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Nutrient Uptake and Efficiency of Rice under Different Soil Conditions

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Abstract: A field experiment was conducted in loamy sand soils of Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal, Union Territory of Pondicherry, India to find out the rice performance under two different soil conditions by raising sesame in previous season and without it, during the year 2004-05 in two consecutive seasons in a Factorial Randomized Block Design (FRBD). The field was divided into 60 plots and in the summer season sesame was raised in 30 plots and the other 30 plots were kept fallow. In the next season (Kharif), rice was raised in all the 60 plots of two different situations viz., with sesame as previous crop (Situation I) and without sesame as pervious crop (Situation II) with two rice cultivars viz., ADT 38 and KR 99001 and five levels of nitrogen viz., 0, 50, 100, 150 and 200 kg N ha^{-1}. The uptake of Nitrogen (N), phosphorus (P) and potassium (K) by sesame was 30.4, 10.2 and 26.3 kg ha^{-1}, respectively, resulted in soil available N, P and K loss of 37.0, 19.8 and 29.0 kg ha^{-1}, respectively. The N and K uptake was equal under both situations at Active Tillering (AT) and Panicle Initiation (PI) but P was accumulated more in situation II in the stage AT but comparable at PI. This might be due to initial low requirement of nutrients met by inorganic sources and later situation I managed the nutrient lost in previous season with mineralization process, whereas the P, though applied as basal, might not be fully available in the initial stages itself and might have been fixed. The nutrient uptake by straw was higher in situation II owing to higher dry matter production and grain uptake was comparable because grain nutrient content is genetic character, not much influenced by management practices. The efficiency parameters (agronomic efficiency, physiological efficiency, harvest index and apparent N recovery) were found to be higher in situation I over situation II and they were more pronounced at lower levels of N.

Key words: Nitrogen, rice, sesame, uptake, efficiency

INTRODUCTION

Nitrogen is the most important nutrient for rice and its deficiency occurs almost everywhere, unless nitrogen (N) is applied through fertilizer. Rice is the maximum consumer of N fertilizer constituting one third of the total N consumption of the world (Saravana Pandian and Rani Perumal, 2002). Thus, N is the most critical input that limits rice productivity and increasing rice productivity would mean more supply of N to the crop. Lowland rice depends more on soil fertility than on fertilizers. The dependence of lowland rice on soil fertility is best illustrated by a Japanese saying "Grow paddy with soil fertility, Grow barley with fertilizers" (Yoshida, 1981). A specific situation in the Cauvery delta region of Tamil Nadu and Pondicherry is the crop rotation of rice-rice-sesame, where sesame is grown as rice-fallow crop during summer season with the use of residual moisture and nutrients of pervious season (Rabi) rice. Hence, no fertilizers are applied to the sesame, which is also an N responsive crop. The response of sesame to N fertilizer varies from 20-150 kg ha^{-1} (Hemalatha *et al*., 1999). This sesame may utilize the native soil N also for its growth and development. This may leads to deficiency of N in the soil for the next season rice cultivation. The

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deficit of soil native nutrient status may affect the nutrient up take and its use efficiency by the succeeding rice. Hence, this experiment was attempted to study the nutrient up take and its use efficiency by the rice grown after a sesame and it was compared with the up take and use efficiency of rice grown without sesame in previous season.

MATERIALS AND METHODS

Experimental Design and Treatment Details

The experiment was conducted in a loamy sand soil of Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal, Union Territory of Pondicherry, India in 2004-2005 season. The experimental site which is situated 12 km from Bay of Bengal, lies between latitude 10° 49' and 11° 01' North and longitude 78° 43' and 79° 52' East with an altitude of 4 m above Mean Sea Level (MSL). The initial soil analyses show that the soil was loamy sand in texture and falls in *Fluventic Haplustept* taxonomic class. The soil was optimum in bulk density (1.33 Mg m^{-3}) and particle density (2.66 Mg m^{-3}) with the total porosity of 50%. The soil reaction was neutral (pH: 7.61) and the electrical conductivity is low (EC: 0.21 dS m^{-1}). The soil was low in organic carbon content (0.32%) and available nitrogen ($KMnO_4$-N: 213 kg ha^{-1}), medium in available potassium (NH_4OAc-K: 262 kg ha^{-1}) and high in available phosphorus (Olsen-P: 31.4 kg ha^{-1}). The experiment was conducted in Factorial Randomized Block Design (FRBD) design with three replications.

