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Effect of Integrated Use of Industrial and Organic Waste Fertilization on Rice (*Oryza sativa* L.) Performance in Cauvery Delta

Abdalla Adda*, M.V. Sriramachandrasekharan

Department of Soil Science and Agriculture Chemistry, Faculty of Agriculture,
Annamalai University, Annamalainagar, 608002
*Corresponding author: abdallaadda75@gmail.com

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Abstract Field experiments were carried out during kharif season of 2017 and 2018 to evaluate the effect of integrated use of lignite fly ash (LFA) with organics and fertilizers separately or in combinations on growth, yield parameters, yield and nutrient uptake of rice (*Oryza sativa* L) in Vertisol. The results revealed that incorporation of 10 t LFA ha^{-1} alone or in combination with organics plus fertilizers was most effective in enhancing the growth, yield attributes, rice yield and nutrient uptake over control. Interaction effect between LFA and fertilizers was realized in straw and nutrient uptake only. Application of 10 t LFA ha^{-1} caused 6.2, 6.6 % (grain yield), 5.5, 12.4% (straw yield) over no LFA in 2017 and 2018, respectively. Among conjoint application of organics and fertilizers, addition of 100 % NPK +10 t SPM ha^{-1} recorded the maximum grain (6.89, 6.92 t ha^{-1}) and straw yield (8.26, 8.44 t ha^{-1}) during 2017, 2018 respectively, besides growth and yield attributes. In the presence of LFA, grain and straw yield improved further with all the fertilizer treatments. Addition of RDF or combination with organics resulted in higher uptake and interaction with LFA was significant and the maximum nutrient uptake were noticed with 100 % NPK + SPM + LFA of 122 and 127 (N), 35 and 39 (P), 97 and 103 kg ha^{-1} (K) in 2017and 2018, respectively.

Keywords: *inorganic fertilizers, lignite fly ash, nutrient uptake, organics, rice yield*

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1. Introduction

Rice (*Oryza sativa* L.) is the most important food for more than half the world’s population. Intensive agriculture and decreasing input of organic materials have led to severe depletion of soil fertility and productivity especially in rice agriculture [1]. To fulfill the increased rice demand with shrinking resources, it is necessary to increase yield per unit area with sustainable and nutrient balance technology package which will increase the rice production substantially without harming precious environment. Organic materials are being increasingly used for restoration and augmentation of soil fertility and crop productivity. Farm yard manure is a heterogeneous composted organic material which has a lot of potential to be used in the fertilizer schedule of rice. Due to presence of almost all the nutrients required for plant growth, vermicompost is now widely used for growing crops [2]. Green manuring is an efficient technology in economizing the agricultural production system ensuring the productive capability of soil without causing environmental harm [3]. Pressmud is a solid waste by product of sugar mill and rich in NPK and organic carbon [4], thus pressmud can serve as a premium source of organic fertilizer [5]. Fly ash is an amorphous mixture of ferroaluminum silicate material generated from the combustion of ground or powdered coal [6]. [7] reported that fly ash act as a premium soil modifier, conditioner and good source of essential plant nutrients for appreciably improving fertility with a significant increase in yield over control. Application of fly ash increased the yield of cereal crops by 10-15%, pulses, oilseeds, and vegetables respectively by 20-25% and other crops by 40% [8]. The combined use of fly ash along with farmyard manure and fertilizer increased rice yield by 24.4% over control [9]. Rice is one of the crops which consumes a large amount of nutrients, in India nearly 40% of total plant nutrients are consumed by rice crop, and even though the large amount of fertilizers is added to produce rice, nutrients use efficiency is still low [10]. There is a need to develop strategies to improve soil nutrient use efficiency to sustain the productivity and soil health in intensive rice cultivation areas. This study was undertaken to investigate the effect of the integration of organic materials and chemical fertilizers with and without lignite fly ash on performance of rice (ASD 16) in Cauvery delta.

