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Yield maximization through different sources of nutrients in summer rice

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Abstract

A field experiment was conducted during dry (*boro*) season of 2015-16 and 2016-17 at Rice Research Station, Chinsurah, Hooghly, West Bengal to evaluate the performance of improved nutrient sources in maximizing the productivity of summer rice. The results revealed that maximum grain yield (5.66 t/ha) was achieved through application of recommended dose of fertilizer (RDF) at 130-65-65 kg N-P_2O_5-K_2O/ha in combination with Tabsil at 5.0 kg/ha in two equal splits at 25 and 50 days after transplanting (DAT), on par with RDF in combination with Vigore as basal application (625 g/ha) and also as foliar spray (1.25 g/L) at panicle initiation (5.47 t/ha). Different combinations of RDF with improved sources of nutrient supplements (Vigore and Tabsil) exhibited economic yield advantages to the extent of 2.93-10.55, 3.94-11.64 and 54.09-65.50% over RDF, farmers' fertilizer practice and absolute control, respectively. Supply of nutrients in required quantities through the combinations of these nutrient sources facilitated balanced crop nutrition as well as improved nutrient use efficiency resulting in maximum grain yields due to higher values of growth and yield attributes in summer rice.

Key words: Nano fertilizer, Nutrient use efficiency, Productivity, Summer rice, Tabsil, Vigore, Yield advantage.

Introduction

Rice is an important staple food of more than half of the global population. Although India is the second largest producer of rice after China and contributes about one-fifth of global rice production, rice productivity is still constrained by several factors including climate change, acute water and labour shortage at the time of critical farm operations, escalating input costs, minimal or nominal profit margin *etc*. Besides all these, yield stagnation due to soil health problem coupled with inappropriate supply of nutrients or crop growth supplements is one of the major constraints to sustain rice production in the country. Although conjunctive use of organic and inorganic sources of nutrients is essential to sustain soil health as well as crop productivity, the availability of organic manures is becoming scarce as a result of urbanization and reduction in animal wealth (Subramanian and Tarafdar, 2011). Improved sources of nutrients *viz*. Vigore and Tabsil may be explored for improving crop health and maximizing rice productivity (ICAR-IIRR, 2018; Bhowmick *et al*., 2019a and 2019b). Vigore is a nano-technological product developed from naturally occurring substances in plants, minerals or other materials by using infinite decimal doses and with the process of denomination and potentiating which increases the product effectiveness and helps in removing toxicity (Kumari *et al*., 2016; Ramachandra and Sowmyalatha, 2020). Tabsil is a silica effervescent tablet fertilizer with 100% water soluble silicon nutrient that can be used as foliar spray and/or soil application for improving crop health and minimizing infestation of insect pests and diseases (ICAR-IIRR, 2018). To address the sustainability of rice-based cropping systems, precision farming has been a long-desired goal toward maximizing crop yields while minimizing the use of chemical inputs through monitoring environmental variables and applying targeted actions (Manjunatha *et al.*, 2016). Keeping these perspectives in view, the present study was undertaken to evaluate the performance of different improved nutrient supplements in enhancing the grain yield of summer rice and to compare yield performance of field-specific fertilizer materials with the existing blanket recommendation for rice crop nutrition.

Materials and Methods

Experimental site and season

A field experiment was conducted during dry (*boro*) season of 2015-16 and 2016-17 at the Rice Research Station, Chinsurah, Hooghly, West Bengal, located at $22^0 52'$ N latitude and $88^0 24'$ E longitude with an altitude of 8.62 m above mean sea level. The experimental soil was clay loam having pH 6.90, EC 0.5 dS/m, organic carbon 1.18%, available N 357 kg/ha, available P_2O_5 132 kg/ha and available K_2O 410 kg/ha.

