



RESEARCH ARTICLE

Promotional Effect of Water Soluble Fertilizers on Growth and Yield of Lowland Rice

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ABSTRACT

The present study aimed to study the effect of foliar nutrition of water-soluble fertilizers for enhancing yield and quality of rice during Kharif-2019 in clay loam soils of wetland farms, TNAU, Coimbatore. The experiment consisted of eleven treatments that include- 100% RDF combined with foliar feeding of commercially available 19:19:19 @ 1% and 2%, TNAU WSF 19:19:19 @ 1% and 2%, TNAU Liquid Multi Micronutrient @ 1% either alone or in combination depending upon the treatments and absolute control. The experiment was laid out in a randomized block design (RBD) with eleven treatments replicated thrice using CO-51 rice as a test crop. The results revealed that foliar feeding of rice crop with different water-soluble fertilizers had a marked promotional effect on growth and yield of rice. Among the water-soluble fertilizers evaluated, foliar spray of TNAU water-soluble fertilizers 19:19:19 @ 2% + TNAU Liquid Multi Micronutrient @ 1% (T₁₀) concentration at active tillering, panicle initiation, 50% flowering and harvest stage along with a recommended dose of fertilizers recorded the maximum growth (plant height (45.8, 81.2, 93.5 and 105.6 cm), chlorophyll as SPAD value (45.7, 46.8, 48.6 and 44.5) and LAI (3.01, 8.10, 6.72 and 3.92)) and yield attributes (number of panicles m⁻² (352), number of grains panicle⁻¹ (198) and number of filled grains panicle⁻¹ (180) and the maximum grain and straw yield of 6233 kg ha⁻¹ and 7730 kg ha⁻¹ respectively. The promotional effect was to the tune of 113.5 percent in grain and 79.8 percent in straw yield over control. Concerning normal practice, it was a 19.7 percent increase in grain yield, and a 5.2 percent increase in straw yield was observed.

Keywords: Water soluble fertilizers; foliar fertilization; growth; yield; rice

INTRODUCTION

Cereals are the most important sources of food and nutrients in both developed and developing countries. Rice (*Oryza sativa* L.), a member of the family Poaceae, is the most important cereal crop and the staple food of over half the world's population and is central to the lives of billions of people around the world. India is the world's second-largest producer of Rice (Ladha *et al.*, 2016). Rice has the total harvested area of approximately 158 million hectares and production of more than 700 million tonnes annually (470 million tonnes of milled rice) (Ricepedia and Irri, 2018). In recent days, there is a slowdown in the rice area and yield. To meet out the demand, it is inevitable to take necessary steps to improve rice yield. Nutrient management is the most basic factor and is found to exert a great influence not only on growth and yield attributes but also for

obtaining sustained productivity (Mudalagiriappa *et al.*, 2016). Foliar feeding of nutrients along with soil application helps in augmenting the nutritional requirements of crops. Foliar nutrition facilitates to overcome problems like immobilization, fixation, and leaching of nutrients and provides efficient nutrition for correcting deficiencies, especially for short duration crops. For foliar feeding and fertilization, recently, new generation specialty fertilizers have been introduced. Water-soluble fertilizers supply crops with optimal rates of nutrients throughout the growth cycle in the most efficient manner and without degrading soil and water resources and they have high content of primary nutrients with low salt index and high solubility. The objective of the present study was to find out the effect of foliar nutrition of water soluble fertilizers on rice yield and subsequently to standardize the concentration of foliar spray of water soluble fertilizers.

