

EFFECT OF PHOSPHORUS AND SULPHUR MANAGEMENT ON YIELD, NUTRIENT UPTAKE, AND NUTRIENT USE INDICES IN RICE BEAN (*VIGNA UMBELLATA* L.)

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ABSTRACT

The Rice Bean (RB) (*Vigna umbellata* L.), which is native to South and Southeast Asia, is an annual underutilized grain legume crop that belongs to the family Fabaceae. It has a higher nutritional quality compared to many other legumes within the *Vigna* family. Yet, there is a lack of understanding of the impact of plant nutrients on the diverse attributes of RBs. Therefore, the research aims to examine the effect of diverse levels of Phosphorus (P) along with Sulphur (S) on the yield, Nutrient Uptake (NU), and nutrient use indices of RB crops. During the *Kharif* seasons of 2017-18 and 2018-19, a field experiment is conducted at an agricultural research farm in West Bengal. A total of 3 diverse levels of P and S are tested with Factorial Randomized Block Design (FRBD) (3×3+1 factorial). As per the outcome, an application of 30kg/ha S along with 80kg/ha P has recorded higher yield, nutrient content and uptake, and nutrient use indices of RB crop.



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1. INTRODUCTION

The RB, which is a warm-season self-pollinated annual vine legume crop, belongs to the Leguminosae family [3], [1]. RB is categorized as a crop that is well reformed to sub-humid regions with 1000 to 1500mm precipitation [6]. The RB seeds are a nutrients' well-balanced source [11]. Nutrient management is a basic agronomic practice that alters the yield potential of any crop that needs attention for higher productivity. RBs' nutritional quality is higher when analogized to that of several other *Vigna* family legumes [15]. The nutritional quality and crop yield are improved by fertilizer application. The effects of the fertilizer applied on the plant significantly impact the growth along with yield [21], [8]. RB necessitates a short day length to harvest seeds and has a high yield potential [20].

In crop plants, macro and micronutrients influence seed yield along with its quality [9]. The S and P growing application, singly and combination, can increase the Grain Yield (GY) as well as contents of N, P, and K over control [19]. The crop's quality and quantity are augmented by P and S. P is a second major nutrient for plants because of their high requirement [2]. Variation in P requirements depends on the nutrient content of the soil. S is the 2nd important plant nutrient after P for pulses. These nutrient elements' interactions might impact available P along with S (critical levels) below which the crop response to their application might be observed [16], [12], [14]. S is an essential element for plant growth, ranking in prominence with N and P in plant protein formation [4]. P's application influences the pulses' yield and nutritional quality [10], [18].

RB is a crucial legume crop in many areas, but its yield, growth, and grain quality can be limited by P and S deficiencies. Thus, for optimizing productivity and nutritional value, understanding P along with S application's effects on RBs is essential. Numerous prevailing studies have examined the impact of P and S on crop growth and yield of crops, such as wheat, moth bean, mungbean, etc. Yet, there is a lack of studies on P and S (effect) in RBs. Thus, it aims to appraise P and S levels' impact on the yield, NU, along with nutrient use indices of RBs. Examining the different levels of P as well as S on the GY, Stover Yield (SY), and Biological Yield (BY) of RBs is the study's objective. Also, the study investigates the nutrient use indices of P and S and nutrient content along with uptake in grain, stover, as well as total (grain + stover) of RBs.

2. MATERIALS AND METHODS

2.1. Experiment site

During 2017-18 and 2018-19 (*kharif* seasons), a field experiment was directed at the agricultural research farm, Palli Siksha Bhavana, Visva-Bharati, Sriniketan, Birbhum, West Bengal, which is at 23°39' N latitude, 87°42' E longitude, along with 58.90 m above mean sea level under the sub-humid, semi-arid region of West Bengal. The experimental site soil was sandy loam in texture and slightly acidic (pH 6.2) in reaction with 0.48 dsm⁻¹(electrical conductivity). The available organic carbon estimated by Walkley along with Black's rapid titration technique was 0.74%. The available Nitrogen (N₂) estimated by the alkaline KMNO₄ was 263kg/ha⁻¹. The existing P(P₂O₅) in the soil estimated by Bray's methodology no. 1 was 25kg/ha⁻¹. The available K(K₂O) in the soil estimated by normal NH₄ OAC flame photometer was 130kg/ha⁻¹, and available S(SO₄²⁻) was 27kg/ha⁻¹.

