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Dynamics of Nutrient Uptake in Long Term Fertilizer Experiments on Rice in Kerala

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SUMMARY

The present study is based on the secondary data of grain yield, obtained from AICRP on Long Term Fertiliser Experiment (LTFE) on rice conducted at RARS Pattambi during *kharif* and *rabi* seasons. The objective of the study was to study the influence of plant nutrients namely N, P and K uptake on grain yield of rice using nonlinear regression. Quadratic model was able to capture the relationship between yield and plant nutrients in both the seasons.

Keywords: Plant nutrients, Nonlinear, Regression, LTFE, Quadratic.

1. INTRODUCTION

Increased supply of nutrients has played a key role in enhancing food production to address the necessity of rapidly growing world population. Nutrients exhausted by crops are substituted with chemical fertilizers, to attain nutrient balance and soil fertility. Among various factors that contributeto better yield and quality, the appropriate use of fertilizers is of utmost importance (Sankaran *et al.*, 2005). Determination of optimum levels of NPK fertilizers is crucial for achieving maximum economic gains. According to Ananthi *et al.* (2010) best rate of fertilizer application is that which gives maximum returns at least cost. Among various essential plant nutrients, the macro nutrients N, P and K are crucial for determining the yield and quality. It has been noticed that farmers utilize imbalanced dose of chemical fertilizers which lead to higher insects/disease attack ultimately leading to lower yield (Mannan *et al.*, 2009; Alam *et al.*, 2011). Therefore, there is prodigious need to estimate the best level of NPK fertilizers for maximizing the profit. The first step for this is to estimate the functional relationship existing between the nutrient uptake and crop yield.

The Rothamsted experiments has proved the effectiveness of chemical fertilizers in enhancing the yield of crop plants (Rasmussen *et al.,* 1998; Smil 2002). The long-term experiments at Rothamsted showed that yields were two to three times higher than those without fertilizers or manures (Johnston, 1994).). Also, an increasing supply of nutrient can boost the yield to a threshold value after which the production may be affected in a negative way, *ie.,* the plant doesn't take up all the nutrient that is supplied to them. Nutrient management should ideally provide an input-output balance in long term (Heckman *et al.*, 2003).

Rice, being the staple food of Kerala, the need to increase the yield and quality of rice through sustainable agriculture by proper fertilizer applications and various soil fertility management practices has gained importance. The present study was undertaken to study the influence of plant nutrients *viz;* N, P and K uptake on treatment responses of rice under long term experiments.

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2. MATERIALS AND METHODS

The present study was based on secondary data from All India Coordinated Research Project on Long-Term Fertilizer Experiments (AICRP-LTFE) in rice, which was initiated at Regional Agricultural Research Station (RARS), Pattambi in 1997 to study changes in soil quality, crop productivity and sustainability under long term fertilizer experiments in rice. The experiment was carried out in RARS, Pattambi, Kerala using the variety Aiswarya in two planting seasons namely *kharif* and *rabi*. Aiswarya variety of rice developed at RARS, Pattambi is resistant to blast, blight and BPH. It is well suited for first and second crop seasons. The *kharif* season starts from July to October during the south-west monsoon season and the *rabi* cropping season is from October to March (winter).

The following are the details of the experiment:

Number of replications: 4

Number of treatments: 12

Design: Randomized Complete Block Design (RCBD)

Plot size: 125 m^2

Following are the fertiliser treatments:

T_1: 50 percent NPK (as per POP recommendation of KAU)

T_2: 100 percent NPK (90 N: 45 P_2O_5: 45 K_2O)

T_3: 150 percent NPK

T_4: 100 percent NPK + lime @ 600 kg/ha

T_5: 100 percent NPK

T_6: 100 percent NP

T_7: 100 percent N

T_8: 100 percent NPK + FYM @5t/ha to the kharif rice only

T_9: 50 percent NPK + FYM @5t/ha to the kharif rice only

T_{10}: 100 percent NPK + *in situ* growing of *Sesbaniaaculeata,* as green manure crop for kharif rice only

T_{11}: 50 percent NPK + *in situ* growing of *Sesbaniaaculeata,* as green manure crop for kharif rice only