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MATERIAL AND METHODS

The field experiment was conducted during Kharif 2019 at wetland farms, TNAU, Coimbatore (11° North Latitude, and 77° East Longitude). The experimental soil belonged to the Noyyal series (*Typic haplustalf*) and was clay loam in texture (Piper, 1966), moderately alkaline in reaction (pH 8.2) (Jackson, 1973) and non - saline (EC 0.50 dS m⁻¹) (Jackson, 1973). The initial soil fertility status showed low available KMnO₄-N (252 kg ha⁻¹) (Asija and Subbiah, 1956), medium available Olsen-P (22 kg ha⁻¹) (Olsen, 1954) and high available NH₄OAc-K (600 kg ha⁻¹) (Stanford *et al.*, 1949) status. The experiment was conducted with the following eleven treatments viz., T₁ (100% RDF +1% Urea + 2% MAP + 1% KCl FS) T₂ (100% RDF + 19:19:19 @ 1% FS (Commercially available)), T₃ (100% RDF + 19:19:19 @ 2% FS (Commercially available)), T₄ (100% RDF + TNAU WSF 19:19:19 @ 1% FS) T₅ (100% RDF + TNAU WSF 19:19:19 @ 2% FS) T₆ (100% RDF + TNAU Liquid multi micronutrient @ 1% FS) T₇ (100% RDF + 19:19:19 @ 1% (Commercially available) + TNAU Liquid multi micronutrient @ 1% FS) T₈ (100% RDF + 19:19:19 @ 2% (Commercially available) + TNAU Liquid multi micronutrient @ 1% FS) T₉ (100% RDF + TNAU WSF 19:19:19 @ 1% + TNAU Liquid multi micronutrient @ 1% FS) T₁₀ (100% RDF + TNAU WSF 19:19:19 @ 2% + TNAU Liquid multi micronutrient @ 1% FS) T₁₁ (Absolute control (WS)). Irrespective of treatments, common dosage of fertilizer based on STCR recommendation for the

yield target of 8 t ha⁻¹ was applied to all the plots except absolute control (T₁₁). Foliar feeding was given at active tillering, panicle initiation, 50% flowering and grain filling stages. The experiment was laid out in randomized block design (RBD) with eleven treatments replicated thrice using CO-51 rice as a test crop. The biometric observation for its growth parameters like plant height, number of tillers m⁻², leaf area index (Palaniswamy and Gomez, 1974), and chlorophyll index (using SPAD meter) were recorded at consecutive stages. The yield attributes like the number of productive tillers m⁻², number of filled grains panicle⁻¹, % chaffy grains, panicle length, and 1000-grain weight were recorded from the randomly labeled five plants of each plot. At the maturity stage, the net plots were harvested, and hand threshing was done manually. Then the grains were cleaned, and sun-dried. Plot-wise straw and grain yields were recorded after drying to constant weight.

RESULTS AND DISCUSSION

Rice Growth

A perusal of data depicted in Tables 1 and 2 divulged the significant influence of foliar spray of various fertilizers on plant height, chlorophyll as SPAD value, LAI, and the number of tillers hill⁻¹ of rice over water spray (control). The plant height, chlorophyll as SPAD value, LAI increased with crop growth and declined at grain filling except for plant height, irrespective of treatments.

Table 1. Growth attributes of rice as influenced by the foliar application of water-soluble fertilizers

Treatments	Plant height (cm)				Total chlorophyll (SPAD Reading)			
	Active tillering	Panicle initiation	50% Flowering	Grain filling	Active tillering	Panicle initiation	50% Flowering	Grain Filling
T ₁	38.2	73.5	83.4	96.5	38.6	40.9	40.8	38.6
T ₂	40.5	75.6	87.1	97.6	40.1	42.5	42.7	39.0
T ₃	42.3	78.5	88.8	100.9	43.3	44.1	44.1	40.2
T ₄	41.0	76.5	87.6	98.2	41.5	43.1	43.2	39.5
T ₅	43.0	78.9	89.2	101.8	43.9	44.8	45.1	40.9
T ₆	44.0	79.0	90.0	102.5	44.2	45.1	45.5	41.5
T ₇	44.5	79.6	91.5	103.5	44.9	45.6	46.5	42.5
T ₈	45.2	80.9	92.8	104.5	45.6	46.7	47.5	44.2
T ₉	44.7	79.8	92.0	103.9	45.2	45.9	46.8	43.1
T ₁₀	45.8	81.2	93.5	105.6	45.7	46.8	48.6	44.5
T ₁₁	35.0	71.0	81.0	92.5	35.5	37.6	35.7	33.3
SE _d	0.9	1.8	1.9	2.2	1.0	0.9	0.9	0.9
CD (p<0.05)	1.9	3.8	3.9	4.7	2.1	1.9	2.0	1.9