2.2. Experimental design and treatment combination

The experiment was laid out in an FRBD (3×3+1 factorial), which comprised combinations of absolute control along with '3' levels of S and P at 10, 20, and 30 kg/ha along with 40, 60, and 80 kg/ha, respectively. N₂ and Potassium (K) were applied as a blanket application in RB crops in 2017 and 2018 at 30 and 60kg/ha and 40 and 30kg/ha, respectively. The gross experimental area, gross plot size, and net plot size were 692.64 m², 3×6 m², and 2×3 m², respectively.

2.3. Crop management

The RB variety (RBL-6) was sown on July 19, 2017, and July 19, 2018, with a seed rate of 30kg/ha. The average maturity period for RBs ranged from 106-122 days. The nutrient sources of P, K, S, and N₂ were diammonium phosphate, muriate of potash, elemental S, along with urea. Two irrigations were given to RBs in 2017 and 2018 at 61 and 107 DAS and 77 and 97 DAS, respectively. Two-hand weeding was given to RBs in 2017 and 2018 at 35 and 60 DAS and 32 and 59 DAS, respectively. In 2017 and 2018, Chloroxa-505 was sprayed for RBs to protect the crop.

2.4. Plant Analysis

For dry matter accumulation estimation, plant samples were gathered; also, were grounded into a fine powder along with passed via a 40 mm mesh sieve. This prepared sample was then used for chemical analysis to define the concentration of N₂, P, K, along with S in the plant and to calculate the uptake of these nutrients in RBs after harvesting. The N₂, P, K, along with S content was determined by employing Kjeldahl, Vanadomolybdophosphoric yellow colour, flame photometry, and turbidimetric methods, respectively. Nutrient uptake was estimated using the formula given below,

$$\text{Nutrient uptake by crops (kg/ha)} = \frac{(\text{Stover yield (kg/ha)} \times \text{Nutrient content (\%)})}{100} + \frac{(\text{Grain yield (kg/ha)} \times \text{Nutrient content (\%)})}{100}$$

2.5. Nutrient use efficiencies

RBs' P use indices were Agronomic P Use Efficiency (UE) (APUE), Argo-Physiological P UE (APPUE), Physiological P UE (PPUE), Apparent P Recovery (APR), Physiological Efficiency Index of P (PEIP), P Efficiency Ratio (PER), P Harvest Index (HI) (PHI), along with Partial Factor Productivity (PFP). S use indices of RBs were Agronomic S UE (ASUE), Physiological S UE (PSUE), Agro- Physiological S UE (APSUE), Apparent S Recovery (ASR), S Efficiency Ratio (SER), Physiological Efficiency Index of S (PEIS), S HI (SHI), along with Partial Factor Productivity (PFP). The formulas to calculate the indices are given below.

Phosphorus use indices:

$$\text{APUE} = (Y_t - Y_0) / A_t; \text{PPUE} = (BY_t - BY_0) / (U_t - U_0); \text{APPUE} = (Y_t - Y_0) / (U_t - U_0); \text{APR} = \frac{(U_t - U_0)}{P_a} \times 100; \text{PER} = Y_d / P_h; \text{PEIP} = Y_g / P_h; \text{PHI} = (P_s / P_t) \times 100; \text{and PFP} = Y_g / P_a,$$

Here, Y_t implies the GY in the test treat, Y_0 is the GY in the control plot, A_t is the units of P applied in the test treat, BY_t is the BY in the treated plot, BY_0 is the BY in the control plot, U_t is the (Grain+Stover) uptake in the test treat, U_0 is the P (Grain+Stover) uptake in the control plot, Y_d is the dry matter yield, P_h is the P accumulated at harvest, Y_g is the GY, P_b is the P absorbed by biomass, P_s is the P uptake by the grain at harvest, P_t is the P uptake by the whole plant at harvest, and P_a is the P applied to the test treat.

Sulphur use indices:

$$\text{ASUE} = (Y_t - Y_0) / A_t; \text{PSUE} = (BY_t - BY_0) / (U_t - U_0); \text{APSUE} = (Y_t - Y_0) / (U_t - U_0); \text{ASR} = \frac{(U_t - U_0)}{S_a} \times 100; \text{SER} = Y_d / S_h; \text{PEIS} = Y_g / S_h; \text{SHI} = (S_s / S_t) \times 100; \text{and PFP} = Y_g / S_a.$$

Here, A_t implies the units of S applied in the test treat, U_t depicts the S (Grain+Stover) uptake in the test treat, U_0 signifies the S (Grain+Stover) uptake in the control plot, S_h is the S accumulated at harvest, S_b is the S absorbed by biomass, S_s is the S uptake by the grain at harvest, S_t is the S uptake by the whole plant at harvest, and S_a is the S applied to the test treat.

