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Effect of sources, split and foliar application of KCl and $KClO_3$ on uptake of potassium in aerobic rice

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Abstract
A field experiment was conducted in the sandy loam soil (*Fluventic haplustept*) of Pandit Jawaharlal Nehru College of Agri- culture and Research Institute, Karaikal, during *Kharif 2015* 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. The experiment was laid out in Randomised Block Design with three replications. As such, the treatments consisted of three factors *viz.*, sources, split and foliar applications. 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). The results of field experiment revealed that the growth para meters like plant height, leaf area index, number of tillers, productive tillers, dry matter production and root biomass were significantly influenced by sources, split and foliar application of potassium. Similarly, the yield components *viz*., panicle length, panicle weight, test weight, number of grains per panicle, number of spikelets per panicle, spikelet fertility, high density grains per panicle were also found to be significantly influenced by the sources, splits and foliar application of potassium.
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.

Keywords: split, foliar application, KCl and $KClO_3$, potassium, aerobic rice

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. 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 developed 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.

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 % of potassium was determined by Flame photometric method using triacid extract method given by Jackson (1973) [8] and nutrient uptake was calculated by the following formula

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

Results

Potassium uptake at different stages of crop growth

At active tillering stage

Potassium uptake at active tillering stage (Table 1) was moderately influenced by the split application of potassium. Three split application of potassium recorded higher potassium uptake (28.1 kg ha^{-1}), followed by the two splits, basal and control treatment of potassium. All the split applications of potassium performed equally in the uptake of potassium at this stage in a sequential manner. However, the three split showed its greater performance than basal (18.8 kg ha^{-1}) and K control treatment and the two splits with 23.1 kg ha^{-1} was better in mobilizing the K to the crop than K control.

At panicle initiation stage

The uptake of K was influenced by split application at this stage also (Table 1). The higher uptake was observed in three splits (52.5 kg ha^{-1}), followed by two split (50.5 kg ha^{-1}) application of potassium, which were at par with each other in mobilizing the K, but greater than basal application. The lower uptake was noticed with control treatment (30.5 kg ha^{-1}).

At flowering stage

The potassium uptake of this stage was significantly influenced by the split, foliar and their interaction (Table 2). While comparing the split applications, the two splits of potassium recorded higher K uptake (93.2 kg ha^{-1}), but it was on par with the three split application of potassium (90.3 kg ha^{-1}). The other two treatments viz., basal and K control also performed equally with each other in mobilizing the K to the crop, but inferior to split application of potassium. In the case of foliar application of potassium, the significant influence in the uptake of potassium was noticed by the foliar application by mobilizing 92.0 kg ha^{-1} of potassium to crop.

While comparing the interaction effect of split and foliar applications of potassium, two splits with foliar (111 kg ha^{-1}) and three splits with foliar (108 kg ha^{-1}) excelled the uptake of K over other interactions at this stage. The lower uptake of K was invariably noticed in no foliar application of potassium in all the split foliar interactions.

Potassium uptake by grain

The uptake of K by grain (Table 2) markedly differed due to the main effect of split and foliar and the interaction effect of sources with splits and with foliar application of potassium. Among the split application, the three split application registered higher uptake of 45.0 kg ha^{-1}, followed by two split (42.4 kg ha^{-1}) and they were at par with each other, but greater than basal and (24.5kg ha^{-1}) and control treatment (20.6 kg ha^{-1}). The lower uptake by basal and K control treatment (20.6 kg ha^{-1}) were also on par with each other in the uptake of potassium by grain.

With regard to foliar application of potassium, the uptake of potassium by grain was influenced significantly by foliar application (36.2 kg ha^{-1}) over the no foliar application (30.0 kg ha^{-1}) of potassium.

In the case of interaction effect between sources and foliar, the $KClO_3$ with foliar application recorded higher K uptake (37.8 kg ha^{-1}) by grain, which was comparatively followed by $KClO_3$ without foliar application (34.6 kg ha^{-1}) and KCl without foliar application (33.5 kg ha^{-1}). The KCl with foliar application registered lower uptake (26.6 kg ha^{-1}) of K by grain.

