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Studies of Foliar Nutrients on Yield Attributes and Yield of *Boro* Rice

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Abstract

An experiment was conducted to study the effect of different foliar nutrients on the growth and yield of *boro* rice variety "Satabdi (CR 146-7027-224)" at the Agricultural Experimental Farm, University of Calcutta, Baruipur, Kolkata during the consecutive *boro* seasons of 2021 and 2022. The eight foliar nutrient treatments were: water spray, potassium chloride (KCl) @ 0.75%, sodium chloride (NaCl) @ 0.75%, potassium dihydrogen phosphate (KH_2PO_4) @ 0.75%, sodium dihydrogen phosphate ($NaHPO_4$) @ 0.75%, potassium nitrate (KNO_3) @ 0.75%, potassium sulphate (K_2SO_4) @ 0.75%, NPK 10:26:26 @ 0.75% and NPK 19:19:19 @ 0.75%. These treatments were assigned in a randomized block design with 3 replications. Foliar nutrient treatments were applied twice at panicle initiation stage and grain development stage along with 100% recommended dose of fertilizer (RDF) and other recommended package of practices. From the salient features of the findings, it was found that supplementary foliar application of NPK 10:26:26 at 0.75% and NPK 19:19:19 at 0.75% were significantly ($P<0.05$) superior to the rest of the treatments in the number of effective tillers m^{-2}, grain filling percentage, 1000 grain weight, grain yield. Whereas the production economics were concerned the higher benefit: cost ratio (BCR) (1.66) was recorded with foliar spray of NPK 10:26:26 at 0.75% which was at par with NPK 19:19:19 at 0.75%. Only these two treatments were found cost effective compared to control plot (1.57) BCR.

***Key words*:** *Boro* rice, Economics, Foliar Nutrient, Yield

Rice is the main source of food for more than half the world's population and its cultivation secures a livelihood for more than two billion people. India is the second leading producer of rice in the entire world after China. Rice is one of the most important food crops and feeds more than 60% population of India. Rice produces up to 50% of the dietary caloric supply for millions of people living in poverty in Asia [1]. The rice productivity of 668 kg ha^{-1} in 1950-51 has increased to 2576 kg ha^{-1} during 2017-18 [2] but the productivity level is low compared to that of many countries in the world (6710 kg ha^{-1} in China, 5573 kg ha^{-1} in Vietnam, 5152 kg ha^{-1} in Indonesia, 4375 kg ha^{-1} in Bangladesh). The grave concern is that demand for rice in India is continuously increasing as par increasing population because India is an agriculture dependent country and more than two-third of its population depends on agriculture for their survival [3]. The introduction of high-yielding varieties, fertilizers, pesticides and irrigation has improved rice yields significantly and expanded the area under which rice is cultivated. However, in the last 20 years yields and the area under rice have stagnated. The two most significant reasons for this stagnation are the lack of adequate water for irrigation and the increased costs of cultivation. India will need to produce a lot more rice if it is to meet the growing demand, likely to be 130 million tonnes of milled rice in 2030 according to some estimates. Since there is not much scope to increase the area of rice cultivation (due to urbanization and severe water constraints), the additional production will have to come from less land, less water and less human labour. In India, West Bengal, Uttar Pradesh, Andhra Pradesh, Punjab, Odisha are the major rice producing states. Among them, Uttar Pradesh has highest area (5.81 million ha) under cultivation. West Bengal is leading in production *i.e.*, 14.97 million tonnes in 5.12 million hectares area followed by Uttar Pradesh has 13.27 million tonnes production in 5.81 million hectares area and Punjab has production of 13.38 million tons & area of 3.07 million hectares [4]. The state of West Bengal is the rice bowl of India. West Bengal shares only 2.7% land in India, producing more than 8% of country's food production and providing space for 7.6% of the country's population. Generally, in West Bengal rice is grown in 3 different seasons viz., *Aus* (autumn rice), *Aman* (winter rice) and *Boro* (summer rice); among them both *Aman* and *Boro* are the most important concerning acceptability by the farmers. During three different seasons maximum rice area is in *kharif* (*Aman*) season (4.24 m ha), whereas the productivity becomes more in *boro* season (4.67 t ha^{-1}). West Bengal is the largest rice producing state of India and contributing almost 14% of total rice production of India. Considering the fact that *boro* rice is easy to manage as compared to that in *kharif* season, a marginal increase in the productivity of *boro* rice in the state in particular and the eastern India as a whole can significantly increase the total rice production in the country. The *boro* rice is commonly known as summer rice is Bengali originated from the Sanskrit word *"Boro"* which refers to a cultivation from November-May under irrigated condition. Among the several yield limiting factor imbalance nutrient management and loss of nutrients are important. The critical stages of rice are emergence, tillering, panicle Initiation, booting, heading and maturation. These stages are more sensitive and crop should be saved from stress of nutrition. The lack of nutrients is one of the main causes of