2.6. Statistical analysis

By adopting the analysis of variance (ANOVA), the data recorded for diverse characteristics were subjected to statistical analysis.

3. RESULTS

3.1. Performance of different levels of Phosphorus and Sulphur on the yield parameters in rice bean

The RB crop was treated with '3' levels of S (10, 20, and 30kg/ha), '3' levels of P (40, 60, and 80kg/ha), and absolute control. In 2017, the highest GY, SY, BY, and HI were recorded as 968.2, 1935.6, 2903.8 kg ha⁻¹, and 33.3%, respectively for S (30kg/ha) and 974.2, 1959.9, 2934.1 kg ha⁻¹, and 33.2%, respectively for P (80kg/ha). Also, during 2018, the GY, SY, BY, and HI were observed as high for the application of 30kg/ha of S and 80kg/ha of P. In Table 1, the results of RBs' different yield attributes are summarized.

Table 1: Different levels of phosphorus and sulphur on the yield of rice bean

Treatments	Grain yield (kg ha ⁻¹)		Stover yield (kg ha ⁻¹)		Biological yield (kg ha ⁻¹)		Harvest index (%)	
	2017	2018	2017	2018	2017	2018	2017	2018
Sulphur levels (kg ha⁻¹)								
S0: 10	914.0	1017.4	1810.4	2014.7	2724.3	3032.1	33.6	33.6
S1: 20	946.1	1071.9	1898.4	2099.8	2844.5	3171.7	33.3	33.8
S2: 30	968.2	1101.4	1935.6	2153.0	2903.8	3254.4	33.3	33.8
SEm ±	10.0	6.5	22.9	7.7	23.5	12.1	0.4	0.1
CD (p=0.05)	29.9	19.2	68.0	23.0	69.9	36.1	NS	NS
Phosphorus levels (kg ha⁻¹)								
P0: 40	905.9	1011.3	1807.8	2010.7	2713.7	3022.0	33.4	33.5
P1: 60	948.1	1074.9	1876.7	2109.6	2824.8	3184.4	33.6	33.7
P2: 80	974.2	1104.6	1959.9	2147.2	2934.1	3251.8	33.2	34.0
SEm ±	10.0	6.5	22.9	7.7	23.5	12.1	0.4	0.1
CD (p=0.05)	29.9	19.2	68.0	23.0	69.9	36.1	NS	NS
Control vs Rest								
Control	731.3	834.0	1683.3	1662.7	2414.6	2496.7	30.3	33.4
Rest	942.7	1063.6	1881.5	2089.1	2824.2	3152.7	33.4	33.7
SEd ±	18.3	11.8	41.8	14.1	42.9	22.2	0.7	0.2
CD (p=0.05)	38.5	24.8	87.8	29.7	90.2	46.6	1.5	NS

From the above observations, it was noted that all the yield attributes of RBs were higher for S at 30kg/ha and P at 80kg/ha. The HI remained the same for the application of S at 20kg/ha and 30kg/ha, i.e., 33.3% for 2017 and 33.8% for 2018. Also, during 2017 and 2018, the HI was the same (33.6%). Also, the rest of the treatments attained the maximum GY, SY, BY, and HI for 2017 and 2018 when comparing the control with the rest of the treatments.

3.2. Effect of phosphorus and sulphur application on nutrient uptake (kg/ha) by grain, stover, and total (grain+stover)

Phosphorus levels on nutrient content and uptake

The data obviously indicated that the application of P (40, 60, as well as 80kg/ha) augmented the N₂, P, K, along with S content and uptake by seed, stover, and total uptake. Table 2 represents the level of P on nutrient content in the stover and grain of the RB crop.