T_{12}: Absolute control

The data recorded on grain yield and nutrient uptake with respect to N,P and K of rice crop in *kharif* and *rabi* seasons for twenty years from 1997- 2017 were collected. Preliminary investigation of the data was done with the help of descriptive and exploratory data analysis. To compare the mean nutrient uptake, analysis of variance was employed. *Post hoc* analysis was carried out using Duncan's Multiple Range Test (DMRT). The relative performance of different treatments with respect to grain yield were compared using independent t test. Nonlinear regression was performed using SPSS software (version 22) to quantify the relative contribution of plant nutrients on crop yield. The regression equation fitted for treatment responses takes the form:

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_1^2 + b_5X_2^2 + b_6X_3^2 + b_7X_1X_2 + b_8X_2X_3 + b_9X_1X_3$$

Where b_i, i=1, 2, …, 9 are the partial regression coefficients

X_1, X_2, X_3 are the independent variables under study *viz.,* N uptake, P uptake and K uptake respectively.

3. RESULTS AND DISCUSSION

The descriptive statistics of yield data revealed that the mean grain yield in *kharif* season was 2742.08 kg/ha with a standard deviation of 835.70 kg/ha. In *rabi* season, the mean grain yield was 3077.69 kg/ha with a standard deviation of 371.17 kg/ha.

Table 1. Descriptive statistics of yield data for kharif and rabi Seasons

Statistic	Season	
	Kharif	*Rabi*
Mean	2742.08	3077.69
Standard deviation	835.70	371.17
Skewness	0.83	0.72
Kurtosis	0.79	2.26
CV	30.48	12.06

Exploratory analysis yield data in both the seasons through box plot depicted that treatment responses in *rabi* was higher and more consistent than those in *kharif* season (Fig 1).

After assessing the influence of long-term applications of nutrients on crop yield, it was concluded that the highest yield was obtained under T_8 (100 percent NPK + FYM @5t/ha to the *kharif* rice only) followed by T_{10} (100 percent NPK + *in situ* growing

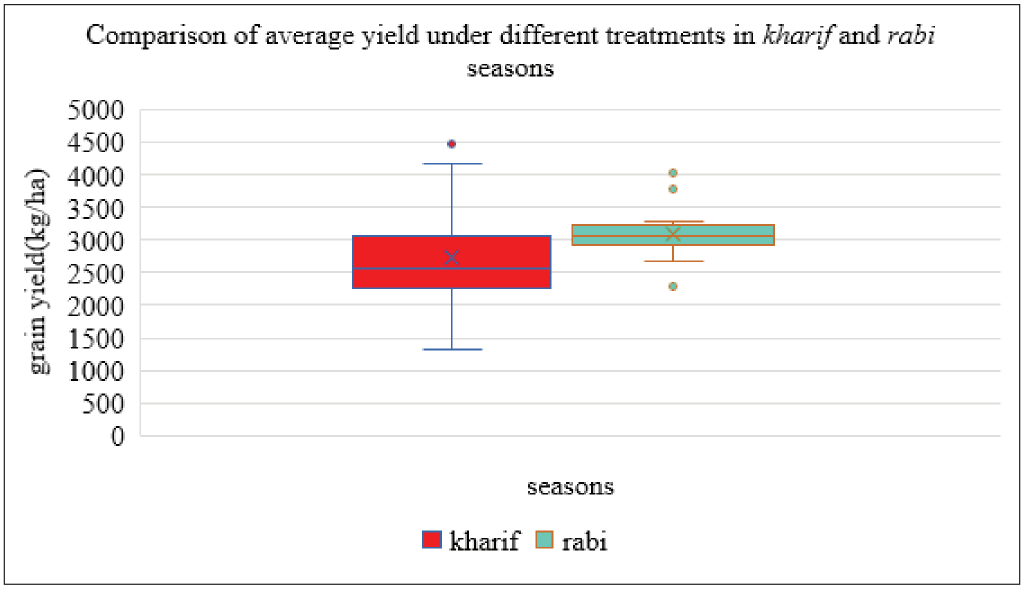

Fig. 1. Comparison of average yield under different treatments in *kharif* and *rabi* seasons