Experimental design and treatment details

The experiment comprising of eight levels of nutrient management practices was laid out in a randomized complete block design with three replications. The treatments included recommended dose of fertilizer (RDF, 130-65-65 kg N-P_2O_5-K_2O/ha) alone, and in combination with Vigore (625 g/ha only as basal), Vigore (625 g/ha as basal + 1.25 g/L as foliar spray at panicle initiation), Tabsil (2.5 kg/ha) at 25 days after transplanting (DAT), Tabsil (5.0 kg/ha at 50 DAT) and Tabsil (2.5 kg/ha, each at 25 and 50 DAT), besides farmers' fertilizer practice (FFP, 120-60-60 kg N-P_2O_5-K_2O/ha) and control (no fertilizer). In the treated plots (5 m × 4 m in size), full doses of P_2O_5 and K_2O along with one-fourth of total N were applied as basal at the time of transplanting whereas the remaining half and one-fourth of total N were applied at active tillering (AT) and panicle initiation (PI) stages, respectively.

Crop establishment

Rice variety '*Triguna*' (IET 12875) was sown in third week of January and last week of December in 2016 and transplanted at the seedling age of 29-34 days in third and first week of February during 2015-16 and 2016-17, respectively (Table 1). Young seedlings at 2-3 leaf stage were carefully transplanted at a spacing of 20 cm × 15 cm. The crop was raised with other recommended package of practices (Bhowmick *et al*., 2012 and 2013) and harvested in last and third week of May during 2015-16 and 2016-17, respectively (**Table 1**).

Table 1 Calendar of major field operations in summer rice during dry season of 2015-16 and 2016-17

Date	2015-16	2016-17
Sowing	January 20, 2016	December 30, 2016
Transplanting	February 18, 2016	February 02, 2017
Harvesting	May 30, 2016	May 19, 2017

Data collection and statistical analyses

Twelve hills were randomly sampled from each plot for determining growth attributes *viz.* plant height and tiller number/m^2 at 30 DAT, 60 DAT and harvest, and yield attributes (panicle number and weight) at harvest. Plant samples collected at harvest were oven dried at 70º C ± 1º C till a constant weight was achieved. Number of panicles/hill under each treatment was recorded from twelve hills by visual counting and their average was multiplied by the number of hills/m^2. Panicle weight **(g)** was also determined from the same twelve hills used for other parameters. Grains were harvested, dried and weighed, and grain weight was adjusted to a moisture content of 0.14 g H_2O/g fresh weight. Grain and straw yields were recorded for each plot separately at harvest and converted into t/ha. Collected data were subjected to statistical analyses as per the procedures outlined by Gomez and Gomez (1984).

Results and Discussion

Effect of treatments on crop growth

Year-wise as well as pooled data on plant height at 30 DAT revealed that the plants grown under RDF + Vigore (either as basal application only or as basal and foliar application both) and RDF + Tabsil (25 DAT) were significantly superior to those established with only RDF or FFP as well as control plots (**Table 2**). With the advancement of crop growth at 60 DAT, application of RDF in combination with Tabsil (25 and 50 DAT) exhibited maximum plant height although it remained at par with RDF in conjunction with either Vigore (either basal only or basal and foliar both) or Tabsil (25 or 50 DAT) as revealed from second year data and pooled data. Application of RDF in combination with Vigore or Tabsil superseded the other treatments in respect of plant height at harvest, when the plants grown under RDF + Tabsil (25 and 50 DAT) recorded maximum plant height, followed by RDF + Vigore (basal and foliar both) and RDF + Vigore (basal only) according to the results of two years and their pooled data. Being a nano-technology product, Vigore possibly helped in boosting absorption and transportation of micro and macro nutrients, thereby maintaining hormonal balance in plants (ICAR-IIRR, 2018) and registering more plant height. As reported, Vigore also might provide the entire natural mineral required for the fast development of roots that could grow deeper and wider into the soil (ICAR-IIRR, 2018). Subramanian and Tarafdar (2011) and Rai and Rawat (2014) suggested using nano-fertilizers as a strategy to regulate the smart release of nutrients that commensurate with crop requirement, thereby increasing nutrient use efficiencies and preventing environmental hazards. .

