Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2020; 9(2): 645-648
Received: 01-01-2020
Accepted: 05-02-2020

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Effect of potassic fertilizer application on available potassium at different growth stages of paddy in calcareous soil of North Bihar

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Abstract
A field experiment was conducted in calcareous soil of North Bihar which was medium in available K. The experiment was carried out in split-plot design with two paddy varieties *viz.*, Inbred and Hybrid in main plot and six combinations of potassium management *viz.*, control, NP(-K), NP + K (100% basal), NP + K (50% as basal + 50% at tillering), NP + K (50% as basal + 50% at panicle) and NP + K (50% as basal + 25% at tillering + 25% at panicle) in sub-plot during *Kharif*, 2017 at Crop Research Farm, RPCAU, Pusa, Samastipur. The availability of K in the soil at different growth stages of paddy was found to improve with split applications of potassium over basal application. At tillering stage, available K was highest in the plots receiving split applications of K *i.e.* 50% as basal + 50% at tillering while at panicle and milking stage, available K was highest in the plots with split application of K *i.e.* 50% as basal + 50% as panicle. At maturity, it was highest in the plots with three split applications of K (50% as basal + 25% at tillering + 25% at panicle).

Keywords: Potassium paddy

Introduction
Paddy (*Oryza sativa*), a major crop cultivated globally in an area of 167.13 million hectares with an annual production of 782 million tons and average productivity of 4678.9 kg ha^{-1} (FAO Stat., 2018) [4]. Rice provides staple food for more than half of the world's population (Somaweera *et al.*, 2016) [12]. In India, paddy is cultivated in 44.5 million hectares with production of 172.58 million tons and productivity of 3878.2 kg ha^{-1} (FAO Stat., 2018) [4]. Global demand of milled rice is estimated to increase from 496 million tons in 2020 to 555 million tons in 2035 as the global population increases (Tuong and Bouman, 2002) [13].
Total fertilizer application for paddy is estimated to be 27.3 million tons in 2015 and is expected to increase further up to 29.3 million tons by 2030 (FAO, 2000) [3]. Moreover, the efficiency of fertilizers applied will be 50% or less for nitrogen (N), less than 10% for phosphorus (P), and 40% for potassium (K) (Baligar *et al.*, 2001) [1]. The application of potassium can minimize the drought effects of paddy.
Reports showed that K deficiency is wide spread across the globe, ranging from tropical to temperate environments. In India, potassium status of soil is 15% low, 47% medium and 38% high whereas in case of Bihar, 12.9% low, 80.2% medium and 6.9% high in Bihar (Soil Health Dashboard, 2018) [11]. Evidences from long-term experiments in different cropping systems strongly indicates significant yield responses to K application and negative K balances where K application is either omitted or applied sub-optimally. Omission of K decreased the paddy equivalent yield by 5 – 15% in calcareous soil of Bihar (Singh *et al.*, 2017) [10].

Material and Methods
The experimental plot is located at 25^0 94'N latitude, 85^0 67'E longitude and an altitude of 52.3 meter above mean sea level under Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar. The experimental design used was split plot with two varieties (inbred-*Sugandha* 5 and hybrid-*Arize 6444*) as main plot and six different rate and time of application of potassium *viz.*, control, NP(-K), NP + K (100% basal), NP + K (50% as basal + 50% at tillering), NP + K (50% as basal + 50% at panicle) and NP + K (50% as basal + 25% at tillering + 25% at panicle) as sub-plot. The dose of NPK, based on Nutrient Expert tool for inbred and hybrid paddy was 108:23:46 and 123:39:65 kg ha^{-1}, respectively. Sources of N, P and K were urea, DAP and MOP, respectively. The pH of 1:2, soil: water suspension was determined with the help of glass electrode pH meter (Systronics μ pH system 361) as described by Jackson, 1967.

The electrical conductivity in the clear extract of soil with water in soil: water ratio of 1:2 was determined with the help of Electrical Conductivity Bridge (Systronics conductivity TDS meter 308) (Bower and Wilcox, 1965). It was determined by rapid titration method as described by Walkley and Black, 1934.

The available K of soils was estimated with the help of flame photometer in the aliquot obtained by equilibrating the soils with the extractant in the 1: 5:: soil: 1*N* neutral Ammonium Acetate for five minutes as per method (Hanway and Heidel, 1952).

Result and Discussion

Physico-chemical properties of post-harvest soil (0-15 cm)

pH and Electrical Conductivity (dS m^{-1})

The changes in pH and electrical conductivity (EC) of the post harvest soil were not significant due to application of K as depicted in table 1. The mean pH of the soil varied from 8.65 and 8.76 in control and K treated plots with two split doses (50% as basal + 50% at panicle), respectively. The highest pH was observed in the treatment receiving potassium 50% as basal + 50% at panicle. Also, the interaction effect between variety and split application of potassium for pH was not significant. Similar effects were also observed for EC (dS m^{-1}) which was not affected by variety and potassium fertilization. However, it varied from 0.432 to 0.445 dS m^{-1} in K treated plots with two split doses (50% as basal + 50% at tillering) and control, respectively.