2. Materials and Method

Field trials were undertaken during kharif 2017 and 2018 at farmers holding at Pinnalore village, Cuddalore district, Tamil Nadu state, India. The soil of experimental site was clay loam in texture (33.2% sand, 25.6% silt and 41.2% clay), bulk density (1.28 Mg m^{-3}), pH (7.7), EC (0.40 dSm^{-1}) in 1.25 soil: water, soil organic carbon (6.25 g kg^{-1}), low in available N (239.0 kg ha^{-1}), medium in available P (12.7 kg ha^{-1}) and high in available K (318 kg ha^{-1}). The experiment was conducted in RBD design with two factors replicated thrice. The factor A) LFA levels- 0 t ha^{-1} (-FLA), 10 t ha^{-1} (+LFA) and factor B; fertilizer treatments T_1: Absolute control, T_2: 100% NPK, T_3: 50% N+100% PK+ 12 t FYM ha^{-1}, T_4: 50% N+100 % PK + 5 t VC ha^{-1}, T_5: 50% N + 100% PK+ 6.25 t GM ha^{-1}, T_6: 50% +100 % PK+ 10 t SPM ha^{-1}, T_7: 100% NPK+ 12.5 t FYM ha^{-1}, T_8: 100% NPK+5 t VC ha^{-1}, T_9: 100% NPK+ 6.25 t GM ha^{-1}, T_{10}: 100% NPK+10 t SPM ha^{-1}. Recommend dose of fertilizers was added (120: 38: 38 kg N P_2O_5 and K_2O ha^{-1}), through urea, single supper phosphate and muriate potash. The chemical composition of organic manures were FYM (1.02% N, 0.36% P, 1.62% K), vermicompost (1.25% N, 0.41% P, 0.82% K), green manure (1.61% N, 0.5% P, 2.15% K) sugar pressmud (1.90% N, 1.8% P, 0.8% K) and fly ash (0.04% N, 0.08% P, 0.16% K) were incorporated manually in the soil two weeks before transplanting of rice ASD 16 on 21st June 2017 and 8th July 2018. Five hills from each plot in both years were chosen to measure plant height, number of tiller $hill^{-1}$, number of panicles m^{-2}, number of grain panicle $^{-1}$, panicle length, and thousand grains weight. Straw and grain yields were recorded at harvest on 15th September 2017 and 28th September 2018. The grain and straw samples were analyzed for their N, P, and K content by adopting standard procedures [11]. Total nutrient N, P, and K uptake were obtained by multiplying the (concentration of the nutrient in straw and grain as a percent into the weight of grain and straw (kg))/100. Total uptake was obtained by the summation of straw and grain nutrients uptake (kg ha^{-1}). Data on various parameters were statistically analyzed by adopting standard statistical analysis [12].

3. Results and Discussion

3.1. Growth and Yield Parameters

Incorporation of 10 t LFA ha^{-1} brought marked effect on growth and yield attributes over no LFA (Table 1, Table 2 and Table 3). The percent impact of LFA was to the tune of 2.0 and 5.1 (plant height), 14.8 and 18.4 (No of tiller $hill^{-1}$), 7.2 and 9.9 (No of panicle m^{-2}), 6.0 and 8.3 (No of grain panicle-^{1}), 4.1 and 4.9 (panicle length), 1.8 and 1.4 (thousand grain weight) over no LFA in 2017 and 2018, respectively. The application of fly ash for soil fertilization is associated with plant growth and yield increase as it contains almost all minerals necessary for the metabolic processes of plants. [13,14] Macro and microelements delivered to the soil from fly ash had a positive effect on plant growth and upgrade its agronomic properties and according to [15], the incorporation of fly ash in the different compositions without adding any fertilizer improves plant growth. With respect to fertilizer treatments, application of nitrogen at (50 % or 100%) plus 100 % PK with organics facilitated significantly higher growth and yield characters over RDF besides control. Performance of pressmud followed by FYM, vermicompost and green manure in combination with chemical fertilizers was the best. The highest value of 108.5 and 110.4 cm (plant height), 17.7 and 18.5 (No of tiller $hill^{-1}$), 332.8 and 350.0 (No of panicle m^{-2}), 137.0 and 140.5 (No of grain $panicle^{-1}$), 27.8 and 28.5 cm (panicle length) and 22.8 and 22.3 g (thousand grain weight) in 2017, 2018, respectively was manifested in rice plants which received 100% NPK + 10 t SPM ha^{-1}. Organic manures contain appreciable quantity of nutrients, when incorporated into soil, on decomposition release the nutrients from it and also improve the native and applied nutrients and other soil properties thereby making favorable condition for growth and development of rice [16]. Optimum use of inorganic and organic sources would have created favorable environment of nutrition in the rhizosphere of low land rice. Nutrients form fertilizer would be available to the crop instantly and immediately after application, while nutrients from organic sources would be slowly mineralized. Thus, initial requirements of nutrients would have met from the former source and subsequent requirement of nutrients from the latter source and thus providing nutrients supply throughout the growing period. Such a situation favors nutrient uptake by rice at different growth stages. Timely availability of nutrients under various fertilizer treatments would have facilitate better photosynthesis activity and promote plant growth in turn promote yield attributes [17]. [18] confirmed the outcome of present study by observing application of RDF + 15 t ha^{-1} pressmud recorded the maximum growth and yield characters in their experiment. Although the interaction between LFA and organics plus fertilizer on growth and yield characters were non-significant, there was numerical increase in the parameters studied. The highest value was recorded with 100% NPK + 10 t SPM ha^{-1} + 10 t LFA ha^{-1}. The conducive environment in the soil already brought about by the co-existence of organics and fertilizer is further boosted by addition of LFA has spiked the growth and yield characters probably to a limited extent in this study. The results of [19] showed that combined application of fly ash with organic and fertilizers increased rice yield parameters over no-fly ash application lend support to the present outcome.