Table 2: Phosphorus level on nutrient content

		Phosphorus levels (kg ha ⁻¹)					
			P0: 40	P1: 60	P2: 80	SEm ±	CD (p=0.05)
Nitrogen content (%)	Grain	2017	2.71	2.84	2.97	0.04	0.11
		2018	2.92	2.98	3.08	0.03	0.08
	Stover	2017	1.17	1.24	1.28	0.01	0.03
		2018	1.18	1.26	1.3	0.01	0.02
Phosphorus content (%)	Grain	2017	0.41	0.43	0.47	0.01	0.02

Potassium content (%)	Stover	2018	0.42	0.46	0.49	0.01	0.03
		2017	0.21	0.22	0.24	0.01	0.02
		2018	0.22	0.24	0.26	0.01	0.02
	Grain	2017	0.91	0.94	0.96	0.01	0.03
		2018	0.93	0.97	0.98	0.01	0.02
		2017	1.41	1.45	1.47	0.01	0.02
Sulphur content (%)	Stover	2018	1.42	1.46	1.48	0.01	0.02
		2017	0.15	0.16	0.17	0.004	0.01
		2018	0.16	0.17	0.18	0.002	0.01
	Grain	2017	0.078	0.081	0.091	0.002	0.01
		2018	0.08	0.082	0.092	0.003	0.01
		2017	0.078	0.081	0.091	0.002	0.01

The application of P80kg/ha attained a significant maximum N₂, P, K, and S contents of 2.97%, 0.47%, 0.96%, and 0.17% for grain and 1.28%, 0.24%, 1.47%, and 0.091% for stover, respectively during 2017. Likewise, the application of P80kg/ha attained the maximum N₂, P, K, along with S contents of 3.08%, 0.49%, 0.98%, and 0.18% for grain and 1.3%, 0.26%, 1.48%, and 0.092% for stover in 2018. This treatment was significantly higher when compared to P 60kg/ha and 40kg/ha during both 2017 and 2018. In Figure 1, the graphical illustration of the P levels on NU of seed, stover, and total is represented.

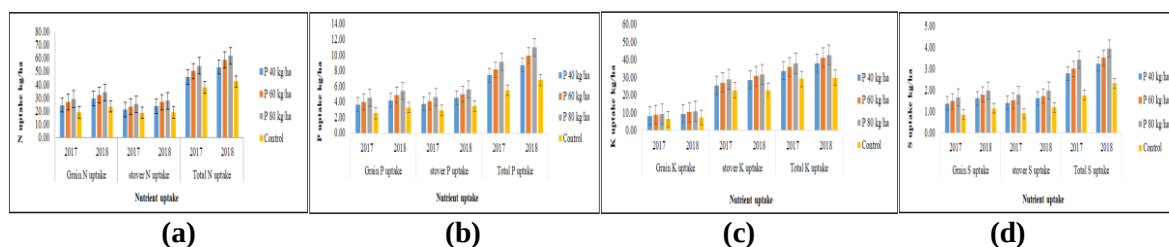


Figure 1: Phosphorus levels on nutrient uptake: (a) N uptake, (b) P uptake, (c) K uptake, and (d) S uptake

When compared to 2017, the total N, P, K, as well as S uptakes for 2018 were 61.95kg ha⁻¹, 11.05kg ha⁻¹, 42.68kg ha⁻¹, and 3.97kg ha⁻¹ with P 80kg/ha, which were found to be higher. The remaining treatments were significantly higher than the control.

Sulphur levels on nutrient content and uptake

S application at 30 kg/ha augmented the N₂, P, K, and S content and uptake in both grain and stover, along with the total uptake in RBs. The level of S on nutrient content in the stover and grain of the RB crop is depicted in Table 3.

Table 3: Sulphur level on nutrient content

		Sulphur levels (kg ha ⁻¹)					
			S0: 10	S1: 20	S2: 30	SEm ±	CD (p=0.05)
Nitrogen content (%)	Grain	2017	2.78	2.82	2.92	0.04	0.11
		2018	2.92	3	3.06	0.03	0.08
	Stover	2017	1.2	1.22	1.27	0.01	0.03
		2018	1.22	1.24	1.28	0.01	0.02
Phosphorus content (%)	Grain	2017	0.41	0.43	0.46	0.01	0.02
		2018	0.44	0.45	0.48	0.01	0.03
	Stover	2017	0.21	0.22	0.23	0.01	0.02
		2018	0.23	0.24	0.25	0.01	0.02
Potassium content (%)	Grain	2017	0.92	0.93	0.96	0.01	0.03
		2018	0.94	0.96	0.98	0.01	0.02
	Stover	2017	1.41	1.46	1.47	0.01	0.02
		2018	1.43	1.47	1.47	0.01	0.02
Sulphur content (%)	Grain	2017	0.15	0.16	0.17	0.004	0.01
		2018	0.16	0.17	0.18	0.002	0.01
	Stover	2017	0.078	0.081	0.091	0.002	0.01