Table 2 Effect of treatments on plant height of summer rice during dry season of 2015-16 and 2016-17

Treatment	Plant height (cm)								
	30 DAT			60 DAT			Harvest		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
RDF	40.66	44.60	42.63	65.90	71.50	68.70	92.62	97.00	95.31
RDF + Vigore (basal)	45.30	52.10	48.70	70.37	74.55	72.46	96.06	100.00	98.03
RDF + Vigore (basal + foliar)	45.50	51.30	48.40	72.00	75.11	73.56	96.40	100.20	98.30
RDF + Tabsil (25 DAT)	41.68	49.60	45.64	69.70	72.70	71.20	94.60	97.24	95.92
RDF + Tabsil (50 DAT)	40.41	45.40	42.91	68.82	73.90	71.36	94.45	97.75	96.10
RDF + Tabsil (25+50 DAT)	41.62	51.00	46.31	74.65	76.50	75.58	96.80	100.54	98.67
FFP	39.00	42.90	40.95	64.70	67.94	66.32	92.10	93.43	92.77
Control	33.08	40.20	36.64	61.74	64.60	63.17	87.00	89.40	88.20
LSD (P=0.05)	4.36	4.88	5.25	5.70	6.13	5.68	3.86	5.30	4.10
C.V. (%)	7.49	6.34	6.90	8.61	9.87	9.35	8.29	8.15	7.46

DAT: Days after transplanting; FFP: Farmers' fertilizer practice; RDF: Recommended dose of fertilizer.

Application of RDF along with either Vigore (as basal only or basal and foliar both) or Tabsil (25 or 25 +50 DAT) initially recorded more number of tillers/m^2 at 30 DAT than those with other treatments in both the years (**Table 3**). Significantly more number of tillers/m^2 was recorded under RDF + Tabsil (25+50 DAT) and RDF + Vigore (basal + foliar) as reflected from year-wise data and their pooled values at 60 DAT and harvest (Table 3). Kumar *et al*. (2019) also reported higher values of growth attributes with the application of 100% RDF through inorganic fertilizers + Vigore at 625g/ha in wet season. With the content of a wide range of natural minerals, enzymes, vitamins, nutrients and antioxidant in nano form, Vigore helped to supplement the nutrients required for complete growth and healthy development of rice plants (Kumari *et al*., 2016), besides activating enzymatic activities inside the plants (Manjunatha *et al.* 2016). As reported, Tabsil might help in developing healthy growth of stems and leaves through enhanced uptake of potassium and phosphorus, and thereby reducing the chances of lodging (ICAR-IIRR, 2018). Application of silicate effervescent tablet was reported to activate the enzymatic activity within the plants, and thereby promoting more number of tillers/m^2 (ICAR-IIRR, 2018). Savant *et al*. (1997) detailed the definitive need of silicon (Si) management for sustainable rice production. Compared with data at 30 and 60 DAT, tiller number/m^2 was, however, found to decrease at harvest, irrespective of treatments. Poor tillering was recorded in control plots, which might be due to an impaired transpiration in Si-deficient rice plants as earlier reported by Bergmann (1992).

Table 3 Effect of treatments on tillering profile of summer rice during dry season of 2015-16 and 2016-17

Treatment	Number of tillers/m^2								
	30 DAT			60 DAT			Harvest		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
RDF	242	252	247	412	434	423	391	429	410
RDF + Vigore (basal)	255	274	265	427	457	442	418	438	428
RDF + Vigore (basal + foliar)	256	271	264	429	470	450	425	445	435
RDF + Tabsil (25 DAT)	249	262	256	415	449	432	413	426	420
RDF + Tabsil (50 DAT)	238	256	247	414	451	433	408	433	421
RDF + Tabsil (25+50 DAT)	246	265	256	435	479	457	429	451	440
FFP	236	250	243	409	430	420	387	403	395
Control	216	226	221	369	381	375	340	362	351
LSD (P=0.05)	10.26	10.79	12.30	11.75	10.98	12.61	13.38	11.83	12.77
C.V. (%)	13.18	12.31	13.50	12.90	12.70	12.36	12.35	14.60	12.81

DAT: Days after transplanting; FFP: Farmers' fertilizer practice; RDF: Recommended dose of fertilizer.