3.2. Rice yield

Incorporation of lignite fly ash, organics and fertilizer caused an expressive impact on grain and straw yield over control (Figure 1). Addition of 10 t LFA ha^{-1} recorded (6.20 and 6.36 t ha^{-1}) of grain and (7.29 and 7.80 t ha^{-1}) of straw yield over no LFA in 2017 and 2018, respectively. The extent of influence of LFA was in the order of 6.1 and 6.5 % (grain yield) and 5.49 and 12.3% (straw yield) in 2017 and 2018, respectively over no LFA. The positive effect of LFA stems from the fact that LFA improved the parameters (growth and yield attributes) that contribute to the rice yield as witnessed in the present study. Secondly improved plant nutrition also contributes to higher yield.

In the present experiment, LFA has contributed to enhanced nutrient uptake visa viz., no LFA. Fly ash is recognized as the useful resource and not just a waste and could be potential inorganic soil amendment to raise rice productivity and also restore the soil nutrient balance in paddy soils [15]. [21] reported increase in rice yield in soil amended with 10 t fly ash ha^{-1}. Conjoint application of N (50 or100%) plus 100 % PK with organics brought in marked improvement in rice yield over RDF alone. The quantum jump in the promotional effect was in the region of (7 to 21%, 1.3 to 14% in grain yield) and (8 to 22.2 %, 0.9 to 18.9% in straw yield) during 2017 and 2018, respectively. Similarly, the effect over control was (71 to 93.5%, 74 to 96.5% in grain yield) and (55.3 to 86.4%, 64.1 to 93.1% in straw yield) during 2017 and 2018, respectively. The most effective treatment noticed for grain (6.89, 6.92 t ha^{-1}) and straw yield (8.26, 8.44 t ha^{-1}) during 2017 and 2018, respectively was the combination of 100 % NPK + 10 t SPM ha^{-1}. Pressmud is extremely soluble and readily available for microbial action and so to the soil added and endowed with high nutrients in its stock has caused higher rice yield compared to other organics. Further adequate biomass production, improved yield parameters and better nutrient uptake by rice noted in this plot has resulted in higher yield [22]. The present result was in consonance with earlier researchers of [23,24] who testified significant role of SPM in improving rice yield when applied with chemical fertilizers over RDF and control. The interplay between LFA and organics and fertilizer was significant to straw yield only. In the presence of LFA, combined application of fertilizer and organics and fertilizer alone recorded higher rice yield than in the absence of LFA. The highest grain yield (7.18, 7.21 t ha^{-1}) and straw yield (8.64, 8.93 t ha^{-1}) during 2017 and 2018, respectively was perceived with 100 % NPK + 10 t SPM ha^{-1}+ 10 t LFA ha^{-1} .The extra benefit accrued on addition of LFA on an average was 8.8 and 11.1% for grain and straw yield, respectively. The supply of nutrients conducive to physical environment leading to improve aeration, root activity and nutrient absorption and the consequent complimentary effect by fly ash addition with organics and chemical fertilizers would have resulted in higher rice yield [17]. [25] reported that fly ash at lower dose with pressmud improved paddy yield in nutrient poor soil by 138% (grain yield) and 78.9% (straw yield) over control.