Further perusal of interaction effect between split and foliar applications of potassium revealed that the maximum potassium uptake by the grain (50.2 kg ha^{-1}) was recorded in three splits with foliar application of potassium and it was closely followed by two spilt with foliar application (48.4 kg ha^{-1}). These two splits and three splits interactions with foliar application showed their marked difference in mobilizing the K to the grain than other type of interactions. In K control and basal applications, foliar spray did not express its influence on the uptake of K by the grain.

Potassium uptake by straw

The K uptake by straw (Table 3) increased with increased splits of potassium. The effects of splits of potassium were much pronounced in the accumulation of K in straw of aerobic rice. The higher uptake of K was registered at three split application (65.9 kg ha^{-1}), but it was on par with the uptake of two splits and basal (no split) application of potassium. The control treatment significantly recorded lower K uptake (46.7 kg ha^{-1}) by the straw.

In the case of interaction effect of source and split application of potassium, one of the two sources, potassium chloride with three splits showed maximum uptake of potassium (70.5kg ha^{-1}) over the potassium chlorate. Both the sources performed equally in the case of control and basal application of potassium. Whereas, these two sources showed their independent performances in the case of two and three splits treatments in the uptake of potassium by straw. However, equal performance of three and two splits through KCl were also noticed in the uptake by straw.

Potassium uptake by root

Split application of potassium alone showed their significance in the uptake of K by root (Table 3). Among the split applications, higher uptake (11.2 kg ha^{-1}) was recorded with three split application of potassium which was on par with the uptake of two splits of potassium. While in the case of basal and no application of potassium, the control treatment registered lower uptake (7.68 kg ha^{-1}) of potassium, but its performance was on par with the performance of basal application of potassium.

Discussion

Potassium uptake at different stages of crop growth

The potassium uptake was found to be significantly influenced by the split application of potassium at different stages of crop growth. The increased split of potassium increased the K uptake. This could be ascribed due to adequate avail ability of K in split doses than the no split and control treatment of k. The continuous supply of K through split at important stages of crop growth provide higher mobility of K to the plant from soil. As per Hu *et al.* (2004) [7], the phase from panicle initiation to flowering was critical for K up take by rice and more than half of the total K was accumulated during this phase. This was achieved by split applications in this investigation.

At flowering stage, the foliar and interaction of split and foliar spray showed significant influence and it was so evident on K uptake. The foliar spray facilitates the penetration of nutrients into the leaves, ultimately increase the uptake of K. The similar trend of increased K uptake by foliar spray was observed by Howard *et al* (1998) [6]; Ali *et al*. (2005 a, b) [2, 3]; Ali *et al*. (2007) [1] and Arabi *et al*. (2002) [4].
With regard to interaction effect, three split doses of potassium with foliar spray recorded higher K uptake which was due to the availability of potassium to plant both from the soil and from the foliar spray. Krishnappa *et al.* (2006) [9] reported that application of K increased the soil K availability, K content in grain and straw and uptake of K.

Potassium uptake by grain

The accumulation of potassium in grain was significantly influenced by the main effect of split and foliar and the interaction effect of source with foliar and split with foliar application.
Within split applications, three splits recorded higher K uptake than other splits. The response to more K uptake might be due to the satisfactory avail ability of applied K (Rehman *et al*., 2006) [3]. It is obvious that phasing of potassium at different stages of crop growth reduces the fixation losses of K and would favour the uptake of K at different stages, ultimately the K mobilized to grain. Manzoor *et al.* (2008) [10] also experienced that the efficient K uptake by rice plant resulted in better growth and development, when applied at maximum tillering stage and at panicle initiation stage.
The foliar spray of potassium significantly increased the uptake of K by grain, which is due to the penetration of K into leaves and serves a vital role in photosynthesis to accumulate more K in grain. Finck (1982) [5] emphasized the foliar application of K in the earlier period of research in rice.
The interaction effect of source and foliar showed significant influence on K uptake by grain. Both the sources are on par with each other in three split application of potassium. This shows evidently that both the sources of K could be able to supply required quantity of K through soil and foliar spray applications. The interaction of split and foliar spray showed higher uptake than the no foliar spray. This might be due to the satisfactory availability of applied K both through soil and foliar applications.

