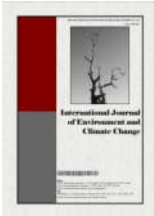

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Effect of Sources, Split and Foliar Application of KCl and $KClO_3$ on Availability and Uptake of Nitrogen in Aerobic Rice

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Authors' contributions

This work was carried out in collaboration among all authors. Author PAB designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors KOH and LA managed the analyses of the study. Author RM managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aim: To investigate the effect of KCl and $KClO_3$ as sources of potassium in aerobic rice with four types of split doses and two levels of foliar applications of potassium.
Study Design: The experiment was laid out in Randomized Block Design with three replications.
Place and Duration of Study: Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal, Puducherry.
Methodology: The rice variety PMK 4 was tested with two sources of potassium *viz.,* Potassium chloride (KCl) and Potassium chlorate ($KClO_3$), four types of split application *viz.,* K control (S_1), basal with no split (S_2), two splits (S_3) and three splits (S_4) along with foliar application treatments viz., no foliar (F_1) and foliar spray (F_2).
Results: The results of field experiment revealed that the N availability in soil was more at all stages of crop growth by two and three split doses of potassium. The $KClO_3$ increased the available N status at active and panicle initiation stages. Whereas in flowering stage, the KCl

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recorded the higher available N status in soil. The nitrogen uptake at active tillering stage and flowering stage was evidently improved with three split doses of potassium. Whereas in panicle initiation stage, the two split doses registered higher N uptake. The nitrogen uptake by both grain and straw was conspicuously higher in three and two split doses of potassium.

Conclusion: The split applications tested in this investigation influenced the available N status in soil. Almost in all the stages, three split applications retained more available N in soil. This implies the positive interaction of potassium with nitrogen.

Keywords: KCl; $KClO_3$; available nitrogen; nitrogen uptake and aerobic rice.

1. INTRODUCTION

Rice gives life for major populations of the world and it is deeply embedded in the cultural heritage of societies. Rice is the staple food for about 50 % of the world`s populations that live in Asia. Rice is the second most important crop next to wheat in terms of area in the world and about 40 % of the world's population consumes rice as a major source of calorie to human kind [1]. The increasing scarcity of water threatens the sustainability of the irrigated rice production system and hence, the security and livelihood of rice producers and consumers are in question. Several strategies for water saving were dev eloped in recent years, to increase water productivity and reduce water losses in the rice system. The concept of aerobic rice was first developed in China during mid-1980. The term "Aerobic rice" was coined by International Rice Research Institute (IRRI). Aerobic rice cultivation will curb methane production and saves water without affecting the productivity. It is the time to save water from the irrigated system of rice cultivation by adapting the aerobic rice cultivation. This technology is a better remedy for future climate change under drought condition with lesser green house gas emission.

2. MATERIALS AND METHODS

The three factor experiment was conducted in Randomized Block Design (RBD) with three replications in the east farm of Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal during the year of 2015.The factor I includes two sources of potassium kcl (k_1) and $kclo_3$ (k_2), factor II includes split doses of potassium like S_1 - K control; S_2 - K as basal (15 DAS) without split; S_3 - K in two splits (Basal & PI); S_4 - K in three splits (Basal, PI & Flowering) and factor III includes Foliar spray (2%) - F_1 - Without foliar spray ; F_2 - With foliar spray (2 times at AT & PI). The blanket recommendation of 150:50:50 kg N, P_2O_5 and K_2O ha^{-1}, adopted for aerobic rice was followed in this investigation. Nitrogen and phosphorus were applied through urea and super phosphate respectively to meet the blanket recommendation. Potassium was applied through the sources of KCl and $KClO_3$ as per the treatment structure. The available nitrogen was determined by Alkaline permanganate method given by Subbiah and Asija [2] and nutrient uptake was calculated by the following formula

$$\textbf{Nutrient uptake (kg ha}^{-1}\textbf{)} = \frac{\text{Nutrient content (\%) x DMP or Grain or straw or root biomass (kg ha}^{-1}\text{)}}{100}$$

3. RESULTS

3.1 Available Nitrogen at Different Stages of Crop Growth

3.1.1 At active tillering stage

The availability of nitrogen in the active tillering stage was significantly influenced by the main effect sources Table 1. The interaction effects of two factors viz., sources with splits and sources with foliar application and the interaction effects of three factors viz., sources, split, and foliar application of potassium were established at this stage. With regard to different sources, the potassium chlorate registered higher availability of nitrogen (208 kg ha^{-1}) when compared to potassium chloride (199 kg ha^{-1}). Both the sources differed with each other in maintaining the availability of N in soil at this stage.

The influence of interaction effect of sources with split application of potassium revealed that almost all the interactions between sources and split application maintained the availability of nitrogen in the same level, ranging from 194 to 214 kg ha^{-1} except K control of potassium chloride (179 kg ha^{-1}).