Table 1. Effect of fly ash, organic manure and fertilizers on growth features

	Plant height (cm)						**Tiller count hill^{-1}**					
	Kharif 2017			**Kharif 2018**			**Kharif 2017**			**Kharif 2018**		
Treatments	+LFA	-LFA	Mean	+LFA	-LFA	Mean	+ LFA	-LFA	Mean	+LFA	-LFA	Mean
T_1	80	71	75.7	93	70	81.3	7.5	6.6	7.1	9.0	6.2	7.6
T_2	94	93	93.7	96	94	95.2	13.2	12.2	12.7	13.6	11.5	12.6
T_3	103	101	102.1	105	101	102.9	16.4	13.6	15.0	16.5	14.5	15.5
T_4	98	96	97.0	100	97	98.3	13.7	12.1	12.9	14.1	12.3	13.2
T_5	96	96	96.0	99	96	97.6	13.6	12.4	13.0	13.9	11.6	12.8
T_6	103	102	102.6	105	102	103.3	16.4	14.1	15.3	18.0	14.9	16.5
T_7	105	103	103.7	105	104	104.4	17.1	14.9	16.0	17.6	15.5	16.6
T_8	100	99	99.6	101	100	100.4	15.7	13.8	14.8	15.9	14.0	15.0
T_9	99	98	98.8	101	99	99.6	14.8	12.7	13.8	15.3	13.2	14.3
T_{10}	111	106	108.5	115	106	110.4	19.3	16.0	17.7	20.2	16.8	18.5
Mean	99	97		102	97		14.7	12.8		15.4	13.0	
FA		0.3			1.1			0.8			0.8	
T		0.8			2.5			2.2			1.9	
FA x T		ns			ns			ns			ns	

CD P=0.05.

Table 2. Effect of fly ash, organic manure and fertilizers on growth features

	No of panicle m^{-2}						No of grain panicle^{-1}					
	Kharif 2017			**Kharif 2018**			**Kharif 2017**			**Kharif 2018**		
Treatments	+LFA	-LFA	Mean	+LFA	-LFA	Mean	+ LFA	-LFA	Mean	+LFA	-LFA	Mean
T_1	193	166	179.1	184	150	167.0	80	62	71.0	92	60	76.0
T_2	233	210	221.5	237	214	225.5	116	110	113.0	124	117	120.5
T_3	286	255	270.2	297	277	287.0	128	123	125.5	135	128	131.5
T_4	241	232	236.2	262	250	256.0	123	118	120.5	131	124	127.5
T_5	236	215	225.6	258	225	241.5	120	116	118.0	127	120	123.5
T_6	287	277	281.8	341	295	318.0	132	125	128.5	137	131	134.0
T_7	331	312	321.3	356	330	343.0	137	130	133.5	141	134	137.5
T_8	265	244	254.8	284	272	278.0	127	122	124.5	133	126	129.5
T_9	250	248	249.4	283	270	276.5	125	120	122.5	132	124	128.0
T_{10}	340	325	332.8	369	331	350.0	139	135	137.0	144	137	140.5
Mean	266	248		287	261		123	116		130	120	
FA		8.5			11.1			3.9			3.6	
T		19.1			20.0			9.3			8.1	
FA x T		ns			ns			ns			ns	

CD P=0.05.