T₁ 100% RDF +1% Urea + 2% MAP + 1% KCl FS, T₂ 100% RDF + 19:19:19 @ 1% FS (Commercially available), T₃ 100% RDF + 19:19:19 @ 2% FS (Commercially available), T₄ 100% RDF + TNAU WSF 19:19:19 @ 1% FS, T₅ 100% RDF + TNAU WSF 19:19:19 @ 2% FS, T₆ 100% RDF + TNAU Liquid multi micronutrient @ 1% FS, T₇ 100% RDF + 19:19:19 @ 1% (Commercially available) + TNAU Liquid multi micronutrient @ 1% FS, T₈ 100% RDF + 19:19:19 @ 2% (Commercially available) + TNAU Liquid multi micronutrient @ 1% FS, T₉ 100% RDF + TNAU WSF 19:19:19 @ 1% + TNAU Liquid multi micronutrient @ 1% FS, T₁₀ 100% RDF + TNAU WSF 19:19:19 @ 2% + TNAU Liquid multi micronutrient @ 1% FS, T₁₁ Absolute control (WS)

Among the treatments tried, at all stages, foliar feeding of 100% RDF + foliar nutrition of TNAU WSF 19:19:19 @ 2% + TNAU Liquid Multi

Micronutrient (TNAU-LMM) @ 1% (T₁₀) registered the tallest plant 45.8, 81.2, 93.5 and 105.6 cm at active tillering, panicle initiation 50% Flowering

and grain filling respectively. It was comparable with T₈ (100% RDF + commercially available 19:19:19 @ 2% + TNAU Liquid Multi Micronutrient @ 1%), T₉ (100% RDF + TNAU WSF 19:19:19 @ 1% + TNAU Liquid Multi Micronutrient @ 1%), T₇ (100% RDF + commercially available 19:19:19 @ 1% + TNAU Liquid Multi Micronutrient @ 1%) and T₆ (100% RDF + TNAU Liquid multi micronutrient @ 1%) at active tillering and 50%flowering stage and T₈ (100% RDF + commercially available 19:19:19 @ 2% + TNAU

Liquid Multi Micronutrient @ 1%), T₉ (100% RDF + TNAU WSF 19:19:19 @ 1% + TNAU Liquid Multi Micronutrient @ 1%), T₇ (100% RDF + commercially available 19:19:19 @ 1% + TNAU Liquid Multi Micronutrient @ 1%), T₆ (100% RDF + TNAU Liquid multi micronutrient @ 1%) T₅ (100% RDF + TNAU WSF 19:19:19 @ 2%) and T₃ (100% RDF + Commercially available 19:19:19 @ 2%) at panicle initiation and grain filling stages.

Table 2. Influence of foliar application of water-soluble fertilizers on Leaf area index and No of tillers m⁻²

Treatments	Leaf Area Index				No. of tillers m ⁻²
	Active tillering	Panicle initiation	50% Flowering	Grain filling	
T ₁ 100% RDF +1% Urea + 2% MAP + 1% KCl FS	1.18	3.21	3.45	1.52	304
T ₂ 100% RDF + 19:19:19 @ 1% FS (CA)V	1.24	3.61	3.82	1.61	320
T ₃ 100% RDF + 19:19:19 @ 2% FS (CA)	1.31	5.11	4.41	2.32	336
T ₄ 100% RDF + TNAU WSF 19:19:19 @ 1% FS	1.29	4.02	3.91	1.91	320
T ₅ 100% RDF + TNAU WSF 19:19:19 @ 2% FS	1.35	5.52	4.81	2.56	352
T ₆ 100% RDF + TNAU LMM @ 1% FS	1.36	6.01	4.99	2.82	368
T ₇ 100% RDF + 19:19:19 @ 1% (CA) + TNAU LMM @ 1% FS	1.43	7.01	5.42	3.02	368
T ₈ 100% RDF + 19:19:19 @ 2% (CA) + TNAU LMM @ 1% FS	2.60	7.90	6.01	3.68	384
T ₉ 100% RDF+TNAU WSF 19:19:19@1% + TNAU LMM @ 1% FS)	1.53	7.60	5.83	3.41	368
T ₁₀ 100% RDF + TNAU WSF 19:19:19 @ 2% + TNAU LMM @ 1% FS	3.01	8.10	6.72	3.92	384
T ₁₁ Absolute control (WS)	1.05	3.03	3.20	1.01	224
SE _d	0.03	0.14	0.12	0.06	7
CD (p<0.05)	0.05	0.28	0.24	0.12	14

CA- Commercial available, FS- Foliar spray, LMM –Liquid multi Micronutrient

The stature of the plants leads to structure and capacities to capture sunlight to assimilate photosynthates by more leaves. As a plant grows taller, there are better possibilities to have more

effective leaves. This was confirmed in the present study that there was a significant positive correlation existed between plant height and LAI ($r=0.972^{**}$) and with total chlorophyll ($r= 0.974^{**}$).