of *Sesbaniaaculeata,* as green manure crop for kharif rice only) in both the seasons. The relative performance of different treatments with respect to grain yield revealed that treatment responses T_7 were significantly different in two seasons. T_7 was reported to be the most imbalanced treatment and even a minute variation in weather affected the yield drastically. When comparing the means for nutrient uptake of N, P and K also, it was established that the highest nutrient uptake of N, P and K was for treatment T_8 followed by T_{10} (Table 2). Yield data recorded over the period 1998-2017 for both *kharif* and *rabi* season clearly validated the superiority of integrated use of FYM and green manuring with chemical fertilizers, which provided greater stability in crop production as compared to 100% NPK. This could be linked with the benefits of organics, which apart from N, P and K supply also improves microbial activities, thereby supplying macro and micro-nutrients such as S, Zn, Cu and B, which are not supplied by inorganic fertilizers.

Simple correlation between the treatment responses and N, P, and K uptake was found to be non-significant, emphasizing the probable curvilinear relationship between these variables and yield. Linear regression between yield and plant nutrients could not account for the variability in yield significantly due to low R^2 values (Table 3). It was observed that treatment T_8 had the maximum uptake of N, P and K when compared to the other treatments showing the significance of the

Table 2. Comparison of mean nutrient uptake of N, P and K in kharif and rabi seasons

Treatments	N uptake		P uptake		K uptake	
	Kharif	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*
T1	32.70^{ef}	34.07^{g}	6.95^{f}	7.33^{efg}	56.06^{d}	54.82^{e}
T2	36.51^{cd}	37.61^{ef}	7.33^{def}	7.81^{fg}	63.16^{bc}	59.25^{cd}
T3	36.81^{cd}	38.14^{de}	8.36^{bc}	8.49^{cd}	66.59^{b}	62.63^{c}
T4	36.67^{cd}	38.18^{de}	7.76^{cde}	8.22^{cde}	56.65^{d}	55.60^{de}
T5	34.64^{def}	34.99^{fg}	7.54^{def}	7.47^{fg}	60.59^{cd}	56.00^{de}
T6	38.92^{c}	40.78^{cd}	7.02^{ef}	7.25^{g}	59.02^{cd}	55.91^{de}
T7	32.19^{f}	33.74^{g}	6.84^{f}	7.29^{g}	49.37^{e}	46.98^{f}
T8	51.85^{a}	53.05^{a}	10.78^{a}	11.04^{a}	76.82^{a}	74.08^{a}
T9	39.76^{c}	41.46^{c}	7.99^{cd}	8.55^{c}	60.85^{cd}	59.46^{cd}
T10	46.83^{b}	48.49^{b}	8.86^{b}	9.30^{b}	73.74^{a}	68.48^{b}
T11	35.57^{de}	36.51^{efg}	7.80^{cd}	7.94^{def}	59.82^{cd}	57.47^{de}
T12	25.84^{g}	26.36^{h}	5.10^{g}	5.58^{h}	39.85^{f}	38.55^{g}

nutrients with respect to yield. So, an attempt was made to quantify the uptake of N, P and K in rice crop.

Nonlinear regression was used to quantify the relative contribution of the uptake of plant nutrients N, P and K on the treatment responses for both seasons and the results are depicted in Table 4 and Table 5. During *kharif* season, when the quadratic model was fitted for grain yields with respect to different treatments, the R^2 value ranged from 0.67 to 0.89. During *rabi* season, the R^2 values were comparatively higher than that for*kharif* season and ranged from 0.75 to 0.96. This substantiates

Table 3. Linear regression of treatment responses on nutrient uptake of rice in kharif and rabi seasons