Table 3. Effect of fly ash, organic manure and fertilizers on growth features

	Panicle length (cm)						Thousand grain weight (g)					
	Kharif 2017			**Kharif 2018**			**Kharif 2017**			**Kharif 2018**		
Treatments	+LFA	-LFA	Mean	+LFA	-LFA	Mean	+ LFA	-LFA	Mean	+LFA	-LFA	Mean
T_1	21.0	18.5	19.7	21.2	17.6	19.4	20.0	19.8	19.9	20.2	19.6	19.9
T_2	23.9	23.3	23.6	24.2	23.3	23.7	21.2	20.1	20.7	21.4	21.2	21.3
T_3	25.4	24.4	24.9	25.9	24.8	25.3	21.6	21.3	21.4	21.9	21.6	21.7
T_4	24.6	24.1	24.4	25.0	24.9	25.0	21.4	21.1	21.3	21.6	21.4	21.5
T_5	24.5	23.5	24.0	24.9	23.7	24.3	21.4	21.0	21.2	21.6	21.4	21.5
T_6	25.6	24.6	25.1	26.1	25.0	25.5	21.9	21.3	21.6	21.9	21.7	21.8
T_7	26.4	25.5	25.9	26.9	25.0	26.4	22.3	21.3	22.1	22.1	21.8	22.0
T_8	25.3	24.1	24.7	25.7	24.7	25.2	21.6	21.2	21.4	21.7	21.5	21.6
T_9	24.6	24.2	24.4	25.4	24.7	25.0	21.5	21.2	21.3	21.7	21.4	21.5
T_{10}	28.4	27.3	27.8	29.5	27.5	28.5	22.7	21.7	22.2	22.5	22.2	22.3
Mean	24.9	23.9		25.4	24.2		21.5	21.1		21.7	21.4	
FA		0.41			0.33			0.25			0.21	
T		0.92			0.74			0.55			0.45	
FA x T		ns			ns			ns			ns	

CD P=0.05.