		2018	0.08	0.082	0.092	0.003	0.01
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In 2017, the application of 30kg/ha of S recorded the maximum N₂, P, K, along with S contents of 2.92%, 0.46%, 0.96%, and 0.17% for grain and 1.27%, 0.23%, 1.47%, and 0.091% for stover, respectively. Similarly, the application of S at 30kg/ha attained the maximum N₂, P, K, along with S content of 3.06%, 0.48%, 0.98%, and 0.18% for grain and 1.28%, 0.25%, 1.47%, and 0.092% for stover in 2018, respectively. This treatment was significantly higher than S at 20kg/ha and 10kg/ha during both 2017 and 2018. In Figure 2, the graphical illustration of the S levels on NU of seed, stover, as well as total is represented.

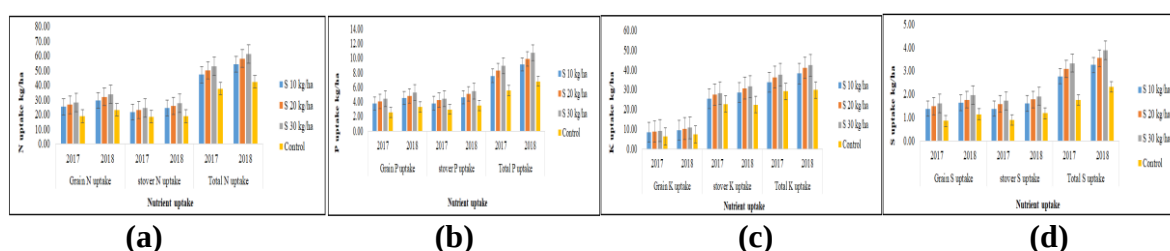


Figure 2: Sulphur levels on nutrient uptake: (a) N uptake, (b) P uptake, (c) K uptake, and (d) S uptake

2018 had recorded the highest N₂, P, K, together with S uptake of 33.75kg/ha, 5.27kg/ha, 10.78kg/ha, and 1.97 for grain and 27.67kg/ha, 5.47kg/ha, 31.72kg/ha, and 1.92 kg/ha for stover, respectively, with the application of S at 30kg/ha, while comparing 2017 and 2018. Further, the total uptake of the nutrients was found as high in 2018 when 30kg/ha of S was applied. The remaining treatments were higher than the control during both years.

3.3. Nutrient use efficiencies in rice bean

In Table 4, the response of P levels on nutrient use indices, such as APUE, PPUE, APPUE, APR, PEIP, PER, PHI, along with PFP is provided.

Table 4: Phosphorus use indices for different levels of sulphur, phosphorus, and absolute control

Treatments		Sulphur levels (kg/ha)					Phosphorus levels (kg/ha)					Control(C) vs Rest(R)			
		10	20	30	SEm±	CD	40	60	80	SEm±	CD	C	R	SEd±	CD
APUE	2017	3.24	3.77	4	0.25	NS	4.37	3.61	3.04	0.25	0.73	0	3.67	0.45	0.95
	2018	3.16	4.05	4.62	0.11	0.34	4.43	4.01	3.38	0.11	0.34	0	3.94	0.16	0.43
PPUE	2017	155.3	160.3	172	9	NS	157.6	184.1	145.9	9	NS	0	162.5	16.5	34.7
	2018	302.3	235.7	209.8	30.4	NS	338.9	226.4	182.6	30.4	90.3	0	249.3	55.5	116.5
APPUE	2017	110.6	81.7	71.7	13.1	NS	109	86.3	68.7	13.1	38.9	0	88	18.5	50.2
	2018	103.8	81.7	73.2	10.8	NS	115.6	77.9	65.2	10.8	32.1	0	86.2	19.8	41.5
APR (%)	2017	4.06	4.64	5.65	0.33	0.98	5.65	4.35	4.53	0.33	NS	0	4.78	0.6	1.26
	2018	3.74	5.03	6.53	0.41	1.23	4.83	5.2	5.28	0.41	NS	0	5.1	0.76	1.59
PEIP	2017	121.7	114.6	109	2.67	7.92	121.6	116.8	106.9	2.67	7.92	132.1	115.1	4.87	10.23
	2018	112.5	109.1	103.4	2.14	6.36	116.4	108.3	100.3	2.14	6.36	122.1	108.3	3.91	8.21
PER	2017	752.9	706.5	680.3	15.8	46.9	749	723	667.7	15.8	46.9	971.8	713.2	28.8	60.5
	2018	705.8	665	637.8	13.8	40.9	722.6	663.7	622.3	13.8	40.9	855.3	669.5	25.1	52.8
PHI (%)	2017	49.76	49.05	49.95	0.8	NS	49.52	49.61	49.62	0.8	NS	46.58	49.59	1.45	3.05
	2018	49.53	48.6	49	0.56	NS	48.33	49.31	49.49	0.56	NS	48.65	49.04	1.02	NS
PFP	2017	16.44	16.98	17.21	0.25	NS	22.65	15.8	12.18	0.25	0.74	0	16.88	0.45	0.95
	2018	18.21	19.11	19.68	0.11	0.32	25.28	17.91	13.81	0.11	0.32	0	19	0.2	0.42