The field was divided in 60 equal plots of 20 m^2. The experiment was carried out in two consecutive seasons. In the summerseason (*Chithirai pattam*), 30 plots of the field was raised with sesame and the other plots were kept fallow without any vegetation, as like the farmers practice to avoid nutrient loss through sesame. The sesame was cultivated with the residual nutrients of previous season (Rabi) rice without applying any fertilizers. In the Kharif season, the left out sesame stubbles of about 15-20 cm height were incorporated 15 days before transplanting. Rice was raised in all the 60 plots of two different situations viz., with sesame as previous crop and without sesame as pervious crop (situation II) with two cultivars viz., a medium duration variety of ADT 38 and a long duration pre-release culture of KR 99001 with five levels of N viz., 0, 50, 100, 150 and 200 kg N ha^{-1}. The treatment details are given in Table 1. The rice seedlings were transplanted in the spacing of 20×15 cm. The N was supplied through urea in four equal splits as basal, at Active Tillering (AT), Panicle Initiation (PI) and grain filling stages as per the treatment levels. Phosphorus (P) (at the rate of

Table 1: Treatment details (Rice varieties (V) under field conditions (S) with Nitrogen levels (N))

	Treatment details		
Notation	Previous season crop	Variety	N dose (kg ha^{-1})
$S_1V_1N_0$	Sesame	ADT 38	0
$S_1V_1N_{50}$	Sesame	ADT 38	50
$S_1V_1N_{100}$	Sesame	ADT 38	100
$S_1V_1N_{150}$	Sesame	ADT 38	150
$S_1V_1N_{200}$	Sesame	ADT 38	200
$S_1V_2N_0$	Sesame	KR99001	0
$S_1V_2N_{50}$	Sesame	KR99001	50
$S_1V_2N_{100}$	Sesame	KR99001	100
$S_1V_2N_{150}$	Sesame	KR99001	150
$S_1V_2N_{200}$	Sesame	KR99001	200
$S_2V_1N_0$	Fallow	ADT 38	0
$S_2V_1N_{50}$	Fallow	ADT 38	50
$S_2V_1N_{100}$	Fallow	ADT 38	100
$S_2V_1N_{150}$	Fallow	ADT 38	150
$S_2V_1N_{200}$	Fallow	ADT 38	200
$S_2V_2N_0$	Fallow	KR99001	0
$S_2V_2N_{50}$	Fallow	KR99001	50
$S_2V_2N_{100}$	Fallow	KR99001	100
$S_2V_2N_{150}$	Fallow	KR99001	150
$S_2V_2N_{200}$	Fallow	KR99001	200

50 kg ha^{-1}) was supplied through single super phosphate in two equal splits as basal and during AT; potassium (K) (at the rate of 50 kg ha^{-1}) through muriate of potash in four equal splits as that of N and zinc through zinc sulphate (at the rate of 12.5 kg ha^{-1}) as basal. A hand weeding was done at 25 days after transplanting to remove the competitive weeds in the field. A pesticide spray of monocrotophos at the rate of 250 mL ha^{-1} was given at 30 days after transplanting to control leaf folders. The Dry Matter Production (DMP) was recorded at the stages of AT and PI. The plant samples were analyzed for N, P and K content and multiplying with DMP, the uptake was calculated. The crop was harvested separately from the plots, threshed and winnowed and grain and straw yields were recorded. The N, P and K contents of grain and straw were analyzed, multiplied with dry weight of yields and the uptake was calculated. The observations collected from the field experiment and the data on the results of analysis of soil and plant samples were subjected to statistical analysis as per the procedure of Gomez and Gomez (1984).

Computation of Efficiency Parameters

Agronomic Efficiency (AE)

The response of rice (increase in grain yield per kg of fertilizer N applied) in different treatments were calculated from the formula:

$$AE = \{(Y_t - Y_0)/X\} \text{ (Yoshida, 1981)}$$

Where,

Y_t : Grain yield in treated plot in (kg ha^{-1})
Y_0 : Grain yield in control plot in (kg ha^{-1})
X : Total N applied in (kg ha^{-1})

Physiological Efficiency (PE)

Physiological efficiency is the efficiency with which the crop utilizes the acquired N to produce more grains. It was computed as follows:

$$PE = (dy/dNu) \text{ (Yoshida, 1981)}$$

Where,

dy : Incremental grain yield in a N applied treatment over zero N (kg ha^{-1})
dNu : Incremental crop N uptake in a N applied treatment over zero N (kg ha^{-1})

Harvest Index (HI)

Harvest index represents the ratio of quantity of economic produce to total biomass

HI = (Grain yield/Total biomass at harvest) (Reddy and Reddi, 2002).