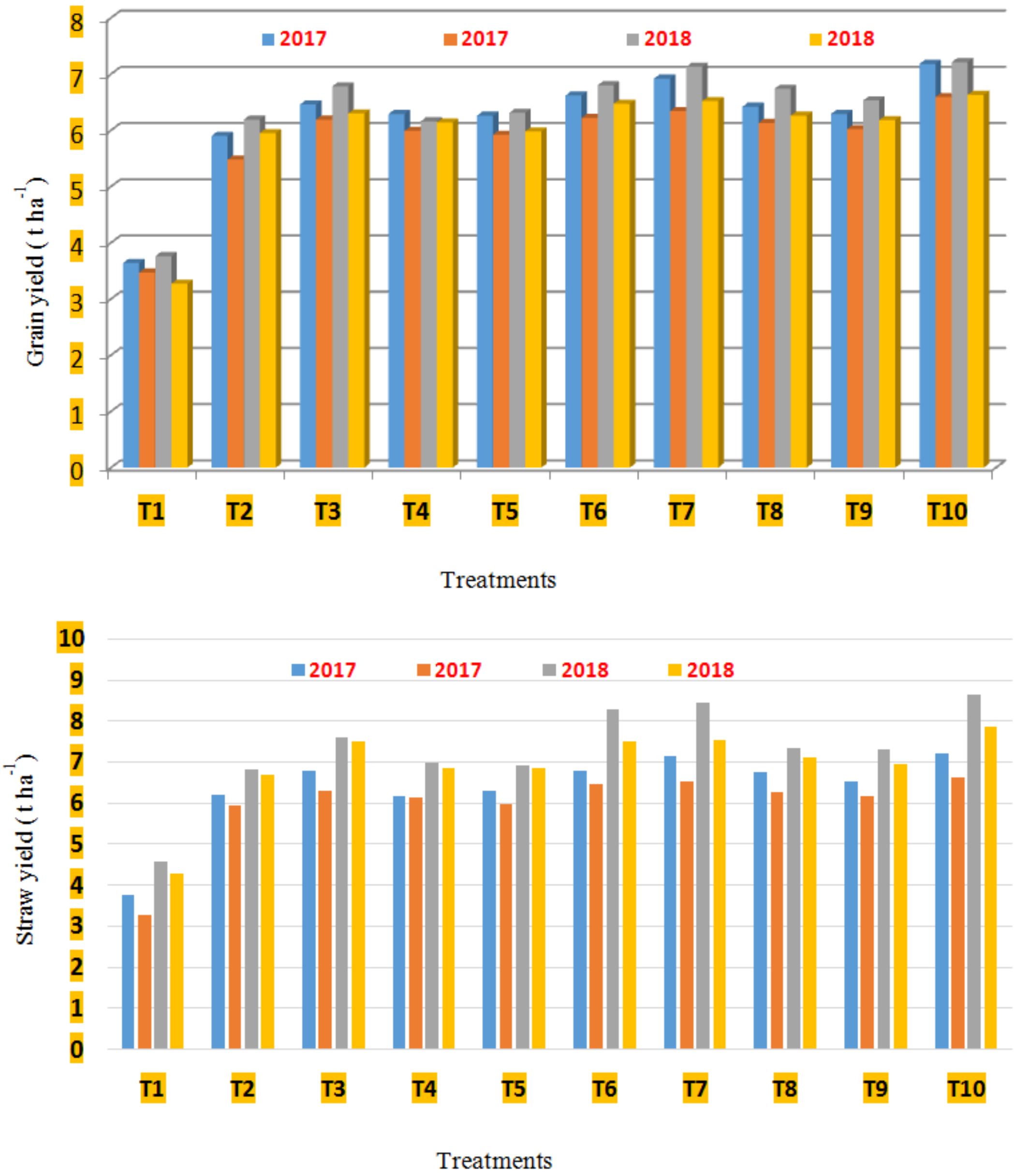

Figure 1. Effect of lignite fly ash, organics and fertilizers on grain and straw yield