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stagnation in crop productivity. In paddy fields, the applied fertilisers, after dissolution, are not only transported over and infiltrate the soil, but are also diffused out and channelled in all possible directions due to the transverse variation of water velocity and depth [5]. Inadequate supply of nutrients there are some yield losses in paddy field is observed. Lack of nutrients at certain growth development stage may affect in yield attributing characters. Loss of nitrogen due to leaching and volatilization, phosphorus due to fixation and potassium due to leaching & fixation may not be available adequately at reproductive stage of crop, resulting in low yield due to transient nutrient deficiency. Inactivation of the root's activity may be additional cause for this deficiency. To overcome this foliar application of nutrients can be a solution. This procedure improves nutrient utilization and lower environmental pollution through reducing the amount of fertilizers added to soil. Foliar fertilization is an effective way of quickly supplying plant nutrients during critical periods of flowering and seed development stages. There is a direct link between foliar feeding and the activities of the enzymatic systems of the plant. Foliar nutrition with nitrogen at later stage of crop growth delays the synthesis of abscisic acid and promotes cytokinin activity and causes high chlorophyll retention and thereby photosynthetic activity in effective leaves for supply of current photosynthates to the grains resulting in higher yield [6]. If the micronutrient deficiencies do occur during the growing season, the most effective method for overcoming these deficiencies is through foliar fertilizer applications [7]. Foliar nutrition may change the concentration of some metabolites in the root zone, can improve solubility of mineral elements in soil and ultimately stimulate nutrient absorbing power of root system [8-9]. The advantages of foliar fertilizers were more noticeable under growing conditions restricting the incorporation of nutrients from the soil [10]. Foliar nutrient application gives the advantage of quick and efficient utilization of nutrients, elimination of losses through leaching and fixation and regulation on the uptake of nutrient by plants [11]. Foliar application of nitrogen and potassium before flowering increased rough rice yield and biological yield, and that foliar application of nitrogen at the maximum tillering stage had the greatest effect on the number of tillers per hill and spikelets per panicle [12]. Foliar application of nitrogen is more appropriate than soil application because it allows for a rapid and efficient transportation of nitrogen to the grain [13]. Foliar fertilization method may also be a good substitute to the predictable soil application to avoid the loss of fertilizers by leaching and thereby minimizing the ground water pollution. Keeping all above facts in view the present experiment was undertaken to find out the performance and economics of different foliar spray on the yield of *boro* rice.

MATERIALS AND METHODS

The present investigation was carried out with rice cultivar "*Satabdi* (CR 146-7027-224)" during *boro* season of 2021 and 2022 at Agricultural Experimental Farm University of Calcutta, Baruipur, South 24-Parganas, West Bengal (88°26' E; 22°22' N; 9 m altitude). The soil of the experimental site was clay loam in texture having pH of 6.8, organic carbon 13.1 g kg^{-1}, available nitrogen 175.5 kg ha^{-1}, phosphorus 27.5 kg ha^{-1} and potassium 265.9 kg ha^{-1}. The land was prepared by giving two cross ploughings followed by one planking with optimum moisture condition to bring the experimental field into appropriate tilth. Healthy seeds were kept in water bucket for 24 hours and then it was kept tightly in gunny bags. The seeds started sprouting after 48 hours, then the germinated seeds were mixed with Carbendazim 2g kg^{-1} seeds. The fungicide mixed seeds were kept under a shade for 12 hours. The sprouted seeds were broadcasted at the rate of 55 kg ha^{-1} in nursery bed on 7th January and transplanted on 14th February in 2021 while in next season seeds were broadcasted on 14th January, 2022 and seedlings were transplanted on 22nd February, 2022 to the main field with 20 cm row to row and 15 cm plant to plant distances. Whereas, harvesting was done on 4th May 2021 in 1st season and 8th May 2022 in 2nd season. Farm Yard Manure (FYM) was incorporated into soils as per recommended dose fertilizer (RDF) in the nursery bed before sowing and before transplanting in case of RDF, full dose of P_2O_5 through SSP (Single Super Phosphate), one third of N (Nitrogen) through Urea, half of K_2O through MOP (Muriate of Potash) were applied as basal application (after final main field preparation). Remaining one third dose of N were top dressed at 21 and last one third dose of N and rest of the K_2O were applied at 45 DAT. The eight foliar nutrient treatments were: water spray, potassium chloride (KCl) @ 0.75%, sodium chloride (NaCl) @ 0.75%, potassium dihydrogen phosphate (KH_2PO_4) @ 0.75%, sodium dihydrogen phosphate ($NaHPO_4$) @ 0.75%, potassium nitrate (KNO_3) @ 0.75%, potassium sulphate (K_2SO_4) @ 0.75%, NPK 10:26:26 @ 0.75% and NPK 19:19:19 @ 0.75%; were assigned in a randomized block design with three replications. These foliar nutrient treatments were applied twice *viz*. panicle initiation stage and grain development stage with 100% RDF and other recommended package of practices like irrigation, weed management, pest and disease management. Nutrient solutions used as various treatments were applied at a spray volume of 750 lt ha^{-1}. Observations recorded on panicle length, number of tiller m^{-2}, grain filling percentage, 1000 grain weight, grain yield and economics at the time of harvest in both the years. Collected data from two years were subjected to pooled analysis [14]. The critical differences were calculated at 5% level of probability wherever F test was found significant for various parameters under study.