Table 1. Available nitrogen (kg ha^{-1}) at active tillering stage

(Mean of three replications)

	Control (S_1)	No split (S_2)	Two splits (S_3)	Three splits (S_4)	KCl (K_1)	$KClO_3$ (K_2)	Mean
K_1F_1 - KCl + No foliar spray	176	188	189	184	-	-	-
K_1F_2 - KCl + foliar spray	182	199	232	239	-	-	-
K_2F_1 - $KClO_3$ + No foliar spray	221	221	205	222	-	-	-
K_2F_2 - $KClO_3$ + foliar spray	207	203	194	197	-	-	-
K_1 - KCl	179	194	210	211	-	-	-
K_2 - $KClO_3$	214	212	199	209	-	-	-
F_1 - No foliar spray	198	205	197	203	184	217	201
F_2 - Foliar spray	194	201	213	218	213	200	206
Mean	196	203	205	210	199	208	-

Sources	S.Ed.	C.D. (p = 0.05)
K sources (K)	3.632	6.0
Split application	5.136	*NS*
Foliar application	3.632	*NS*
K x S	7.263	12.0
K x F	5.136	9.0
S x F	7.263	*NS*
K x S x F	10.272	17.0

In the case of interaction effect of source and foliar application of potassium, the availability of nitrogen provided by the application of potassium through potassium chlorate without foliar application was significantly noticed (218 kg ha^{-1}) than the other combinations except the combination of potassium chloride with foliar application (213 kg ha^{-1}).

The three way interaction of sources, split and foliar application of potassium showed significant influence in the availability of nitrogen of tillering stage. The maximum available nitrogen (239 kg ha^{-1}) was recorded by three splits concomitant with foliar spray through KCl and the lowest uptake was recorded in K control treatment with no foliar application of potassium chlorate.

3.1.2 At panicle initiation stage

The available N status was greatly influenced by almost all the main factors and their interaction effects except the interaction between split and foliar application of potassium at this stage Table 2. Among the two sources tried, potassium chlorate provided higher available N status (198 kg ha^{-1}) than the potassium chloride (167 kg ha^{-1}).

With regard to foliar application, the higher available N (187 kg ha^{-1}) was noticed when the potassium was applied in the form of foliar spray and it was significantly differed from the no foliar application of potassium (177 kg ha^{-1}).

While in the case of split application, all the split applications performed equally in maintaining the available N status, except control treatment. The higher available N (191 kg ha^{-1}) was recorded in three splits and lower available N (171 kg ha^{-1}) was recorded in control treatment.

In the case of interaction effect of source and split application of potassium, higher available N was recorded by potassium chlorate (211 kg ha^{-1}) with three split application. It was closely followed by the same source with two splits (203 kg ha^{-1}). On persuing the other interaction effect, both the sources performed equally in the case of basal application only. The remaining split treatments tried through these two sources showed their significant influence in maintaining the available N status.

Regarding the interaction effect of sources and foliar application, the higher available N (208 kg ha^{-1}) was recorded in the case of potassium chlorate with foliar application. The potassium chlorate showed its conspicuous difference between foliar and no foliar situations, whereas the potassium chloride performed equally in both foliar and no foliar conditions in keeping the available nitrogen in soil.

The three way interaction also showed its significant influence on availability of N at this stage. The maximum available N (216 kg ha^{-1}) was recorded with three splits of potassium chlorate along with foliar application. The potassium chlorate along with foliar spray performed equally in all split application of potassium. The same trend was also seen in the case of potassium chloride with foliar application. The lowest available nitrogen of 150 kg ha^{-1} was noticed in K control of KCl without foliar application.

3 .1.3 At flowering stage

The available N status of this stage was greatly influenced by all the main factors viz., sources, split and foliar and also by the interaction effect of sources with split application Table 3. Potassium chloride recorded with more of available N (226 kg ha^{-1}) than potassium chlorate.

In the case of split application, higher level of available N was recorded in two splits (227kg ha^{-1}), but it was on par with three splits (225 kg ha^{-1}). The lower available N was recorded in control treatment (202 kg ha^{-1}). With respect to foliar application, significant variations had not been observed between foliar and no foliar spray.

While seeing the interaction effect of source and split application of potassium, the potassium chloride with three splits provided the maximum availability of nitrogen (251 kg ha^{-1}), which was closely followed by two splits of the same source (242 kg ha^{-1}). Both the sources in basal application showed equal in performance by keeping the availability of nitrogen in soil at this stage.

3.1.4 At post-harvest stage

The available N status at post-harvest was mainly influenced by split and interaction effect of split and foliar application of potassium Table 4. The available N was more in three splits (218 kg ha^{-1}), which was on par with two split application (217 kg ha^{-1}) of potassium. At the same time, the basal and control treatments also showed their on par performance in maintaining the available N status in soil.