Apparent N Recovery (ApN)

$$ApN = (dNu/X)$$

Where,

dNu : Incremental crop N uptake in a N applied treatment over zero N (kg ha^{-1})
X : Total N applied in (kg ha^{-1})

RESULTS AND DISCUSSION

The sesame mobilized the macronutrients from the soils and accumulated as an uptake of 30.4 kg N ha^{-1}, 10.197 kg P ha^{-1} and 26.324 kg K ha^{-1}. This range of macronutrient uptake was reported by Ravindar *et al.* (1996); Singh *et al.* (2001) and Sumathi and Jaganathan (1999). Cultivation of sesame resulted in the soil available macronutrient loss of 37 kg N ha^{-1}, 19.8 kg P ha^{-1} and 29 kg K ha^{-1}.

Nitrogen Uptake at Active Tillering

There were no significant differences in N uptake under the situations studied (Table 2). Each N level performed similarly under both situations. The reason might be that the requirement and accumulation of N in crops at initial stages would be low as reported by Angayarkanni and Ravichandran (2001) and hence be met out under both the field condition arising due to raising and without sesame in previous season. This is in agreement with the findings of Palaniappan and Siddeswaran (1994) who witnessed no variations in the N uptake by rice at initial stages of crop growth due to different N levels.

Nitrogen Uptake at Panicle Initiation

The same trend as that of AT was noticed here also, but the uptake values were found to be high (Table 2). In general, increasing N levels increased the crop N uptake. The same observation was reported by Palaniappan and Siddeswaran (1994).

Nitrogen Uptake by Straw

The N uptake by straw was found to be significantly higher in situation II (43.61 kg ha^{-1}) than in situation I (37.45 kg ha^{-1}) (Table 2). This was well established in long duration KR 99001, but not in medium duration ADT 38. The variation might be due to higher need of N during PI for long duration variety as reported by Sivasamy *et al.* (1994), who observed the maximum rate of N uptake from urea during PI to first flowering phase in long duration CR 1009.

Nitrogen Uptake by Grain

The N uptake by seeds was not significantly influenced by the situations. Each N level performed similarly under both situations (Table 2). The N levels increased the N uptake but not significantly. The N uptake by grains was found to be low in control, which is quite expected.

Phosphorus Uptake at Different Growth Stages

The P uptake during AT was found to be significantly higher in situation II (2.55 kg ha^{-1}), where the DMP was higher over situation I and accordingly manifested higher P uptake than in situation I (2.34 kg ha^{-1}) (Table 2). The higher uptake of P by medium duration variety ADT 38 in situation II was with 200, 150 and 100 kg N ha^{-1}, but in situation I, it was only with 200 kg N ha^{-1}, revealing the need of N in situation I for P uptake. This might be due to the reason that in situation I the biomass production was high only with 200 kg N ha^{-1}. This possible correlation of N supply with P uptake was pronounced from the findings of Omar Hattab *et al.* (2000). At PI stage the P uptake was not influenced by the situations studied, the varieties and N levels compared. This might be due to the reason that at this stage of crop, equal amount of dry matter was produced by both situations. Increasing N levels increased the P uptake, which was also observed by Omar Hattab *et al.* (2000).

The P uptake of straw was found to be higher in situation II (10.31 kg ha^{-1}) than in situation I (9.31 kg ha^{-1}). The higher straw yield under situation II resulted in higher P accumulation in straw. Increasing N levels increased the P uptake due to higher DMP. With 150 kg N ha^{-1}, the situation II recorded higher P uptake (12.08 kg ha^{-1}) by producing more biomass than in situation I (9.51 kg ha^{-1}). There was no significant variation in P uptake by grain under different situations. The uptake was found to be increased with increased N levels for both varieties under both situations, but the increase was not significant. This slight variation might be due to the variations in grain yield owing to N levels.

