | 379.90 | 351.90 | 341.10 |
| **SE(m)±** | 3.60 | 4.50 | 6.20 | 7.10 | 7.70 | 7.10 | 6.10 | 6.40 |
| **CD(p≤0.05)** | **10.40** | **13.80** | **18.90** | **21.80** | **22.50** | **20.30** | **17.60** | **19.30** |

**Table 3: N content and uptake parameters as influenced by graded levels of nitrogen and sulphur**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Treatments** | **N concentration in grain (%)** | **N concentration in straw (%)** | **N uptake in Grain (kg** **ha-1)** | **N uptake in Straw (kg** **ha-1)** |
| **N0** | 0.90 | 0.42 | 30.28 | 25.62 |
| **N60** | 0.94 | 0.45 | 52.06 | 34.46 |
| **N80** | 0.99 | 0.50 | 76.79 | 46.01 |
| **N120** | 1.07 | 0.52 | 84.37 | 55.88 |
| **SE(m)±** | **0.003** | **0.003** | **3.46** | **2.30** |
| **CD(p≤0.05)** | **0.009** | **0.008** | **10.05** | **6.67** |
| **S0** | 0.95 | 0.46 | 43.64 | 30.35 |
| **S15** | 0.96 | 0.47 | 55.22 | 38.65 |
| **S30** | 0.98 | 0.47 | 68.13 | 45.08 |
| **S45** | 1.00 | 0.49 | 76.51 | 47.90 |
| **SE(m)±** | 0.003 | 0.003 | 3.46 | 0.03 |
| **CD(p≤0.05)** | **0.009** | **0.008** | **10.05** | **6.67** |

**Table 4: S content and uptake parameters as influenced by graded levels of nitrogen and sulphur**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Treatments** | **Sulphur concentration in grain (%)** | **Sulphur concentration in straw (%)** | **Sulphur uptake in Grain (kg** **ha-1)** | **Sulphur uptake in Straw (kg** **ha-1)** |
| **N0** | 0.16 | 0.16 | 5.48 | 9.98 |
| **N60** | 0.17 | 0.19 | 10.15 | 14.80 |
| **N80** | 0.22 | 0.22 | 17.65 | 20.35 |
| **N120** | 0.24 | 0.23 | 19.16 | 24.99 |
| **SE(m)±** | 0.00 | 0.00 | 0.76 | 1.01 |
| **CD(p≤0.05)** | **0.01** | **0.01** | **2.20** | **2.92** |
| **S0** | 0.16 | 0.16 | 7.51 | 10.68 |
| **S15** | 0.17 | 0.19 | 10.38 | 16.02 |
| **S30** | 0.21 | 0.20 | 15.38 | 20.92 |
| **S45** | 0.24 | 0.23 | 19.18 | 22.49 |
| **SE(m)±** | 0.00 | 0.00 | 0.76 | 1.01 |
| **CD(p≤0.05)** | **0.01** | **0.01** | **2.20** | **2.92** |

**Table 5: Protein content of grain and Protein Productivity (g m-2) as influenced by different levels of nitrogen and sulphur**

|  |  |  |
| --- | --- | --- |
| **Treatments** | **Protein content** | **Protein productivity (g m-2)** |
| **N0** | 5.64 | 18.93 |
| **N60** | 5.89 | 32.54 |
| **N80** | 6.21 | 47.99 |
| **N120** | 6.71 | 52.73 |
| **SE(m)±** | 0.02 | 2.17 |
| **CD(p≤0.05)** | **0.06** | **6.28** |
| **S0** | 5.99 | 27.28 |
| **S15** | 6.01 | 34.52 |
| **S30** | 6.16 | 42.58 |
| **S45** | 6.28 | 47.83 |
| **SE(m)±** | 0.02 | 2.17 |
| **CD(p≤0.05)** | **0.06** | **6.28** |

**Table 6: Influence of nitrogen and sulphur fertilization on agronomic efficiency (kg of grain/kg of nutrient applied) of rice**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **S0** | **S15** | **S30** | **S45** |
| **N0** | 0 | 1.78 | 12.67 | 14.22 |
| **N60** | 6.11 | 16.67 | 38.44 | 43.37 |
| **N80** | 20.71 | 39.09 | 53.12 | 52.11 |
| **N120** | 29.00 | 37.93 | 34.64 | 32.16 |

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