Table 2. Available nitrogen (kg ha^{-1}) at panicle initiation stage (kg ha^{-1})

(Mean of three replications)

	Control (S_1)	No split (S_2)	Two splits (S_3)	Three splits (S_4)	KCl (K_1)	$KClO_3$ (K_2)	Mean
K_1F_1 - KCl + No foliar spray	150	192	158	169	-	-	-
K_1F_2 - KCl + foliar spray	154	164	175	173	-	-	-
K_2F_1 - $KClO_3$ + No foliar spray	180	167	195	206	-	-	-
K_2F_2 - $KClO_3$ + foliar spray	201	207	211	216	-	-	-
K_1 – KCl	152	178	167	171	-	-	-
K_2 - $KClO_3$	190	187	203	211	-	-	-
F_1 - No foliar spray	165	180	176	187	167	187	177
F_2 - Foliar spray	178	185	193	194	166	208	187
Mean	171	182	185	191	167	198	-

Sources	S.Ed.	C.D. (p = 0.05)
K sources (K)	3.165	5.0
Split application	4.476	8.0
Foliar application	3.165	5.0
K x S	6.330	11.0
K x F	4.476	8.0
S x F	6.330	*NS*
K x S x F	8.951	15.0

Table 3. Available nitrogen (kg ha^{-1}) at flowering stage

(Mean of three replications)

	Control (S_1)	No split (S_2)	Two splits (S_3)	Three splits (S_4)	KCl (K_1)	$KClO_3$ (K_2)	Mean
K_1F_1 - KCl + No foliar spray	199	224	249	263	-	-	-
K_1F_2 - KCl + foliar spray	183	219	234	239	-	-	-
K_2F_1 - $KClO_3$ + No foliar spray	215	212	221	205	-	-	-
K_2F_2 - $KClO_3$ + foliar spray	211	201	206	193	-	-	-
K_1 – KCl	191	221	242	251	-	-	-
K_2 - $KClO_3$	213	207	213	199	-	-	-
F_1 - No foliar spray	207	218	235	234	234	213	223
F_2 - Foliar spray	197	210	220	216	219	203	211
Mean	202	214	227	225	226	208	-

Sources	S.Ed.	C.D. (p = 0.05)
K sources (K)	4.748	8.0
Split application	6.715	11.0
Foliar application	4.748	8.0
K x S	9.496	16.0
K x F	6.715	*NS*
S x F	9.496	*NS*
K x S x F	13.430	*NS*

Table 4. Available nitrogen (kg ha^{-1}) at harvest stage (kg ha^{-1})

(Mean of three replications)

	Control (S_1)	No split (S_2)	Two splits (S_3)	Three splits (S_4)	KCl (K_1)	$KClO_3$ (K_2)	Mean
K_1F_1 - KCl + No foliar spray	195	198	224	233	-	-	-
K_1F_2 - KCl + foliar spray	203	201	212	207	-	-	-
K_2F_1 - $KClO_3$ + No foliar spray	200	197	225	225	-	-	-
K_2F_2 - $KClO_3$ + foliar spray	209	191	209	207	-	-	-
K_1 - KCl	199	200	218	220	-	-	-
K_2 - $KClO_3$	205	194	217	216	-	-	-
F_1 - No foliar spray	198	198	224	229	213	212	212
F_2 - Foliar spray	206	196	210	207	206	204	205
Mean	202	197	217	218	209	208	-

Sources	S.Ed.	C.D. (p = 0.05)
K sources (K)	3.776	*NS*
Split application	5.340	9.0
Foliar application	3.776	*NS*
K x S	7.552	*NS*
K x F	5.340	*NS*
S x F	7.552	13.0
K x S x F	10.680	*NS*

In the case of interaction effect of split and foliar application of potassium, higher available N was recorded in three splits and two splits with no foliar application of potassium with 229 and 224 Kg ha^{-1} respectively. The basal and control treatments of potassium performed equally in both foliar and no foliar application of potassium.

3.2 Nitrogen Uptake at Different Stages of Crop Growth

3.2.1 At active tillering stage

The split application of potassium significantly influenced the nitrogen accumulation at active tillering stage Table 5. Uptake of N increased with increase in split application of potassium. The higher uptake of 47.8 kg N ha^{-1} was observed in three split application of potassium, but it was on par with the performance of the two split application of potassium (40.1 kg N ha^{-1}). The basal application of potassium was recorded lower N uptake (26.3 kg N ha^{-1}), but it was on par with the N uptake of control treatment of potassium (28.5 kg N ha^{-1}). The other main and interaction effects did not show their influence in the uptake of N at this stage.

3.2.2 At panicle initiation stage

At this stage also, the split application alone significantly influenced the N uptake Table 6. Higher uptake of N (67.0 kg N ha^{-1}) was observed in two split application of potassium, but it was on par with the N uptake (64.4 kg N ha^{-1}) by three split application of potassium. The lower N uptake (37.5 kg N ha^{-1}) was recorded in control treatment, which was on par with the basal application of potassium (48.3 kg ha^{-1}) without any split. The other main effect and interaction effects of different factors did not show any significant influence on N uptake of this stage.