Treatments		*Kharif*					*Rabi*				
		b_0	b_1 (N)	b_2 (P)	b_3(K)	R^2	b_0	b_1 (N)	b_2 (P)	b_3(K)	R^2
T_1	Estimates	1718.98	9.31	44.48	2.31	0.14	2292.50	9.72	43.94	0.55	0.08
	Std Error	769.80	17.19	61.20	17.94		476.90	8.89	32.12	11.30	
T_2	Estimates	2222.81	14.04	73.96	-7.81	0.17	2970.31	6.44	33.64	-4.10	0.15
	Std Error	865.95	15.42	75.82	19.00		388.09	7.20	28.17	7.32	
T_3	Estimates	2112.85	11.83	77.06	-5.10	0.21	2917.73	6.45	109.00	-11.80	0.30
	Std Error	929.10	17.38	71.77	17.33		582.16	9.37	45.54	10.19	
T_4	Estimates	2543.67	5.60	63.05	-9.28	0.10	2685.19	11.94	51.54	-7.29	0.18
	Std Error	882.94	17.29	56.75	15.94		427.82	8.78	38.37	8.55	
T_5	Estimates	2258.26	12.02	32.63	-2.00	0.09	2517.15	9.54	7.21	6.44	0.23
	Std Error	1033.72	17.02	61.08	20.10		450.76	8.70	31.13	10.12	
T_6	Estimates	2087.86	12.17	43.62	-5.81	0.13	2385.37	9.35	86.23	-7.09	0.31
	Std Error	647.54	13.02	50.18	9.57		432.50	7.67	40.28	7.13	
T_7	Estimates	2239.57	17.34	18.12	-11.98	0.17	1746.02	20.68	28.72	3.24	0.57
	Std Error	526.20	12.59	54.33	11.80		281.45	8.60	32.29	8.63	
T_8	Estimates	2120.14	3.30	54.77	6.91	0.17	3227.98	11.82	32.65	-4.94	0.20
	Std Error	979.84	16.79	57.25	13.81		521.26	7.36	29.19	7.15	
T_9	Estimates	2775.67	18.91	83.26	-21.13	0.14	3120.88	13.35	4.01	-6.05	0.11
	Std Error	920.16	17.96	75.36	21.81		527.31	9.93	27.75	8.60	
T_{10}	Estimates	2329.65	0.70	80.65	2.05	0.12	3516.09	12.85	28.37	-11.84	0.15
	Std Error	981.16	18.57	79.64	18.91		636.61	9.70	43.96	11.65	
T_{11}	Estimates	2319.85	0.71	64.47	-1.23	0.08	2877.53	13.61	31.00	-6.78	0.15
	Std Error	1095.85	20.54	62.56	18.72		608.16	10.06	42.85	9.38	
T_{12}	Estimates	1407.85	18.77	51.63	-7.14	0.18	1525.37	12.17	18.76	6.19	0.17
	Std Error	602.15	15.51	70.61	14.51		449.42	9.90	30.29	10.12	

Table 4. Model summary of the nonlinear regression of treatment responses on nutrient uptake of rice in kharif season

Treatments		b_0	b_1 (N)	b_2 (P)	b_3(K)	b_4 (N^2)	b_5 (P^2)	b_6 (K^2)	b_7 (NP)	b_8(NK)	b_9(PK)	R^2
T_1	Estimates	-601.99	138.68	-144.96	12.78	-3.94	-45.95	-1.42	8.69	2.16	12.14	0.83
	Std Error	2616.87	68.67	579.55	94.01	1.19	19.61	1.08	6.05	1.53	9.62	
T_2	Estimates	-3816.96	229.49	3.53	40.91	-3.28	-66.41	-1.21	8.92	0.27	14.16	0.84
	Std Error	3649.33	72.52	541.54	97.00	0.84	33.58	1.24	4.41	1.19	14.84	
T_3	Estimates	-971.95	118.73	471.58	-46.04	-3.13	-39.90	-0.35	7.95	1.63	3.33	0.89
	Std Error	2788.21	72.92	328.58	60.44	0.83	20.33	0.52	5.58	0.96	6.54	
T_4	Estimates	-2894.20	166.81	592.71	-37.63	-3.25	-42.99	0.20	12.66	0.60	-1.17	0.81
	Std Error	4311.43	124.20	643.31	107.09	1.68	22.30	1.40	13.04	1.88	8.45	
T_5	Estimates	262.89	124.37	227.38	-63.98	-5.04	-31.03	-1.39	-1.35	5.29	8.59	0.80
	Std Error	4208.33	99.22	1013.64	134.42	1.20	28.96	1.46	8.19	2.07	17.04	
T_6	Estimates	-1930.47	143.05	458.51	-38.99	-2.45	-48.53	-0.25	8.17	0.76	4.86	0.69
	Std Error	4009.35	72.78	894.44	66.45	1.41	18.16	0.41	6.50	2.08	11.62	
T_7	Estimates	831.62	356.34	-1193.98	-60.93	-6.58	-52.32	-2.40	13.50	1.59	35.32	0.70
	Std Error	2012.11	117.56	693.39	79.98	2.02	22.71	1.36	7.71	1.85	12.88	
T_8	Estimates	-4361.47	416.26	-510.11	-51.25	-5.40	-0.20	-1.62	-5.78	3.86	10.61	0.82
	Std Error	3795.35	179.44	541.09	98.00	2.56	35.06	0.74	10.54	2.64	9.91	
T_9	Estimates	-6771.31	73.50	376.60	216.44	-2.92	-75.58	-3.61	13.02	1.87	13.20	0.83
	Std Error	3146.28	77.67	766.49	148.45	1.14	27.53	2.16	5.84	2.20	16.86	
T_{10}	Estimates	-3448.12	162.26	1129.35	-66.42	-3.04	-10.03	0.27	0.92	2.15	-10.61	0.67
	Std Error	3870.68	96.34	884.01	97.28	1.42	24.30	1.62	6.44	2.42	16.21	
T_{11}	Estimates	-2224.33	136.69	-138.80	48.62	-3.43	-72.44	-1.31	25.07	0.01	13.15	0.76
	Std Error	4485.66	138.41	1067.17	108.14	1.66	34.88	0.97	15.32	3.46	17.20	
T_{12}	Estimates	-4557.69	116.41	488.27	144.23	-3.91	-125.56	-2.38	29.67	-0.89	14.12	0.88
	Std Error	2377.05	68.39	417.78	83.34	0.98	29.60	1.16	11.65	1.88	6.01	