Potassium uptake by straw

The potassium uptake by straw was found to be significantly higher with the three split doses of potash. This might be due to the continuous supply of K at all active growth stages of crop which could be able to provide maximum availability of K. The K uptake was mainly dependent on the dry matter yield and K content of the straw. Efficient plants produce more biomass per unit of nutrient absorption particularly under nutrient stress condition (Yang *et al*., 2003) [12]. The same results were evinced through the studies of Yadav *et al*. (2004) [11] and Hu *et al*. (2004) [7].
Within the interaction of source and split applications, the potassium chloride in three splits could be able to mobilize more K to straw than the potassium chlorate ($KClO_3$). This might be due to the faster dissociation of KCl than $KClO_3$ and absorbed by the plants in higher amount.

Potassium uptake by root

The potassium uptake by root was significantly influenced by the split application of potassium. It is due to phasing of potassium, which reduces the fixation losses of K and increases the availability of K for more uptake by root.

Conclusion

In active tillering stage and panicle initiation stage, higher K uptake was recorded in three splits doses, whereas in flowering stage two splits recorded higher K uptake. The foliar spray individually and interaction with split enhanced the K uptake at flowering stage. The higher K uptake by grain, straw and root was recorded with three split doses of potassium. The foliar spray improved the K uptake by grain only.

Table 1: Potassium uptake (kg ha^{-1}) at active tillering and panicle initiation stages

	Active Tillering Stage							Panicle Initiation Stage						
	S_1	**S_2**	**S_3**	**S_4**	**K_1**	**K_2**	**Mean**	**S_1**	**S_2**	**S_3**	**S_4**	**K_1**	**K_2**	**Mean**
K_1F_1	15.5	19.7	27.7	33.5	-	-	-	28.0	37.1	51.6	54.2	-	-	-
K_1F_2	13.6	23.4	22.4	21.5	-	-	-	32.8	39.0	48.1	55.7	-	-	-
K_2F_1	15.3	9.60	22.8	29.6	-	-	-	28.1	36.3	56.7	56.9	-	-	-
K_2F_2	19.5	22.7	19.9	27.8	-	-	-	33.0	38.6	45.7	43.3	-	-	-
K_1 - KCl	14.5	21.5	24.8	27.5	-	-	-	30.4	38.0	49.8	55.0	-	-	-
K_2 - $KClO_3$	17.4	16.1	21.4	28.7	-	-	-	30.6	37.5	51.2	50.1	-	-	-
F_1	15.4	14.6	25.0	31.6	24.0	19.3	21.6	28.1	36.7	54.1	55.5	42.7	44.6	43.6
F_2	16.5	23.1	21.2	24.6	20.2	22.5	21.3	32.9	38.8	46.9	49.5	43.9	40.2	42.0
Mean	16.0	18.8	23.1	28.1	22.1	20.9	-	30.5	37.7	50.5	52.5	43.3	42.3	-

Sources	S.Ed.	C.D. (p = 0.05)	S.Ed.	C.D. (p = 0.05)
K sources (K)	2.812	NS	2.367	NS
Split application	3.977	6.8	3.347	5.7
Foliar application	2.812	NS	2.367	NS
K x S	5.624	NS	4.733	NS
K x F	3.977	NS	3.347	NS
S x F	5.624	NS	4.735	NS
K x S x F	7.954	NS	6.694	NS