3.2.3 At flowering stage

The significant variations of nitrogen uptake of this stage Table 7 were observed within the split and interaction effect of split and foliar application of potassium. The three splits recorded higher uptake (90 kg ha^{-1}), followed by two splits (85.3 kg ha^{-1}) and basal (73.6 kg ha^{-1}) i.e., no split application of potassium. However, these three types of split applications were equally effective in bringing the uptake of nitrogen at this stage. Significantly lower uptake of nitrogen (50.1 kg ha^{-1}) was noticed in K control.

The interaction effect for N uptake at flowering stage revealed that the highest uptake of 122 kg N ha^{-1} was promisingly pronounced by three splits of potassium without foliar application. It was significantly superior to the other interaction effect of split and foliar application. All other interactions showed their equal performance in accumulating the nitrogen except K control with foliar and without foliar application. The lowest N uptake (45.7 kg N ha^{-1}) was recorded in the control treatment of soil and foliar application.

3.2.4 Nitrogen uptake by grain

The nitrogen uptake by grain was greatly influenced by all the factors of potassium and their interaction effects Table 8. In between the two sources of potassium studied, potassium chlorate showed significantly higher uptake of nitrogen (50.2 kg ha^{-1}) than the other source, potassium chloride (43.1 kg ha^{-1}). In the case of split application, the three splits of potassium registered significantly higher nitrogen uptake (62.4 kg ha^{-1}) by the grain, than two splits (47.9 kg ha^{-1}). The basal and no application of potassium recorded almost equal uptake of nitrogen with 39.4 and 37.0 kg ha^{-1} respectively. Yet another factor, foliar application expressed its significance in the uptake of nitrogen by grain (49.0 kg ha^{-1}) than no foliar application.

Within the interaction effect of potassium sources and split application, the higher nitrogen uptake of 73.1 kg ha^{-1} was recorded by potassium chlorate with three split application. It was followed by the same source with two splits application (56.7 kg ha^{-1}). In the case of basal application without split, both the sources, KCl and $KClO_3$ recorded equally the uptake of nitrogen by grain as 40.3 and 38.4 kg ha^{-1} respectively.

Furthermore, the interaction effect of split and foliar also significantly influenced the nitrogen uptake by grain. The three split application of potassium could be able to mobilize the nitrogen greatly to the grain either with foliar application (64.8 kg ha^{-1}) or without foliar application (60.0 kg ha^{-1}) in almost equal amounts. This treatment combination proved to be superior than the other treatment combinations. Whereas, the foliar spray did not show its effect in two splits and no split (basal) combination also in mobilizing nitrogen to the grain. However, the lowest uptake of N by grain (30.5 kg ha^{-1}) was noticed in no soil and foliar application of potassium.

Table 5. Nitrogen uptake (kg ha^{-1}) at active tillering stage

(Mean of three replications)

	Control (S_1)	No split (S_2)	Two splits (S_3)	Three splits (S_4)	KCl (K_1)	$KClO_3$ (K_2)	Mean
K_1F_1 - KCl + No foliar spray	44.5	30.1	45.3	55.9	-	-	-
K_1F_2 - KCl + foliar spray	16.7	38.3	45.0	40.8	-	-	-
K_2F_1 - $KClO_3$ + No foliar spray	23.1	18.2	44.7	39.7	-	-	-
K_2F_2 - $KClO_3$ + foliar spray	29.7	18.5	25.0	55.0	-	-	-
K_1 - KCl	30.6	34.2	45.1	48.3	-	-	-
K_2 - $KClO_3$	26.4	18.3	34.9	47.3	-	-	-
F_1 - No foliar spray	33.8	24.1	45.0	47.8	44.0	31.4	37.7
F_2 - Foliar spray	23.2	28.4	35.0	47.9	35.2	32.0	33.6
Mean	28.5	26.3	40.0	47.8	39.6	31.7	-

Sources	**S.Ed.**	**C.D. (p = 0.05)**
K sources (K)	5.053	*NS*
Split application	7.146	12.1
Foliar application	5.053	*NS*
K x S	10.106	*NS*
K x F	7.146	*NS*
S x F	10.106	*NS*
K x S x F	14.293	*NS*

Table 6. Nitrogen uptake (kg ha^{-1}) at panicle initiation stage

(Mean of three replications)