Table 3. Yield attributes of rice as influenced by the foliar application of water soluble fertilizers

Treatments	No. of panicles /m ²	No. of grains/ panicle	No. of filled grains/ panicle	Panicle length (cm)	1000 grain weight (g)	% chaffy grains
T ₁ 100% RDF +1% Urea + 2% MAP + 1% KCl FS	240	153	134	25.1	15.1	12.4
T ₂ 100% RDF + 19:19:19 @ 1% FS (CA)	256	164	145	25.2	15.2	11.7
T ₃ 100% RDF + 19:19:19 @ 2% FS (CA)	288	173	154	25.4	15.3	10.9
T ₄ 100% RDF + TNAU WSF 19:19:19 @ 1% FS	272	167	148	25.3	15.2	11.4
T ₅ 100% RDF + TNAU WSF 19:19:19 @ 2% FS	304	177	158	25.6	15.3	10.7
T ₆ 100% RDF + TNAU LMM @ 1% FS	320	180	162	25.7	15.4	10.2
T ₇ 100% RDF + 19:19:19 @ 1% (CA) +TNAU LMM @ 1% FS	336	183	165	25.7	15.4	9.9
T ₈ 100% RDF + 19:19:19 @ 2% (CA) +TNAU LMM @ 1% FS	352	195	177	25.9	15.5	9.4
T ₉ 100% RDF + TNAU WSF 19:19:19@1% + TNAU LMM @ 1% FS	336	185	167	25.8	15.4	9.7
T ₁₀ 100% RDF + TNAU WSF 19:19:19 @ 2% + TNAU LMM @ 1% FS	352	198	180	25.9	15.5	9.1
T ₁₁ Absolute control (WS)	160	142	123	23.0	15.0	13.4
SE _d	6	4	3	0.5	0.3	0.2
CD (p<0.05)	12	8	7	1.0	NS	0.5

CA- Commercial available, FS- Foliar spray, LMM –Liquid multi Micronutrient

Higher plant height might be attributed to foliar application of nutrients for proper nourishment of crop and optimum growth and also increased the

activity of meristematic cell and cell elongation with the application of nutrients as they are known to have favorable effects on metabolic process and

better vegetative growth. The results were in harmony with the results reported by Jagathjothi *et al.* (2012).

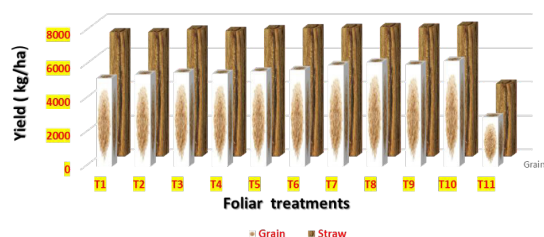


Figure 1. Effect of foliar feeding of water soluble fertilizers on rice yield

Chlorophyll coloration is related to the amount of nutrients absorbed by the plant from soil. Chlorophyll content in rice leaves was maximum (45.7, 46.8, 48.6 and 44.5 as SPAD reading) at active tillering, panicle initiation 50% Flowering and grain filling respectively was bestowed with foliar feeding of 100% RDF + foliar nutrition of TNAU WSF 19:19:19 @ 2% + TNAU Liquid Multi Micronutrient (TNAU-LMM) @ 1% (T_{10}). It was on par with T_8 (100% RDF + commercially available 19:19:19 @ 2% + TNAU Liquid Multi Micronutrient @ 1%), T_9 (100% RDF + TNAU WSF 19:19:19 @ 1% + TNAU Liquid Multi Micronutrient @ 1%), T_7 (100% RDF + commercially available 19:19:19 @ 1% + TNAU Liquid Multi Micronutrient @ 1%) and T_6 (100% RDF + TNAU Liquid multi micronutrient @ 1%) at active tillering and panicle initiation stages and T_8 (100% RDF + commercially available 19:19:19 @ 2% + TNAU Liquid Multi Micronutrient @ 1%), T_9 (100% RDF + TNAU WSF 19:19:19 @ 1% + TNAU Liquid multi micronutrient @ 1%) at 50% flowering and grain filling stages. This increase in chlorophyll content might be attributed to the balanced supply of nutrients at different growth stages. Similar trend was seen with Hashem (2019).