RESULTS AND DISCUSSION

The data on yield attributing characters recorded at harvest stage are presented in (Table 1). The supplementary foliar nutrient treatments significantly influenced number of tillers $plant^{-1}$. From the results (Table 1) it has been observed that significantly highest (560.58) number of effective tillers m^{-2} was found in foliar treatment NPK 10:26:26 at 0.75% which was closely followed by NPK 19:19:19 at 0.75%, potassium nitrate (KNO_3) at 0.75%, potassium dihydrogen phosphate (KH_2PO_4) at 0.75% and sodium dihydrogen phosphate (NaH_2PO_4) at 0.75%. The lowest (465.86) number of effective tillers $plant^{-1}$ was found in control plot (water spray). Higher result in those treatments might be due to adequate nutrient availability of three primary plant nutrients e.g., nitrogen, phosphorus and potassium at critical growth stages and thus enhanced photosynthetic efficiency followed by partitioning efficiency. The nitrogen has a vital role for rice faster crop growth, improves grain yield and quality by increasing tillers number and leaf area development [15]. Phosphorus performs as an element of protein compilers needed for the support of flowers, tillers, fruit and seeds. It accelerates flowering and ripening of grains [16]. Also, potassium is an essential nutrient required by the plant to perform important plant functions, needed for osmoregulation, enzyme activation, regulation of cellular pH, cellular cation-anion balance, regulation of transpiration by stomata, and the transport of the products of photosynthesis and thus improves tillering and shoots and root dry matter production [17]. So, N-P-K balanced nutrition by foliar spray might helped be the reason of significant results. Using foliar application of nutrients during different growth stages of rice plants significantly increases the number of panicles m^{-2} in 2 crop years [18]. There are no significant differences observed in panicle length among the treatments through supplementary foliar nutrient application. However, the maximum (23.57 cm) panicle length was found in foliar treatment NPK 10:26:26 at 0.75%.

Table 1 Effect of foliar nutrients on yield attributes and yields of rice (pooled data of 2021 and 2022)

Treatments	Number of effective tillers m^{-2}	Panicle length (cm)	Grain filling percentage (%)	1000 grain weight (g)	Grain yield (t ha^{-1})	Benefit : Cost ratio (BCR)
T_1: Water spray (Control)	465.86	22.42	67.68	18.22	5.41	1.57
T_2: Potassium chloride (KCl) @ 0.75%	470.40	23.48	74.41	18.26	5.56	1.27
T_3: Sodium chloride (NaCl) @ 0.75%	528.98	23.18	75.02	17.77	5.69	1.45
T_4: Potassium dihydrogen phosphate (KH_2PO_4) @ 0.75%	549.12	23.40	77.75	18.46	5.78	1.53
T_5: Sodium dihydrogen phosphate (NaH_2PO_4) @ 0.75%	542.78	23.30	75.68	17.68	5.74	1.52
T_6: Potassium nitrate (KNO_3) @ 0.75%	555.25	23.42	77.46	18.51	5.82	1.42
T_7: Potassium sulphate (K_2SO_4) @ 0.75%	536.91	23.13	76.08	18.07	5.75	1.23
T_8: NPK 10:26:26 @ 0.75%	560.58	23.57	78.37	18.60	5.91	1.66
T_9: NPK 19:19:19 @ 0.75%	557.83	23.47	77.89	18.31	5.82	1.66
SEm± (0.05)	7.10	0.42	0.85	0.09	0.05	-
CD at 5%	20.50	NS	2.46	0.26	0.14	-