APUE, PPUE, APPUE, PEIP, PER, and PFP were increased with lower levels of P application (40kg/ha) compared to higher levels during both 2017 and 2018. In 2017, the APR decreased with the augmentation of the P level; yet, it augmented with the surge of P in 2018. In 2017 and 2018, APUE, APR, and PFP amplified with the rise in S levels. The remaining treatments recorded higher values than the control for APUE, PPUE, APPUE, APR, PHI, and PFP. Table 5 shows the S use indices for different levels of S, P, along with absolute

control.

Table 5: Sulphur use indices for different levels of sulphur, phosphorus, and absolute control

Treatments		Sulphur levels (kg/ha)					Phosphorus levels (kg/ha)					Control(C) vs Rest(R)			
		10	20	30	SEm±	CD	40	60	80	SEm±	CD	C	R	SEd±	CD
ASUE	2017	18.27	10.74	7.9	0.52	1.54	10.61	12.51	13.79	0.52	1.54	0	12.3	0.94	1.98
	2018	18.34	11.89	8.91	0.63	1.87	10.05	13.75	15.36	0.63	1.87	0	13.05	1.15	2.41
PSUE	2017	313.5	332.6	311.9	25	NS	297.5	345.6	314.8	25	NS	0	319.3	45.7	96.1
	2018	599.9	565.7	502.1	26.9	80	594.1	586.9	486.7	26.9	80	0	555.9	49.2	103.3
APSUE	2017	199	167	150.6	11.2	33.4	186.2	183	147.4	11.2	33.3	0	172.2	20.5	43.1
	2018	206.1	198	176.8	12.1	36.1	202.3	204	174.6	12.1	36.1	0	193.7	22.2	46.6
ASR (%)	2017	10.14	6.64	5.26	0.53	1.58	5.61	6.85	9.59	0.53	1.58	0	7.3	1	2
	2018	9.42	6.17	5.22	0.49	1.47	4.95	6.78	9.08	0.49	1.47	0	6.94	0.9	1.9
PEIS	2017	333.2	307.4	291	7.5	22.3	329.6	317.3	284.7	7.5	22.3	413.4	310.5	13.7	28.8
	2018	313.1	302.2	284.8	5.9	17.5	313.7	305.6	280.8	5.9	17.5	358.7	300	10.7	22.6
SER	2017	2058.7	1900.3	1817.4	57.1	169.8	2036.3	1962.2	1777.9	57.1	169.3	3041.5	1925.5	104.3	219.2
	2018	1963.2	1841.7	1756.7	31.5	93.6	1948.8	1872.1	1740.8	31.5	93.6	2510.5	1853.9	57.5	120.9
SHI (%)	2017	50.2	48.41	48.4	0.69	NS	49.52	49.33	48.15	0.69	NS	48.99	49	1.26	NS
	2018	50.56	49.97	50.68	0.88	NS	50.04	50.99	50.18	0.88	NS	49.8	50.4	1.61	NS
PFP	2017	91.4	47.3	32.27	0.54	1.6	55.3	57.2	58.48	0.54	1.6	0	56.99	0.98	2.06
	2018	101.74	53.59	36.71	0.62	1.83	61.02	64.71	66.32	0.62	1.83	0	64.02	1.13	2.37

During both years, ASUE, ASR, and PFP were high at 80kg/ha of P. APSUE, PEIS, and SER were recorded as high at 40kg/ha of P during both years. SHI was found as high with the application of 40kg/ha of P and 10kg/ha of S in 2017, and it was found as high for 60kg/ha of P and 30kg/ha of S in 2018. All the S use indices were found as high for both years with the application of 10kg/ha of S except for SHI. The rest of the treatments recorded significant and higher values than the control for ASUE, PSUE, APSUE, ASR, SHI, and PFP.