Increased leaf area has implications for light interception and DMP to support plant growth and yield (Vijayakumar *et al.*, 2005). To achieve high yield, the maximization of the leaf area is an essential factor of the crop (Singh and Agrawal, 2010). In the present study, maximum leaf area index in rice (3.01, 8.10, 6.72 and 3.92) at active tillering, panicle initiation 50% flowering and grain filling, respectively was noticed with foliar feeding of 100% RDF + foliar nutrition of TNAU WSF 19:19:19 @ 2% + TNAU Liquid Multi Micronutrient (TNAU-LMM) @ 1% (T_{10}). It was comparable with T_8 (100% RDF + commercially available 19:19:19 @ 2% + TNAU Liquid Multi Micronutrient @ 1%) at the panicle initiation stage, while at other stages, it was superior to rest of the treatments. A progressive increment of LAI of the crop up to certain days maybe because the addition of nitrogen triggers an increased

number of leaves per plant and expansion of individual leaf. The increase in leaf number as well as size due to enough nutrition can be expected in terms of a possible increase in nutrition absorption capacity of the variety through better root development and increased translocation of carbohydrates from source to growing grain (Singh and Agrawal, 2010). This might be due to the development of efficient photosynthetic systems, which enabled the plant to intercept a higher amount of radiant energy which is linked to higher dry matter accumulation per plant. This increase might be due to an increase in nitrogen, being the most important plant nutrient, plays a vital role in plant photosynthesis and biomass production, and also influenced cell division and cell elongation. The same trend was observed by Okasha *et al.* (2019) and Jagathjothi *et al.* (2012). The increased photosynthetic pigment efficiency also can contribute to higher LAI, and it is confirmed in the present study through a significant positive correlation between chlorophyll and LAI ($r = 0.946^{**}$).

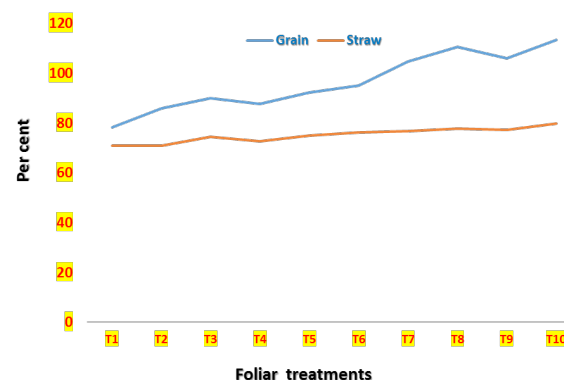


Figure 2. Percent increase in rice yield over control due to foliar feeding of water soluble fertilizers

Among the foliar nutrition treatments, maximum tiller m^{-2} (384) was recorded in rice plots which received foliar feeding of 100% RDF + foliar nutrition of TNAU WSF 19:19:19 @ 2% + TNAU Liquid Multi Micronutrient (TNAU-LMM) @ 1% (T_{10}), and it was superior to rest of treatments. Tillering capacity was hindered in rice plants, which did not receive any of the major nutrients in the fertilizer schedule. Higher tillering is due to favorable root growth and higher mobility of nitrogen in soil solution and its absorption by plant roots. Phosphorus is important for plant growth and promotes root development and tillering. K application was also found effective in producing a prolific root system that might have able to supply adequate potassium to plant in turn improved tiller count. Similar results have been reported by Jagathjothi *et al.* (2012) and Hashem (2019).