Table 5. Model summary of the nonlinear regression of treatment responses on nutrient uptake of rice in rabi season

Treatments		b_0	b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8	b_9	R^2
T_1	Estimates	1295.69	36.12	211.27	-39.55	-1.62	-36.11	-0.48	4.17	1.63	6.59	0.91
	Std Error	2503.54	55.01	344.50	71.55	0.79	11.48	0.52	5.62	0.93	7.33	
T_2	Estimates	-490.34	113.67	159.03	-8.79	-1.76	-28.28	-0.35	4.12	0.66	4.53	0.86
	Std Error	1474.74	66.71	238.53	51.81	0.91	14.25	0.41	5.36	1.12	5.80	
T_3	Estimates	2521.93	-83.12	768.00	-83.57	-0.82	-85.71	-0.14	14.40	1.21	6.93	0.96
	Std Error	1322.14	91.64	166.28	50.13	0.67	15.12	0.40	4.42	0.54	3.62	
T_4	Estimates	2779.93	10.66	271.69	-90.81	0.23	-62.26	-0.03	6.91	-0.35	12.31	0.83
	Std Error	3046.19	111.91	274.82	62.30	1.14	35.65	0.73	9.70	1.28	9.16	
T_5	Estimates	-3444.54	232.11	56.88	67.47	-0.66	-3.81	-0.21	-2.38	-1.94	2.12	0 .75
	Std Error	2195.94	148.25	649.20	71.69	0.75	27.37	1.04	11.25	1.28	12.33	
T_6	Estimates	4075.69	-24.07	-660.93	3.57	-0.26	-76.70	-0.57	25.48	-1.35	16.33	0.92
	Std Error	3180.27	102.46	596.39	46.32	0.73	23.79	0.28	10.22	1.76	8.96	
T_7	Estimates	-579.68	20.63	914.04	-46.75	-5.35	11.16	0.74	11.30	6.12	-28.60	0. 94
	Std Error	563.95	71.45	457.62	35.08	1.56	17.57	0.80	6.05	2.58	16.04	
T_8	Estimates	-3234.09	172.11	17.03	39.36	-1.14	-12.93	-0.34	2.71	-0.33	2.14	0.89
	Std Error	1957.74	105.38	142.64	53.92	0.77	10.31	0.52	3.83	0.59	3.67	
T_9	Estimates	-2983.88	263.02	122.10	-16.78	-2.06	-6.71	0.37	2.54	-0.72	-1.14	0.89
	Std Error	1567.66	95.59	511.55	53.13	1.00	7.52	0.76	5.80	0.95	8.35	
T_{10}	Estimates	-4474.84	139.50	510.05	71.73	-1.77	-11.71	-1.27	-2.22	1.48	-0.72	0.94
	Std Error	1318.92	71.18	317.66	58.02	0.72	24.49	1.06	9.34	1.41	6.36	
T_{11}	Estimates	-2958.63	296.48	-882.27	117.62	-0.91	-16.55	-1.10	6.90	-3.42	15.45	0.85
	Std Error	2469.24	146.49	599.84	65.35	1.32	19.28	0.76	8.09	1.52	6.24	
T_{12}	Estimates	4891.11	-44.71	-3044.50	229.38	3.02	-45.96	-5.81	35.24	-5.89	71.80	0. 76
	Std Error	3196.00	89.36	1517.29	104.78	2.14	14.49	2.97	13.89	2.23	34.88	