As revealed from data (Table 1) it was observed that significantly highest (78.37%) grain filling percentage was recorded in foliar nutrient treatment NPK 10:26:26 at 0.75% which was at par with NPK 19:19:19 at 0.75%, potassium dihydrogen phosphate (KH_2PO_4) at 0.75%, potassium nitrate (KNO_3) at 0.75% and potassium sulphate (K_2SO_4) at 0.75%. From the different foliar nutrient treatment, it was observed that significantly maximum (18.60 g) 1000 grain weight was recorded in foliar nutrient treatment NPK 10:26:26 at 0.75% followed by potassium nitrate (KNO_3) at 0.75% and potassium dihydrogen phosphate (KH_2PO_4) at 0.75%. The reason behind maximum results in these treatments might be due to increasing levels of three primary nutrients (N, P and K) through foliar application met nutrient requirement of the crop during flowering and seed development periods resulting in greater availability, absorption of nutrient and efficient translocation of assimilates to reproductive parts which eventually contributed to the high yield attributes. Also increased yield attributes might be due to enhanced partitioning efficiency and correction of transient nutrient deficiency during flowering and seed filling stages when nutrient demand is at peak but supply from root may not be sufficient to meet the demand. Foliar application of nutrients during three stages (tillering + the first node + reproductive phase) resulted in the highest numbers of panicles m^{-2}, grain numbers panicle^{-1}, 1000-seed weight, and biological yield [19]. Foliar application of potassium dihydrogen phosphate also gave a significant result this may be due to its better utilization of phosphorus and potassium ions [20] especially potassium which regulates other nutrients uptake from soil.

The supplementary foliar nutrient treatments significantly influenced the yield of *boro* rice. It was observed that highest grain yield (5.91 t ha^{-1}) was found in treatment NPK 10:26:26 @ 0.75% which was at par with NPK 19:19:19 @ 0.75%, potassium nitrate (KNO_3) @ 0.75% and potassium dihydrogen phosphate (KH_2PO_4) @ 0.75%. Lowest (5.41 t ha^{-1}) grain yield was recorded in control plot. Those results may be attributed to the fact of supplementary foliar nutrition with recommended fertilizer dose, resulted balanced availability of nutrients and their uptake resulting better sink capacity which ultimately increased the grain yield [21-22]. Foliar feeding with KNO_3 (@1.5 and 2%) found to trigger yields in rice crop over soil applied K_2SO_4, this improvement was because of positive impacts on the tiller count, length of the panicles, 1000 grains weight and also count of the grains panicle^{-1} [23]. Researchers also found that NPK 10:26:26 @1.5% or NPK 19:19:19 @ 0.5% the foliar nutrients spray during 50 % flowering and seed development stages were capable of producing higher seed yield in sunflower crop [24]. The higher benefit: cost ratio (BCR) (1.66) was recorded with foliar spray of NPK 10:26:26 @ 0.75% which was similar with NPK 19:19:19 @ 0.75%. Only these two treatments, were found cost effective compared to control plot (1.57) BCR. Though supplementary foliar application of potassium nitrate (KNO_3) at 0.75% and potassium dihydrogen phosphate (KH_2PO_4) at 0.75% resulted significant grain yield but these treatments were failed to attain economically beneficial than control plot that is only recommended dose of fertilizer with package of practices.

CONCLUSION

On the basis of results of two years experiments it can be concluded that the NPK balanced foliar nutrient treatments significantly improved number of effective tillers m^{-2}, grain filling percentage, 1000 grain weight and grain yield. The increased yield attributes enhanced partitioning efficiency and correction of transient nutrient deficiency during panicle initiation and grain filling stages when nutrient demand was at its peak but supply from root may not be sufficient to meet the demand. Thus, the experimental finding suggests that NPK 10:26:26 @ 0.75% or NPK 19:19:19 @ 0.75% supplementary foliar nutrients spray with recommended dose of fertilizer during panicle initiation and grain filling stages were capable of producing higher grain yield of *boro* rice.

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