Yield attributes

The yield attributes such as the number of panicles m^{-2} , number of grains panicle⁻¹, panicle

length, number of filled grains panicle⁻¹ and 1000 grain weight were influenced by various foliar treatments compared to control (Table 3). All these parameters attained highest values with T₁₀ (100% RDF + TNAU WSF 19:19:19 @ 2% + TNAU Liquid Multi Micronutrient @ 1%). It was comparable with T₈ concerning the number of panicles m⁻², number of grains panicle⁻¹, number of filled grains panicle⁻¹, and it was on par with all treatments concerning 1000 grain weight and panicle length. An increase in yield components is associated with better nutrition, plant growth, and increased nutrient uptake. In rice, sink lies in panicle and grains, and the effect of major nutrients, particularly N on yield attributes, is primarily a function of assimilates accumulation and, in turn, facilitating higher N assimilation with an adequate supply of photosynthates to grain (Pramanik and Bera, 2013). Effective translocation of assimilates to the sink might have resulted in the sound filling of grains as revealed by the highest number of filled grains panicle⁻¹ (Bouman *et al.*, 2006). De Datta (1981) documented that phosphate plays an important role in converting tiller to effective tiller. Ishizuka (1971) opined that phosphorus plays an important role in the translocation of assimilates to the panicles and also as a constituent of protoplasm. This explains the reason for the increased length of the panicle and number of grains per panicle. Hasanuzzaman *et al.* (2012) reported an increase in yield attributes to P supply to rice soil. Potassium nutrition improves the germination of pollen in the floret, which leads to high spikelet fertility in rice (Dobermann *et al.*, 1998). The cumulative effect of increased translocation of photosynthesis to sink by potassium enhanced yield components (Rao *et al.*, 2004). Zinc application improved the nutritional environment of the rhizosphere as well as the plant system as evident from greater uptake of nutrients and, ultimately, metabolic and photosynthetic activity resulting in better development of yield attributes (Khan *et al.*, 2012; Nadeem *et al.*, 2015).

Rice yield

Statistical analyses ($p \leq 0.05$) depicted in figure 1 proclaimed the significant promotional effect of various foliar feeding treatments on rice yield over water spray. The yield response ranged from 2288 to 3313 kg ha⁻¹, and percent improvement (fig 2) ranged from 78.35 to 113.5 due to different treatments. Among the foliar feeding, the maximum grain yield (6233 kg ha⁻¹), straw yield (7730 kg ha⁻¹) and harvest index (0.45) was noticed with 100% RDF + foliar spray of TNAU WSF 19:19:19 @ 2% + TNAU LMM @ 1% (T₁₀) and was on par with T₈ (100% RDF + commercially available 19:19:19 @ 2% + TNAU Liquid Multi Micronutrient @ 1%), T₉ (100% RDF + TNAU WSF 19:19:19 @ 1% + TNAU Liquid

multi micronutrient @ 1%) and T₇ (100% RDF + commercially available 19:19:19 @ 1% + TNAU Liquid Multi Micronutrient @ 1%). An increase in grain yield might be attributed to improvement in plant height, LAI and chlorophyll, which is due to better partition of carbohydrate from leaf to reproductive part (Yoshida, 1972). Greater LAI causes higher light interception, which further enhances GCR, RGR, and NAR and results in higher yield. The explanation is adequately supported by the significant positive correlation noticed in the present study between grain yield with plant height ($r = 0.881^{**}$), chlorophyll ($r = 0.945^{**}$), and LAI ($r = 0.791^{**}$). As yield is the manifestation of the individual yield components, foliar nutrition increased the yield due to improvement in yield attributes. In the present study, different yield attributes showed close association with grain yield, number of panicle m⁻² ($r = 0.957^{**}$), number of grains/panicle ($r = 0.859$), 1000 grain weight ($r = 0.845^{**}$) and panicle length ($r = 0.994^{**}$). An adequate supply of N, P, and K through foliar application would have increased its uptake and increased the dry matter. These results are in confirmation with the results of Rabin *et al.* (2016) Okasha *et al.* (2019), Begum *et al.* (2018), and Hashem (2019).

CONCLUSION

This study concluded that application of fertilizers based on the STCR recommendations combined with the foliar spray of TNAU WSF 19:19:19 @ 2% + TNAU Liquid Multi Micronutrient @ 1% at active tillering, panicle initiation, 50% flowering and harvest stage had increased the growth parameters and yield of rice to a tune of 19.7 percent over regular practice (T₁).

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