Applied at low dosage, Tabsil with the highest percentage (12%) of orthosilicic acid (H_4SiO_4) could increase the P utilization capacity and help in minimizing water loss as well as transpiration since it could easily penetrate the leaves and form a thick silicate layer on the leaf surface, thereby preventing lodging, pest and disease infestation, and enhancing crop growth and yield. Being not very mobile within rice plant, a continued supply of Si would be required during practically all growth stages for healthy and productive development of the plant. Since the active Si absorption by rice was expected to start after tillering or stem elongation stage (Savant *et al*., 1997), the most crucial time of Si application through Tabsil for yield maximization might be during reproductive stage although continued supply of Si element since beginning of crop establishment would be more advantageous. Hence, Tabsil application at 25 and 50 DAT was found to be more effective than that applied only at 25 or 50 DAT in addition to the RDF. Because of high Si requirement, rice crop responded well to Tabsil application. Ma *et al.* (1989) reported the most remarkable effect of Si supply on the growth and development of rice crop plants at their reproductive stage.

Effect of treatments on yield attributes

Application of RDF + Tabsil (25+50 DAT) significantly registered more number of panicles/m^2 with more panicle weight, on par with RDF plus Vigore or Tabsil during both the years (**Table 4)**. Ramachandra and Sowmyalatha (2020) also reported better results with the application of RDF along with Tabsil 100% Silicate Tabs (2.5 kg/ha at 25 DAT and another 2.5 kg/ha at 50 DAT). Higher values of yield attributes under these treatments were ascribed to improved crop growth owing to better nutrient utilization and abalanced nutrition. Savant *et al*. (1997) reported more (several-fold greater) absorption of Si by rice plants from soil than those of macronutrients (N, P, K, S, Ca and Mg). Even Si was reported to interact with other native or applied nutrients, thereby inducing resistance or tolerance in rice plants to different biotic and abiotic stresses including lodging (Savant *et al*., 1997). Control and FFP plots remained inferior to these treatment combinations in terms of major yield attributes. Pooled data also reflected significantly the highest panicle number and panicle weight with RDF + Tabsil at 25 and 50 DAT (350/m^2 and 3.39 g), followed by RDF + Vigore as basal and foliar (338/m^2 and 3.26 g) and RDF + Vigore as basal (334/m^2

Table 4 Effect of treatments on major yield attributes of summer rice during dry season of 2015-16 and 2016-17

Treatment	Panicles/m^2			Panicle weight (g)		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
RDF	309	319	314	3.18	3.08	3.13
RDF + Vigore (basal)	333	334	334	3.24	3.24	3.24
RDF + Vigore (basal + foliar)	340	336	338	3.26	3.25	3.26
RDF + Tabsil (25 DAT)	329	326	328	3.23	3.20	3.22
RDF + Tabsil (50 DAT)	325	332	329	3.20	3.21	3.21
RDF + Tabsil (25+50 DAT)	348	352	350	3.40	3.37	3.39
FFP	299	303	301	3.15	3.20	3.18
Control	230	236	233	2.96	2.98	2.97
LSD (P=0.05)	40.40	44.43	39.25	0.21	0.24	0.23
C.V. (%)	7.34	8.00	7.60	6.25	4.27	6.12

DAT: Days after transplanting; FFP: Farmers' fertilizer practice; RDF: Recommended dose of fertilizer.

and 3.24 g) and RDF + Tabsil at 25 or 50 DAT (328-329/m^2 and 3.21-3.22 g), compared to RDF (314/m^2 and 3.13 g), FFP (301/m^2 and 3.18 g) and control (233/m^2 and 2.97 g), respectively. More number of effective tillers/m^2 in RDF + Tabsil was obviously due to Si fertilization through Tabsil, compared with RDF alone, conforming to the report of Liang *et al.* (1994) Even Si imposed a synergistic effect through positive interaction with applied N, P and K fertilizers (Savant *et al*., 1997).