4. DISCUSSION

Higher levels of P and S generally lead to increased yield due to their crucial roles in plant growth and development. Increased GY, SY, BY, and HI are contributed by favourable weather conditions, lower disease infestation, along with optimal growth factors. As per the HI results, there was no noteworthy difference among the various P and S levels tested. Studies conducted by [13], [7] corroborate these findings, emphasizing the crucial role of P and S in crop yield. [15] found that 25:50:25 NPK kg/ha recorded the highest seed yield (1626kg/ha) and 30:60:30 NPK kg/ha recorded the highest SY of 2901kg/ha.

S and P application augmented the nutrient content, NU, along with total uptake throughout the study's years. S and P availability contributed to enhanced N₂ assimilation and utilization, resulting in increased N accumulation in the grain and stover. The positive interaction between S and K significantly influences plant growth and yield. N uptake was facilitated by the augmented dry matter accumulation and higher nutrient content. Also, the RB plants were more responsive to both P and S under the prevailing environmental conditions of that year, as per the higher nutrient content and uptake in 2018. [17] done research with similar results regarding the applied P and S in the nutrient content, NU, and total uptake. Likewise, [5] stated that the application of higher-level P produced the best results in NPKS content along with uptake by crop (*Vigna radiata* L.) compared with low levels.

The important indicators that signified how efficiently plants utilized P for growth and yield are the APUE, PPUE, and APPUE. APUE, PPUE, APPUE, PEIP, PER, and PFP were increased with lower levels of P application. The partial factor productivity of S and P was an important indicator of the efficiency of S use in relation to crop productivity. The plants that efficiently used the applied S and P led to increased ASR and APR. [2] found that the maximum APUE and ARE were observed lower level of P combined with S, and it

decreased at higher P rates in the wheat crop. Also, the study found that the increasing level of S decreases the ASUE at a given P level. Likewise, the ASR was found as higher for lower levels of S, which was similar to the present study. In Figure 5, the comparison of yield parameters, nutrient content, NU, and nutrient use indices is given.

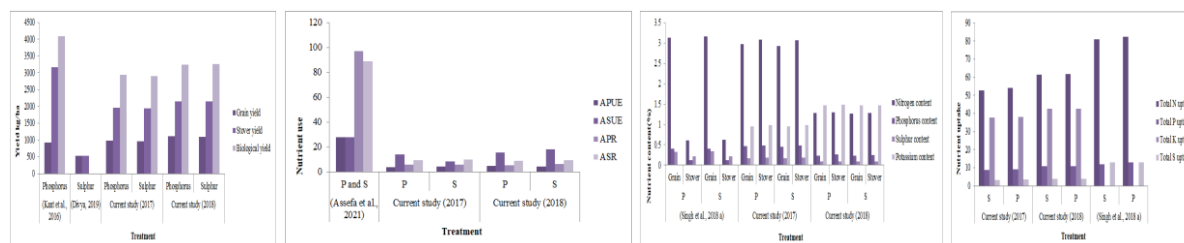


Figure 3: Comparison of yield parameters, nutrient content, nutrient uptake, and nutrient use indices

5. CONCLUSION

To analyze the impact of P and S on the yield, NU, along with nutrient use indices of RBs, the research conducted an experiment *Kharif* of 2017-18 and 2018-19 at an agricultural research farm. As per the study, nutrient content and NU of RBs were higher for S at 30kg/ha and P at 80kg/ha. Also, the crops in 2018-2019 showed the highest GY, SY, and BY. Moreover, the study found that the lower S rate of 10kg/ha was more effective in improving the S use indices compared to a higher S rate of 20kg/ha and 30kg/ha. Yet, the study only focused on the RB crop for two years. Thus, the study will compare the impact of P and S on RB with multiple succeeding crops in the future for a long period of time.

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