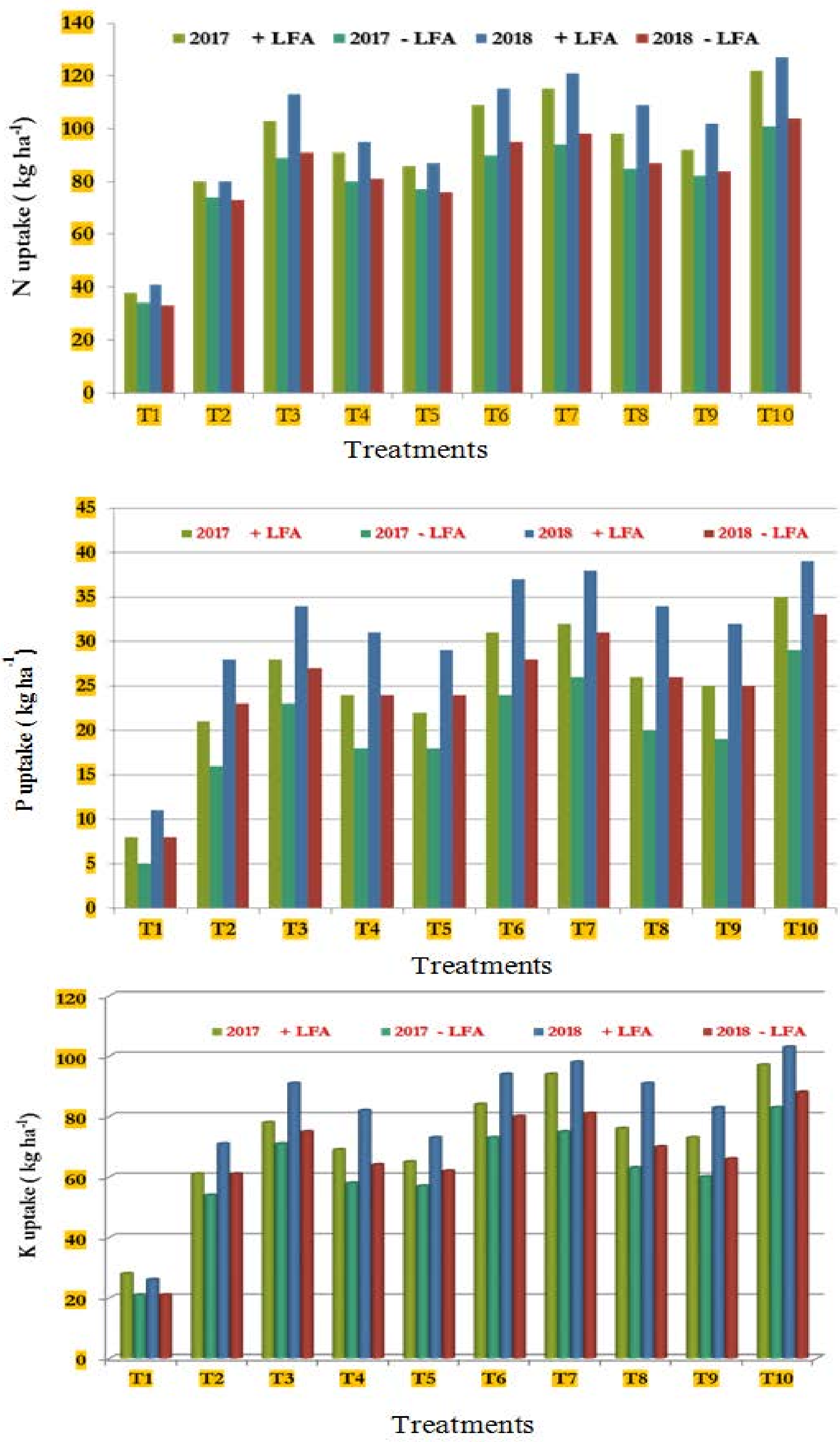

Figure 2. Effect of Lignite fly ash, organics and fertilizers on nutrient uptake

3.3. Nutrient Uptake

Nutrient uptake in grain and straw of rice was appreciably increased consequential to the application of organics, lignite fly and chemical fertilizers over control (Figure 2). The percent impact of LFA on nutrients uptake was to the tune of 15.7 and 20.5 (N), 26.9 and 24.4 (P) and 17.8 and 21.4 (K) over no LFA application in 2017 and 2018, respectively. Fly ash contains appreciably amount of macro and micro elements and consequent to addition in soil increases the availability of these nutrients resulting in higher uptake of nutrients by rice grain and straw [26]. Combined application of organics and fertilizer showed higher N, P, and K uptake over control and RDF. Organics applied with 100 % NPK recorded higher nutrient uptake compared to organics applied with 50% N plus 100 % PK. The highest nutrient uptake of 111.8 and 115.1 kg ha^{-1} (N), 31.9 and 36.0 kg ha^{-1} (P) and 89.8 and 95.7 kg ha^{-1} (K) in 2017 and 2018, respectively were recorded with 100% RDF + 10 t SPM ha^{-1}. The interaction effect between lignite fly ash with organics and fertilizer on nutrients uptake was significant in both 2017 and 2018. The maximum N, P and K uptake of 122.4, 35.2 and 97.1 kg ha^{-1} in 2017 and 126.5, 39.4 and 103.4 kg ha^{-1} in 2018 was reflected in treatment 100% RDF +10 t LFA ha^{-1} + 10 t SPM ha^{-1} which was comparable with (T_7) 100% RDF + 10 t LFA ha^{-1} + 12.5 t FYM ha^{-1}. The improved nutrient uptake is attributed to two aspects. The first is the direct addition of plant nutrients to the soil through fly ash. [27] noted that fly ash supplies most of the major macro and micro plant nutrient like; N, P, K, Ca, Mg, S, Fe, Mn, Cu, and Zn, also high Si concentration in fly ash could be led to increase the availability of P in soil [28]. Secondly, aapplication of organic materials which represent a reservoir of plant nutrients through mineralization contributes to supply nutrients to the soil and its act as a chelating agent to prevent loss of plant nutrients, further production of organic acid such as fulvic and humic acid which may reduce pH causing release some nutrients from soil and LFA, and increase the transfer of plant nutrients between the solid phase and soil solution [29], further improved some soil physico-chemical properties such as CEC. Irrespective of LFA dose, the differential nutrient uptake due to different treatments may be attributed to several factors such as; C/N ratio, total C in organic material, amount of nutrient in organic material, rate of the composition with time and amount of nutrients added to soil [30].

It may be concluded that the addition of RDF along with SPM 10 t ha^{-1} and 10 t LFA ha^{-1} to soil could be advocated to realize maximum rice yield and NPK uptake.

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