Effect of treatments on crop productivity

Application of RDF in combination with Tabsil (2.5 kg/ha, each at 25 and 50 DAT) maximized the productivity of both grain and straw (5.66 and 7.02 t/ha), and was found equally effective as RDF (**Table 5**) in combination with Vigore as basal application + foliar spray (5.47 and 6.80 t/ha) or as basal application only (5.37 and 6.69 t/ha). Similar trend was observed in both the years of study. As with the combinations of different nutrient sources, economic yield advantages were to the extent of 2.93-10.55, 3.94-11.64 and 54.09-65.50% over RDF, FFP and absolute control, respectively. Supply of nutrients in required quantities through the combinations of nutrient sources facilitated balanced nutrition of rice crop, which resulted in enhanced grain yields due to higher values of yield attributes. Use of nanofertilizer was reported to increase nutrient use efficiency by three times, reduce soil toxicity, impart stress tolerance to crop plants, improve soil aggregation and minimize the potential negative effect associated with injudicious use of chemical inputs (Manjunatha *et al*., 2016). Being a superior organic yield enhancer, Vigore possibly helped in boosting absorption and transportation of micro and macro nutrients, besides maintaining hormonal balance in plants (Bhowmick *et al*., 2019a). Mukhopadhyay (2014) reported substantial improvement in input use efficiency by applying nanomaterials which did not remain confined as a point source application, but spread throughout the field. Being eco-friendly and non-toxic for human, animal, soil and plant, Vigore might be advocated as an important nutrient supplement in addition to RDF (Kumari *et al*., 2016).

Table 5 Effect of treatments on crop productivity of summer rice during dry season of 2015-16 and 2016-17

Treatment	Grain yield (t/ha)			Straw yield (t/ha)		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
RDF	4.99	5.25	5.12	6.29	6.67	6.48
RDF + Vigore (basal)	5.33	5.41	5.37	6.72	6.66	6.69
RDF + Vigore (basal + foliar)	5.43	5.50	5.47	6.84	6.76	6.80
RDF + Tabsil (25 DAT)	5.28	5.31	5.30	6.65	6.58	6.62
RDF + Tabsil (50 DAT)	5.21	5.33	5.27	6.56	6.61	6.59
RDF + Tabsil (25+50 DAT)	5.69	5.63	5.66	7.17	6.87	7.02
FFP	4.84	5.30	5.07	6.10	6.62	6.36
Control	3.53	3.31	3.42	4.44	4.17	4.31
LSD (P=0.05)	0.39	0.28	0.31	0.51	0.44	0.43
C.V. (%)	9.69	8.31	10.50	11.42	8.11	10.63

DAT: Days after transplanting; FFP: Farmers' fertilizer practice; RDF: Recommended dose of fertilizer.

Kumar *et al*. (2015) reported an improvement in growth and yield attributes along with higher grain yields under 100% RDF + Vigore, which enhanced grain filling percentage by increasing leaf nutrient concentration and photosynthetic rate of flag leaves, and by delaying leaf senescence due to continuous supply of nutrients in sufficient quantity throughout crop growth stages. In anticipation of crop lodging on account of uncertain cyclonic storm at harvesting time, Si application would be an effective strategy for enabling rice plants to acquire necessary mechanical strength against lodging. Comparatively lower levels of grain and straw yields in the FFP plots might be attributed to abysmal utilization of fertilizer nutrients in absence of improved nutrient sources.

Conclusions

The present study clearly showed that use of nano-technological products or improved sources of nutrient supplements in judicious combination with the RDF would be an effective recommendation for enhancing nutrient use efficiency as well as maximizing summer rice productivity.

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