Table 2: N and P uptake of rice crop under different field condition (kg ha^{-1})

	N uptake at AT (kg ha^{-1})			**N uptake at PI (kg ha^{-1})**		
Treatments	V_1	V_2	Mean	V_1	V_1	Mean
S_1N_0	7.33	7.20	7.27	29.21	26.94	28.08
S_1N_{50}	8.48	9.98	9.23	46.37	32.04	39.20
S_1N_{100}	14.05	13.21	13.63	57.30	46.85	52.08
S_1N_{150}	16.49	18.09	17.29	58.00	51.23	54.62
S_1N_{200}	18.21	19.64	18.92	60.75	54.45	57.60
Mean	12.91	13.62	13.27	50.33	42.30	46.31
S_2N_0	5.05	6.32	5.69	29.32	28.66	28.99
S_2N_{50}	7.85	11.89	9.87	40.22	33.98	37.10
S_2N_{100}	14.27	14.49	14.38	48.07	29.88	38.98
S_2N_{150}	16.05	17.61	16.83	58.25	53.77	56.01
S_2N_{200}	18.85	21.61	20.23	68.77	56.62	62.70
Mean	12.41	14.38	13.40	48.93	40.58	44.75
	S	S×N	S×V×N	S	S×N	S×V×N
SED	0.48	1.09	1.54	2.25	5.03	7.120
CD	NS	NS	3.11	NS	NS	14.39
	N uptake by grain (kg ha^{-1})			**N uptake by straw (kg ha^{-1})**		
S_1N_0	29.87	30.68	30.27	20.86	27.63	24.24
S_1N_{50}	33.15	50.65	41.90	37.33	29.89	33.61
S_1N_{100}	46.24	60.13	53.19	39.54	32.40	35.97
S_1N_{150}	55.83	66.97	61.40	46.34	45.22	45.78
S_1N_{200}	53.25	65.77	59.51	49.17	46.13	47.65
Mean	43.67	54.84	49.25	38.65	36.25	37.45
S_2N_0	28.28	31.97	30.12	32.62	33.55	33.09
S_2N_{50}	40.03	55.95	47.99	34.47	40.19	37.33
S_2N_{100}	50.26	67.99	59.12	42.79	44.98	43.89
S_2N_{150}	55.53	67.64	61.58	44.94	53.86	49.40
S_2N_{200}	58.98	70.07	64.53	54.60	54.11	54.36
Mean	46.61	58.72	52.67	41.89	45.34	43.61
	S	S×N	S×V×N	S	S×N	S×V×N
SED	2.85	6.39	9.03	2.15	4.81	6.80
CD	NS	NS	18.28	4.35	NS	13.76
	P uptake at AT (kg ha^{-1})			**P uptake at PI (kg ha^{-1})**		
S_1N_0	1.36	1.18	1.27	4.83	4.31	4.57
S_1N_{50}	1.62	1.32	1.47	5.95	5.63	5.79
S_1N_{100}	2.45	2.44	2.45	6.12	6.56	6.34
S_1N_{150}	3.07	2.58	2.82	7.82	7.87	7.84
S_1N_{200}	3.82	3.57	3.69	9.54	8.44	8.99
Mean	2.46	2.22	2.34	6.85	6.56	6.71
S_2N_0	1.73	1.43	1.58	5.26	3.93	4.59
S_2N_{50}	1.85	2.05	1.95	6.16	5.27	5.72
S_2N_{100}	2.72	2.76	2.74	7.56	6.98	7.27
S_2N_{150}	3.01	3.05	3.03	8.44	8.19	8.32
S_2N_{200}	3.10	3.82	3.46	9.44	9.11	9.28
Mean	2.48	2.62	2.55	7.37	6.70	7.03
SED	0.08	0.17	0.24	0.28	0.62	0.88
CD	0.16	0.34	0.49	NS	NS	1.77
	P uptake by grain (kg ha^{-1})			**P uptake by straw (kg ha^{-1})**		
S_1N_0	6.45	9.06	7.76	8.19	5.54	6.86
S_1N_{50}	8.14	9.10	8.62	9.19	6.99	8.09
S_1N_{100}	10.34	9.60	9.97	9.74	8.66	9.20
S_1N_{150}	13.52	9.81	11.67	9.35	9.67	9.51
S_1N_{200}	14.29	10.15	12.22	14.78	10.99	12.89
Mean	10.55	9.55	10.05	10.25	8.37	9.31
S_2N_0	8.44	7.99	8.22	7.81	5.61	6.71
S_2N_{50}	8.81	8.92	8.87	9.11	6.63	7.87
S_2N_{100}	10.56	9.98	10.27	12.61	8.67	10.64
S_2N_{150}	13.59	11.67	12.63	13.75	10.42	12.08
S_2N_{200}	14.09	13.41	13.75	14.84	13.62	14.23
Mean	11.10	10.40	10.75	11.62	8.99	10.31
SED	0.48	1.07	1.52	0.35	0.78	1.11
CD	NS	NS	3.07	0.71	1.59	2.24