	Control (S_1)	No split (S_2)	Two splits (S_3)	Three splits (S_4)	KCl (K_1)	$KClO_3$ (K_2)	Mean
K_1F_1 - KCl + No foliar spray	37.4	49.6	68.2	68.2	-	-	-
K_1F_2 - KCl + foliar spray	33.2	48.4	69.7	67.6	-	-	-
K_2F_1 - $KClO_3$ + No foliar spray	37.0	42.5	76.3	63.4	-	-	-
K_2F_2 - $KClO_3$ + foliar spray	42.3	52.7	53.8	58.6	-	-	-
K_1 - KCl	35.3	49.0	69.0	67.9	-	-	-
K_2 - $KClO_3$	39.6	47.6	65.1	61.0	-	-	-
F_1 - No foliar spray	37.2	46.0	72.2	65.8	55.8	54.8	55.3
F_2 - Foliar spray	37.7	50.5	61.8	63.1	54.7	51.8	53.3
Mean	37.5	48.3	67.0	64.4	55.3	53.3	-

Sources	**S.Ed.**	**C.D. (p = 0.05)**
K sources (K)	6.192	*NS*
Split application	8.756	14.8
Foliar application	6.192	*NS*
K x S	12.383	*NS*
K x F	8.756	*NS*
S x F	12.383	*NS*
K x S x F	17.513	*NS*

Table 7. Nitrogen uptake (kg ha^{-1}) at flowering stage

(Mean of three replications)

	Control (S_1)	No split (S_2)	Two splits (S_3)	Three splits (S_4)	KCl (K_1)	$KClO_3$ (K_2)	Mean
K_1F_1 - KCl + No foliar spray	60.8	61.0	88.4	103	-	-	-
K_1F_2 - KCl + foliar spray	45.2	48.8	86.7	65	-	-	-
K_2F_1 - $KClO_3$ + No foliar spray	30.7	89.9	95.1	140	-	-	-
K_2F_2 - $KClO_3$ + foliar spray	63.9	94.5	71.1	50.0	-	-	-
K_1 - KCl	53.0	54.9	87.6	84.6	-	-	-
K_2 - $KClO_3$	47.3	92.2	83.1	95.4	-	-	-
F_1 - No foliar spray	45.7	75.5	91.7	122	78.4	89.1	83.7
F_2 - Foliar spray	54.5	71.7	78.9	58.0	61.7	69.9	65.8
Mean	50.1	73.6	85.3	90.0	70.0	79.5	-

Sources	S.Ed.	C.D. (p = 0.05)
K sources (K)	8.837	*NS*
Split application	12.497	21.2
Foliar application	8.837	*NS*
K x S	17.674	*NS*
K x F	12.497	*NS*
S x F	17.674	29.9
K x S x F	24.995	*NS*

Table 8. Nitrogen uptake (kg ha^{-1}) by grain

(Mean of three replications)

	Control (S_1)	No split (S_2)	Two splits (S_3)	Three splits (S_4)	KCl (K_1)	$KClO_3$ (K_2)	Mean
K_1F_1 - KCl + No foliar spray	36.5	42.6	33.7	47.1	-	-	-
K_1F_2 - KCl + foliar spray	46.0	38.1	44.5	56.3	-	-	-
K_2F_1 - $KClO_3$ + No foliar spray	24.5	41.0	56.9	72.9	-	-	-
K_2F_2 - $KClO_3$ + foliar spray	41.1	35.8	56.6	73.3	-	-	-
K_1 - KCl	41.2	40.3	39.1	51.7	-	-	-
K_2 - $KClO_3$	32.8	38.4	56.7	73.1	-	-	-
F_1 - No foliar spray	30.5	41.8	45.3	60.0	40.0	48.8	44.4
F_2 - Foliar spray	43.5	36.9	50.6	64.8	46.2	51.7	49.0
Mean	37.0	39.4	47.9	62.4	43.1	50.2	-

Sources	S.Ed.	C.D. (p = 0.05)
K sources (K)	1.919	3.3
Split application	2.714	4.6
Foliar application	1.919	3.3
K x S	3.839	6.5
K x F	2.714	*NS*
S x F	3.839	6.5
K x S x F	5.429	*NS*

3.2.5 Nitrogen uptake by straw

There were significant variations observed in N uptake by straw due to split applications only Table 9. Among the split applications, the two splits significantly registered higher uptake nitrogen by straw (80.4 kg ha^{-1}) than the other types of split applications. It was followed by the basal application (67.2 kg ha^{-1}), three splits (66.5 kg ha^{-1}) and they registered almost equal uptake. The control treatment recorded the lower level of N uptake (57.0 kg ha^{-1}) by straw.

3.2.6 Nitrogen uptake by root

Nitrogen uptake by root Table 10 in aerobic rice was found to be influenced by split applications and its interaction with sources and foliar applications of potassium. Among the split applications, the three splits showed higher N uptake (19.0 kg ha^{-1}) by root than other types of split application. The two split and no split i.e., fully as basal recorded almost same value of N uptake by root. The lower uptake of 12.4 kg ha^{-1} was registered in control treatment.

In the case of interaction effect of potassium sources and split applications, higher nitrogen uptake by root was recorded in potassium chlorate with three split application (20.6 kg N ha^{-1}). In this interaction effects, both the sources of potassium with different splits viz., three splits, basal and control performed equally in the uptake of nitrogen by root. The two splits application alone showed the difference between the two sources significantly in the uptake of nitrogen by root.