Table 2: Potassium uptake (kg ha^{-1}) at flowering stage and by grain

	Flowering Stage							Grain						
	S_1	**S_2**	**S_3**	**S_4**	**K_1**	**K_2**	**Mean**	**S_1**	**S_2**	**S_3**	**S_4**	**K_1**	**K_2**	**Mean**
K_1F_1	58.7	64.0	86.6	76.6	-	-	-	23.5	24.4	41.8	44.3	-	-	-
K_1F_2	68.7	78.3	116	111	-	-	-	18.8	23.8	49.3	46.8	-	-	-

K_2F_1	61.6	53.6	63.5	66.8	-	-	-	17.6	22.2	31.1	35.6	-	-	-
K_2F_2	71.8	76.5	106	105	-	-	-	22.8	27.5	47.5	53.5	-	-	-
K_1 - KCl	63.7	71.1	101	94.2	-	-	-	21.1	24.1	45.5	45.5	-	-	-
K_2 - $KClO_3$	66.7	65.0	85.1	86.4	-	-	-	20.2	24.8	39.3	44.5	-	-	-
F_1	60.2	58.8	75.1	71.7	71.5	61.4	66.4	20.5	23.3	36.4	39.9	33.5	26.6	30.0
F_2	70.2	77.4	111	108	93.7	90.2	92.0	20.8	25.6	48.4	50.2	34.6	37.8	36.2
Mean	65.2	68.1	93.2	90.3	82.6	75.8	-	20.6	24.5	42.4	45.0	34.1	32.2	-

Sources	S.Ed.	C.D. (p = 0.05)	S.Ed.	C.D. (p = 0.05)
K sources (K)	3.680	NS	1.626	*NS*
Split application	5.240	8.8	2.300	3.9
Foliar application	3.680	6.2	1.626	*2.8*
K x S	7.360	NS	3.252	*NS*
K x F	5.204	NS	2.300	3.9
S x F	7.360	12.4	3.252	5.5
K x S x F	10.408	NS	4.599	*NS*

Table 3: Potassium uptake (kg ha^{-1}) by straw and root

	Straw							Root						
	S_1	**S_2**	**S_3**	**S_4**	**K_1**	**K_2**	**Mean**	**S_1**	**S_2**	**S_3**	**S_4**	**K_1**	**K_2**	**Mean**
K_1F_1	46.2	48.8	66.0	66.3	-	-	-	7.20	7.37	13.8	8.93	-	-	-
K_1F_2	46.5	53.7	66.5	74.8	-	-	-	7.60	9.33	12.5	11.8	-	-	-
K_2F_1	44.5	57.3	47.3	62.2	-	-	-	7.17	10.9	9.67	12.3	-	-	-
K_2F_2	49.7	61.1	58.6	60.3	-	-	-	8.77	4.87	8.40	11.9	-	-	-
K_1 - KCl	46.4	51.2	66.2	70.5	-	-	-	7.40	8.35	13.1	10.3	-	-	-
K_2 - $KClO_3$	47.1	59.2	53.0	61.2	-	-	-	7.97	7.92	9.03	12.1	-	-	-
F_1	45.3	53.0	56.7	64.2	56.8	52.8	54.8	7.18	9.17	11.7	10.6	9.33	10.0	9.68
F_2	48.1	57.4	62.5	67.5	60.3	57.4	58.9	8.18	7.10	10.4	11.8	10.3	8.49	9.40
Mean	46.7	55.2	59.6	65.9	58.6	55.1	-	7.68	8.13	11.0	11.2	9.82	9.27	-

Sources	S.Ed.	C.D. (p = 0.05)	S.Ed.	C.D. (p = 0.05)
K sources (K)	2.716	NS	1.005	NS
Split application	3.841	6.5	1.422	2.4
Foliar application	2.716	NS	1.005	NS
K x S	5.431	9.2	2.011	NS
K x F	3.841	NS	1.422	NS
S x F	5.431	NS	2.011	NS
K x S x F	7.681	NS	2.844	NS

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