SED: Standard error of deviation, CD: Critical difference at 5% of probability

Table 3: K uptake and efficiency parameters of rice crop under different field condition (kg ha^{-1})

Treatments	K uptake at AT (kg ha^{-1})			K uptake at PI (kg ha^{-1})			K uptake by grain (kg ha^{-1})			K uptake by straw (kg ha^{-1})		
S_1N_0	16.2	10.4	13.2	35.1	41.2	38.1	12.3	13.4	12.8	63.4	60.5	62.0
S_1N_{50}	18.7	19.1	18.9	46.0	52.4	49.2	13.7	14.2	14.0	76.9	71.6	74.3
S_1N_{100}	22.7	20.2	21.5	50.8	74.0	62.4	14.1	15.8	15.0	96.9	79.9	88.4
S_1N_{150}	28.0	31.0	29.5	59.7	67.4	63.6	18.9	17.0	17.9	109.7	103.6	106.7
S_1N_{200}	30.1	41.0	35.6	62.2	62.4	62.3	18.2	14.1	16.2	125.2	103.3	114.3
Mean	23.1	24.3	23.7	50.7	59.5	55.1	15.4	14.9	15.2	94.4	83.8	89.1
S_2N_0	16.4	10.3	13.3	49.7	35.2	42.41	12.6	12.1	12.3	84.7	63.0	73.8
S_2N_{50}	20.6	20.0	20.3	51.6	55.7	53.6	13.1	12.7	12.9	90.8	85.4	88.1
S_2N_{100}	25.2	25.2	25.2	54.3	54.7	54.5	17.6	15.8	16.7	103.6	87.1	95.4
S_2N_{150}	28.7	32.2	30.5	59.7	58.0	58.8	20.5	16.3	18.4	113.6	93.3	103.4
S_2N_{200}	32.4	43.3	37.9	64.7	85.3	75.0	20.5	14.0	17.3	124.5	112.4	118.5
Mean	24.7	26.2	25.4	56.0	57.7	56.9	16.9	14.2	15.5	103.4	88.2	95.8
	S	S×N	S×V×N	S	S×N	S×V×N	S	S×N	S×V×N	S	S×N	S×V×N
SED	0.92	2.1	2.9	2.0	4.5	6.4	0.6	1.3	1.8	3.1	7.0	9.9
CD	NS	NS	6.0		9.1	13.0	NS	NS	3.6	6.3	NS	20.0
	Agronomic efficiency			Physiological efficiency			Apparent N recovery			Harvest index		
S_1N_0										0.340	0.366	0.353
S_1N_{50}	6.27	7.41	6.84	11.68	23.86	17.77	39.50	44.48	41.99	0.354	0.360	0.357
S_1N_{100}	6.88	7.39	7.13	15.28	22.22	18.75	35.06	34.23	34.64	0.332	0.329	0.331
S_1N_{150}	8.26	7.19	7.73	22.67	22.77	22.72	34.30	35.94	35.12	0.337	0.322	0.329
S_1N_{200}	3.79	2.93	3.36	12.46	11.14	11.80	25.85	26.55	26.20	0.310	0.315	0.313
Mean	6.69	7.18	6.94	15.52	20.00	17.76	33.68	35.30	34.49	0.335	0.338	0.337
S_2N_0										0.360	0.346	0.353
S_2N_{50}	6.81	10.23	8.52	23.37	12.33	17.85	27.21	61.22	44.21	0.339	0.318	0.328
S_2N_{100}	9.88	8.67	9.27	31.40	18.84	25.12	32.16	47.45	39.80	0.379	0.329	0.354
S_2N_{150}	7.17	7.04	7.11	27.62	18.96	23.29	26.38	37.32	31.85	0.360	0.334	0.347
S_2N_{200}	3.21	2.08	2.64	12.26	7.06	9.66	26.34	29.27	27.81	0.323	0.307	0.315
Mean	6.63	6.30	6.47	23.66	14.30	18.98	28.02	43.81	35.92	0.352	0.327	0.340