In the case of split and foliar applications of potassium, the nitrogen uptake by root greatly influenced by three split doses of potassium with no foliar application (19.6 kg ha^{-1}), which was closely followed with foliar application (18.5 kg ha^{-1}) and basal application of potassium (18.4 kg ha^{-1}) without foliar spray. The lower N uptakes by root (12.6 and 11.1 kg ha^{-1}) were recorded by basal with foliar and K control without foliar application of potassium respectively.

The three way interaction effect revealed that the highest N uptake by root was registered with three splits of potassium chlorate (25.9 kg ha^{-1}) with no foliar application of potassium. The lowest N uptake was recorded in control treatment of potassium chloride with no foliar application of potassium.

4. DISCUSSION

4.1 Available Nitrogen at Different Stages of Crop Growth

The split applications tested in this investigation influenced the available N status in soil. Almost in all the stages, three split applications retained more available N in soil. This implies the positive interaction of K with N, which was also observed by Mitra et al*.* [3] Weiqui et al. [4] and Sivagnanam et al [5] Rietra et al*.* [6] and Hu et al*.* [7].

With regard to sources, the potassium chlorate increased higher available N status of soil in both active tillering and panicle initiation stages, whereas, in flowering stage the potassium chloride showed higher available N status, but it was on par with the potassium chlorate. Whatever may be the sources of K and their differential behaviour at different stages, the synergistic effect of K with N was established.

With regard to foliar spray, there was a slight increase in available N at panicle initiation stage but in flowering stage, foliar spray did not show any significant influence on available status of N. Therefore, the foliar application might not have an impact on the availability of nitrogen in soil.

4.2 Nitrogen Uptake at Different Stage of Crop Growth

There were significant differences in N uptake at different stages of crop growth. The highest N uptake was observed in three split application of potassium. Increased split doses increase the uptake of N at this stage. This might be due to the positive interaction between K and N under aerobic situations. The applied potassium increases the N uptake by the crop. Under water stress conditions in aerobic rice, the release of N is more in the form of NO_3 and the plant can able to absorb more of N. It is in confirmatory with the findings of Mitra et al. [3] Reddy [8] Frageria et al*.* [9] and Thummanatsakun, V. and Yampracha [10] who were having the opinion that the highest rice yield could be obtained with positive NK, interactions and this interaction also increased the uptake of N, P, K and S in rice.

The beneficial interaction effect of split and foliar was also observed at flowering stage. The maximum N uptake was observed in three splits with no foliar spray of potassium. The higher uptake of N and K by two and three split application of potassium was also reported by Ravichandran and Sriramachandrashekaran [11].

4.3 N Uptake by Grain

The potassium chlorate recorded the higher N uptake than the potassium chloride (Fig 1). This may be due to the applied potassium chlorate, which will increase the redox potential towards positive side and improve the uptake of other nutrients like Nitrogen and of course, this results corresponds to the result of grain yield.

Split applications showed their effect in N uptake by grain. The three split application were superior than the two split, no split and controlled treatment and mobilized more N to grains. These results are in accordance with the findings of and Ravichandran and Sriramachandrashekaran [11], Elliott et al. [12] and Zinguo et al. [13]. The foliar application of potassium also showed its significant effect in N uptake by grain. The uptake of nutrients increased by foliar application was also experienced by Ali et al. [14] and Wierdak et al. [15].

The interaction of source and split established its significant effect on uptake of N by grain. The potassium chlorate with three splits had its higher influence on N uptake by grain. The interaction of split and foliar also showed significant influence. The highest N uptake was registered by three splits of potassium along with foliar spray.

Sarkar and Malik [16] claimed that increase in paddy and straw yield by K application might be attributed to more N utilization in plant system, resulting in more chlorophyll synthesis and efficient translocation of assimilates to reproductive parts. This was the outcome of more mobilization of N to the crop for its utilization.

4.4 N Uptake by Straw

Among the split applications, two split mobilized more N to the straw. This might be due to N recovery efficiency, which can be increased by applying K fertilizers. The effect of split application was also revealed by Johnston et al. [17] Ravichandran and Sriramachandrashekaran [11].

4.5 N Uptake by Root

The N uptake by root was also found to be significantly varied with split application of potassium. The three splits enhanced the root N uptake than other split application. All this kinds of results corresponds to the dry matter production and root biomass, since the uptake is the computed value of nutrient concentration and dry matter production.