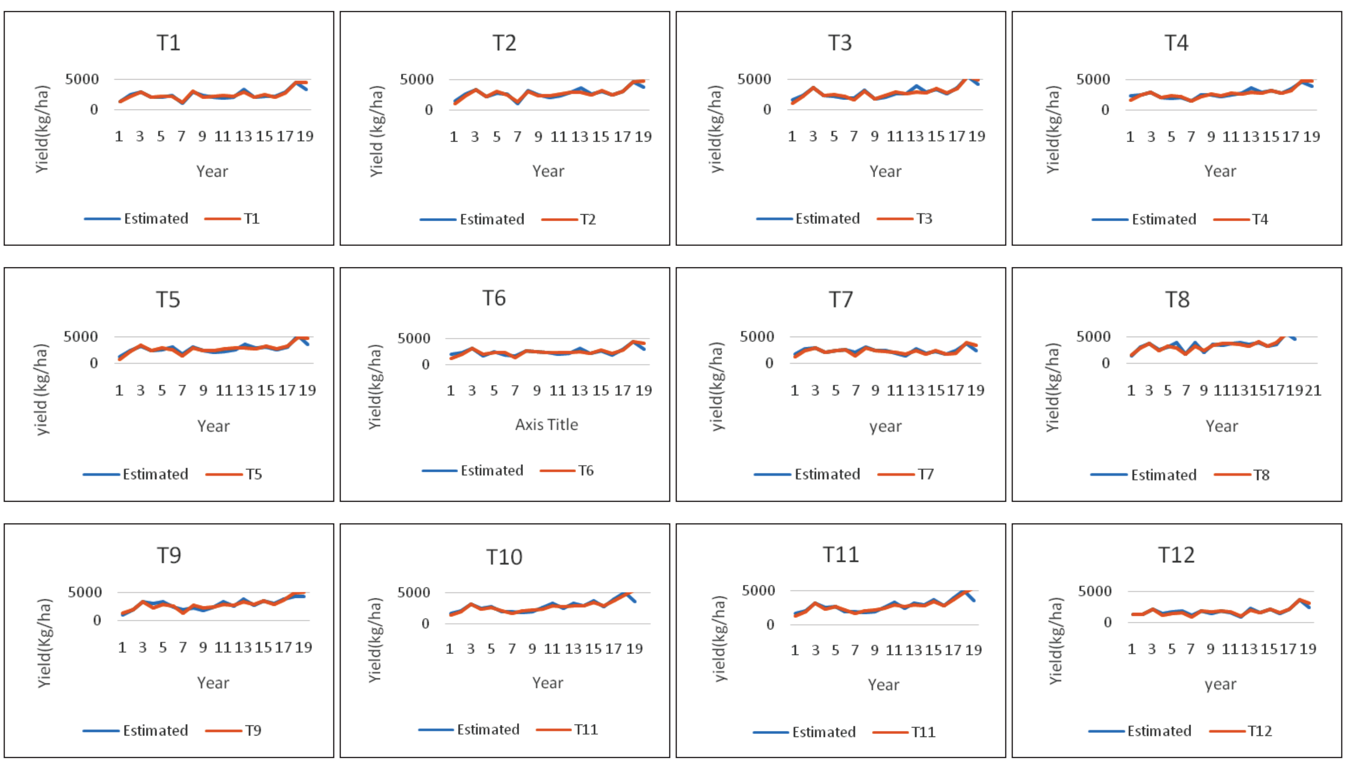

Fig. 2. Comparison of actual and estimated rice yield using quadratic model in *kharif* season