SED: Standard error of deviation CD: Critical difference at 5% of probability

Potassium Uptake

At the stage of AT, the uptake of K was not significantly influenced by the situations studied (Table 3). Each N level also performed equally between the situations. This might be due to the ability of the soils in both situations to supply enough K by direct inorganic source in situation II and by combination of organic and inorganic source in situation I (Priyadarshini and Prasad, 2003). AT PI stage the situations did not create any variations in the K uptake. However, the highest dose of N i.e., 200 kg N ha^{-1} recorded significantly higher uptake of K in situation II over situation I. Again this result could be the reflection of DMP.

K uptake by straw which was found to be significantly higher in situation II (95.8 kg ha^{-1}) than in situation I (89.1 kg ha^{-1}), might be due to the higher straw yield and the fact that K is consumed luxurily by the crop. The fact that straw in situation II showed higher values for K uptake. The accumulation of K in grain was not significantly varied with the situations. The performances of each rice variety and N level were comparable under both the situations.

Agronomic Efficiency

The Agronomic Efficiency (AE) was found to be higher in situation I (6.94) over situation II. There was wide variation in AE produced by N levels over situations and varieties (Table 3). In situation I, for ADT 38, the highest was with 150 kg N ha^{-1} and for the pre-release culture (KR 99001) it was with 50 kg N ha^{-1}. In situation II, 100 kg N ha^{-1} was found to be the highest for both the varieties. The AE varied with N levels and it is in line with the findings of Mahendra Kumar *et al.* (2001) and Velu *et al.* (2002).

Physiological Efficiency

The highest Physiological Efficiency (PE) was found to be higher in situation II (18.98) over situation I (17.76). In situation I, the best PE was achieved with the application of 150 kg N ha^{-1} for both varieties. In situation II, ADT 38 expressed its maximum PE with 100 kg N ha^{-1} and KR 99001 with 150 kg N ha^{-1}. Decrease in PE with increase N levels was observed and this result is in accordance with the findings of Dheebakaran and Ramasamy (1999).

Apparent N Recovery

The apparent N recovery was comparable in both situations (34.49 and 35.92) the highest apparent N recovery found by the application of 50 kg N ha^{-1}. The three way interaction proved the efficiency of 50 kg N ha^{-1} in realizing the higher apparent N recovery.

Harvest Index

A general trend was found in the case of Harvest Index (HI) for both situations and varieties i.e., increase in N levels decreased the HI. There was no marked variation in the HI due to the situations. The highest HI of 0.357 was seen at 50 kg N ha^{-1} in situation I and HI of 0.354 at 100 kg N ha^{-1} in situation II. In both situations, 200 kg N ha^{-1} recorded the lowest HI in both varieties. At lower levels of N, the proportion of nutrient uptake to nutrient applied will be more and the high removal of nutrients resulted in better efficiency. The result was inline with the findings of Bhandari *et al.* (2002), who were reported N and K depletion may have collectively contributed to the yield improvement, resulting in higher (HI).

The efficiency parameters showed a general trend that higher efficiency was found in situation I and with low levels of N. The response of rice was more when there was nutrient deficit in soil. This was because situation I was showed higher efficiencies. The same kind of results was reported by Thiyagarajan *et al.* (1994) and Shivay and Singh (2003), who noticed significantly higher agronomic efficiency, physiological efficiency and apparent N recovery at lower N levels.

CONCLUSIONS

The sesame grown in previous season accumulated 30.4 kg N ha^{-1}, 10.197 kg P ha^{-1} and 26.324 kg K ha^{-1} and the nutrient loss was accounted as 37 kg N ha^{-1}, 19.8 kg P ha^{-1} and 29 kg K ha^{-1}. The N and K uptake was equal under both the situations at AT and PI but P was accumulated more in situation II at the stage of AT but comparable at PI. This might be due to initial low requirement of nutrients met by inorganic sources and later the situation I managed the nutrient lost in previous season with mineralization process, whereas the P, though applied as basal might not fully available in the initial stages itself, might be fixed. The nutrient uptake by straw was higher in situation II owing to higher DMP and grain uptake was comparable because of genetic nature. The efficiency parameters computed viz., AE, PE, HI and ApN were found to be higher in situation I over situation II and they were more pronounced at lower levels of N.

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