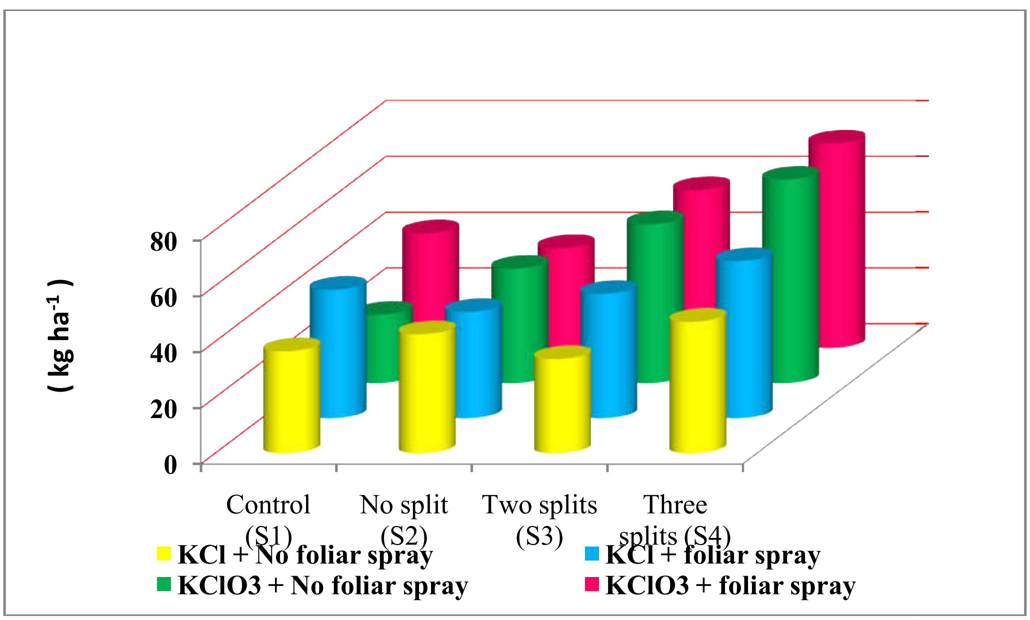

Fig. 1. Nitrogen uptake by grain

Table 9. Nitrogen uptake (kg ha^{-1}) by straw

(Mean of three replications)

	Control (S_1)	No split (S_2)	Two splits (S_3)	Three splits (S_4)	KCl (K_1)	$KClO_3$ (K_2)	Mean
K_1F_1 - KCl + No foliar spray	50.0	70.0	96.6	74.0	-	-	-
K_1F_2 - KCl + foliar spray	62.6	64.8	81.8	66.2	-	-	-
K_2F_1 - $KClO_3$ + No foliar spray	58.6	65.0	65.1	65.2	-	-	-
K_2F_2 - $KClO_3$ + foliar spray	56.8	69.1	78.2	60.6	-	-	-
K_1 - KCl	56.3	67.4	89.2	70.1	-	-	-
K_2 - $KClO_3$	57.7	67.1	71.7	62.9	-	-	-
F_1 - No foliar spray	54.3	67.5	80.9	69.6	72.6	63.5	68.0
F_2 - Foliar spray	59.7	66.9	80.0	63.4	68.9	66.2	67.5
Mean	57.0	67.2	80.4	66.5	70.7	64.8	-

Sources	S.Ed.	C.D. (p = 0.05)
K sources (K)	3.638	*NS*
Split application	5.145	8.7
Foliar application	3.638	*NS*
K x S	7.276	*NS*
K x F	5.145	*NS*
S x F	7.276	*NS*
K x S x F	10.290	*NS*

Table 10. Nitrogen uptake (kg ha^{-1}) by root

(Mean of three replications)

	Control (S_1)	No split (S_2)	Two splits (S_3)	Three splits (S_4)	KCl (K_1)	$KClO_3$ (K_2)	Mean
K_1F_1 - KCl + No foliar spray	10.7	24.0	18.7	13.3	-	-	-
K_1F_2 - KCl + foliar spray	12.6	8.87	18.5	21.7	-	-	-
K_2F_1 - $KClO_3$ + No foliar spray	11.6	12.7	8.60	25.9	-	-	-
K_2F_2 - $KClO_3$ + foliar spray	14.8	16.5	14.2	15.3	-	-	-
K_1 - KCl	11.7	16.4	18.6	17.5	-	-	-
K_2 - $KClO_3$	13.2	14.6	11.4	20.6	-	-	-
F_1 - No foliar spray	11.1	18.4	13.6	19.6	16.7	14.7	15.7
F_2 - Foliar spray	13.7	12.6	16.3	18.5	15.4	15.2	15.3
Mean	12.4	15.5	15.0	19.0	16.0	14.9	-

Sources	S.Ed.	C.D. (p = 0.05)
K sources (K)	1.098	*NS*
Split application	1.552	2.6
Foliar application	1.098	*NS*
K x S	2.195	3.7
K x F	1.552	*NS*
S x F	2.195	3.7
K x S x F	3.105	5.3

5. CONCLUSION

The N availability in soil was more at all stages of crop growth by two and three split doses of potassium. The $KClO_3$ increased the available N status at active and panicle initiation stages. Whereas in flowering stage, the KCl recorded the higher available N status in soil.