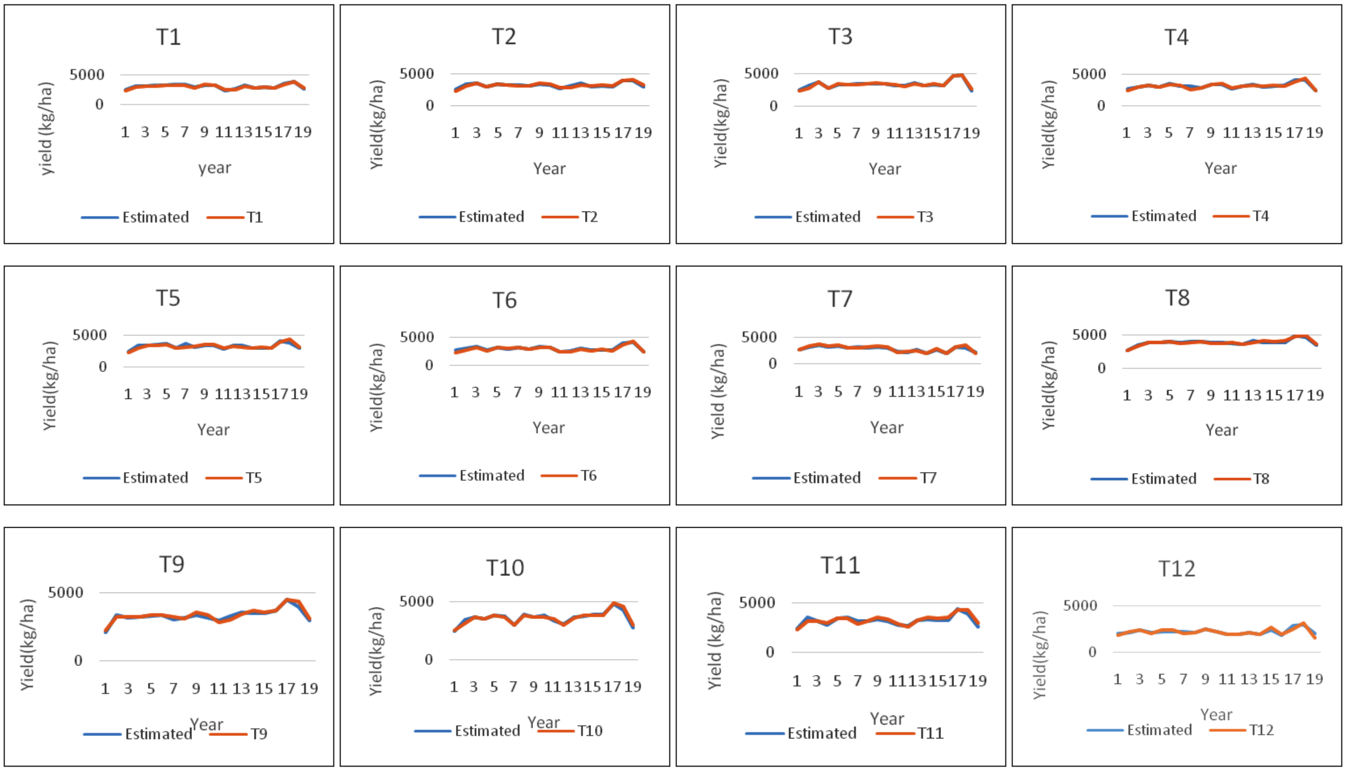

Fig. 3. Comparison of actual and estimated rice yield using quadratic model in *rabi* season

that the relationship existing between crop yield and nutrient uptake is not linear (Fig. 2 and 3).

4. CONCLUSION

The grain yield in Rabi season was found to be higher and more consistent than that of *kharif* season. The uptake of NPK was found to be maximum under T8 (100 percent NPK + FYM @5t/ha to the *kharif* rice only) which was ranked as the best treatment for maximum grain yield in both the seasons. Despite the idealized vegetation and climatic conditions, the empirical results derived here highlights the nonlinear relationship existing between nutrient uptake of N, P, K and rice yield and can effectively employed to quantify it resulting in high degree of predictability. A similar approach can be encouraged to contribute to our understanding of both regional and larger-scale variations in nutrient uptake dynamics in a more holistic manner.

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