The nitrogen uptake at active tillering stage and flowering stage was evidently improved with three split doses of potassium. Whereas in panicle initiation stage, the two split doses registered higher N uptake. The nitrogen uptake by both grain and straw was conspicuously higher in three and two split doses of potassium. The $KClO_3$ recorded higher N uptake by grain. The foliar spray of potassium increased the N uptake by grain. Where as in root, only split application showed its influence, as such three splits recorded higher N uptake.

On the whole, this investigation had revealed that $KClO_3$ could also be used as one of the sources of potassium for the growth and yield of aerobic rice. The application of potassium either through KCl or $KClO_3$ in three equal splits at basal, panicle initiation and flowering stages along with foliar application could be suggested as a strategy of potassium management for yield maximization in aerobic rice.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Banik P. Cold injury problems in boro rice. In: Proc. of the workshop on modern rice cultivation in Bangladesh. Bangladesh Rice Res. Inst. Joydebpur, Gazipur, Bangladesh. 1999;4–16:37.
2. Subbiah BV, Asija CL. A rapid procedure for the estimation of available nitrogen in soils, Curr. Sci. 1956;25:259-260.
3. Mitra GN, Sahoo D, Rout KK. Effect of N-K on yield., nutrient uptake and grain quality of rice - groundnut cropping sequence in the alluvial soils of Orissa J. Potassium Res. 2011;17:71-78.
4. Weiqui S, Zhang GP, Limeng Ma, Robin Szmidt. Uptake of Nitrogen, Phosphorus and Potassium by Mat Rush and Effects of Nitrogen and Potassium fertilization on Plant Yield and Quality in Paddy field soil. J. Plant nutrition. 2003;26(4):757 – 768.
5. Sivagnanam S, Arivazhagan K, Arunkumar V, Natarajan S. Effect of timing and graded levels of nitrogen and potassium in SRI cultivation. J Appliedand Natural Sci. 2015;7(2):616 –620.
6. Rietra RP, JJ, Heinen M, Dimkpa C, Bindraban PS. Effects of nutrient antagonism and synergism on fertilizer use efficiency. Communications in Soil Science and Plant Analysis. 2015;48:1895-1920.
7. Hu W, Zhao W, Yang J, Oosterhuis DM, Loka DA, Zhou Z. Relationship between potassium fertilization and nitrogen metabolism in the leaf subtending the cotton (*Gossypium hirsutum* L.) boll during the boll development stage. *Plant Physiol.Biochem.* 2016b;101:113–123.
8. Reddy SM. Integrated nitrogen management in aerobic rice (*oryza sativa l.*). MSc. Thesis, Tamil Nadu Agricultural University, Coimbatore; 2015.
9. Fageria NK, Oliveira JP. Nitrogen, Phosphorus and Potassium Interactions in Upland Rice. Journal of Plant Nutrition. 2014; 37:1586–1600.
10. Thummanatsakun V, Yampracha S. Effects of interaction between nitrogen and potassium on the growth and yield of cassava. International Journal of Agricultural Technology 2018;14(7): 2137-2150.
11. Ravichandran M, Srirama chandrase kharan MV. 2011. Optimizing timing of potassium application in productivity enhancement of crops. Karnataka J. Agric. Sci. 2011;24(1):75-80.
12. Elliott G. Duncan, Cathryn A. O’Sullivan, Margaret M. Roper, Jairo Palta, Kelley Whisson and Mark B. Peoples. 2018. Yield and nitrogen use efficiency of wheat increased with root length and biomass due to nitrogen, phosphorus, and potassium interactions. J. Plant Nutr. Soil Sci. 2018;181:364–373.
13. Zhiguo Li, Runhua Zhang, Shujie Xia, Li Wang, Chuang Liu, Runqin Zhang, Zhanhui Fan , Fang Chen, Yi Liu. Interactions between N, P and K fertilizers affect the environment and the yield and quality of satsumas. Global Ecology and Conservation. 2019;e00663.
14. Ali A, Mahmood I.A, Hussain F, Salim M. Response of rice to soil and foliar

application of K_2SO_4 fertilizer.Sarhad J. Agric. 2007;23(4).

15. Wierdak RN, Katarzyna Dzida, Ewa Rożek, Zbigniew Jarosz. Effects of nitrogen and potassium fertilization on growth, yield and chemical composition of garden rocket. Acta Sci. Pol., Hortorum Cultus. 2012;11(2):289-300.
16. Sarkar RK, Malik GC. Effect of foliar spray of $KN0_3$ and Ca $(N0_3)_2$ on grass pea *(Lathyrussativus*L) grown in rice fallows. Lathyrism Newsletter. 2001;2:47-48.
17. Johnston AE, Milford GFJ. Potassium and nitrogen interactions in crops. In: Potash Development Association, England, rothamsted research. 2012;4-16.

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