Organic carbon (g kg^{-1})

Organic carbon content in post-harvest soil as shown in table 2, revealed that it was non-significantly affected by variety and application of potassic fertilizers. The mean organic carbon content was found to varied from 6.44 to 6.64 g kg^{-1} and the highest content (6.64 g kg^{-1}) was observed under the treatment receiving three splits of K (50% as basal + 25% at tillering + 25% at panicle).

Available K in soil (0-15 cm) at tillering stage

The effect of K fertilization on available K in soil at tillering stage of paddy plant is presented in table 3. Application of potassic fertilizer increased the available K significantly over NP(-K) and control at tillering stage and mean available K content varied from 112.56 to 147.72 mg kg^{-1} in control and K treated plots with two split doses (50% as basal+ 50% at tillering), respectively. The availability of K was significantly higher (147.72 mg kg^{-1}) in the treatment receiving K in two splits (50% as basal + 50% at tillering).

Table 1: Effect of K fertilization on pH and EC in post harvest soil (0-15 cm)

Treatment	pH			EC (dSm^{-1})		
	Inbred	Hybrid	Mean	Inbred	Hybrid	Mean
Control	8.51	8.79	8.65	0.447	0.444	0.445
NP(-K)	8.63	8.79	8.71	0.448	0.440	0.444
NP + K (100% as basal)	8.68	8.74	8.71	0.437	0.432	0.434
NP + K (50% as basal + 50% at tillering)	8.64	8.63	8.63	0.428	0.435	0.432
NP + K (50% as basal + 50% at panicle)	8.66	8.86	8.76	0.432	0.433	0.433
NP + K (50% as basal + 25% at tillering + 25% at panicle)	8.74	8.58	8.66	0.433	0.435	0.434
Mean	8.64	8.73	-	0.438	0.436	-
	S.Em±	CD (P=0.05)	-	S.Em±	CD (P=0.05)	-
V	0.06	NS	-	0.002	NS	-
K	0.07	NS		0.014	NS	
V X K	0.09	NS		0.020	NS	

V= Variety, K= Potassium

Table 2: Effect of K fertilization on organic carbon content (g kg^{-1}) in post harvest soil

Treatment	Inbred	Hybrid	Mean
Control	6.44	6.45	6.44
NP(-K)	6.49	6.44	6.47
NP + K (100% as basal)	6.59	6.55	6.57
NP + K (50% as basal + 50% at tillering)	6.58	6.53	6.55
NP + K (50% as basal + 50% at panicle)	6.64	6.59	6.62
NP + K (50% as basal + 25% at tillering + 25% at panicle)	6.65	6.64	6.64
Mean	6.57	6.53	
	S.Em±	CD (P=0.005)	CV (%)
V	0.02	NS	5.43
K	0.15	NS	
V X K	0.21	NS	

V= Variety, K= Potassium

However, it was at par with 50% as basal + 50% at panicle, 50% as basal + 25% at tillering + 25% at panicle and 100% as basal. Available K in soil (140.27 mg kg^{-1}) under hybrid paddy grown plot was 11.1% higher than inbred paddy grown plot (126.30 g kg^{-1}). However, the interaction effect between variety and potassium fertilization was not significant.

Available K in soil (0-15 cm) at panicle stage

The effect of K fertilization on available K in soil at panicle stage is presented in table 3. At panicle stage of paddy, significantly higher mean available K (118.57 mg kg^{-1}) was observed in the treatment receiving K in two splits (50% as basal + 50% at panicle), compared to other treatments. However, it was found at par with treatment receiving K as 50% as basal + 25% at tillering + 25% at panicle, 50% as basal + 50% at tillering. The available K in hybrid paddy grown plot (103.35 mg kg^{-1}) was 6.7% higher than inbred paddy grown plot (110.30 mg kg^{-1}). The interaction effect between variety and potassium fertilization was not significant.

Available K in soil (0-15 cm) at milking stage

The effect of K fertilization on available K in soil at milking stage is presented in table 4. At milking stage treatment receiving in two split (50% as basal + 50% at panicle) recorded significantly higher mean available K content than other treatments however, it was found at par with NP + K (50% as basal + 50% at tillering), NP + K (50% as basal + 25% at tillering + 25% at panicle) and NP + K (100% as basal). The available K in soil (145.41 mg kg^{-1}) at milking stage in hybrid paddy grown plot was 9.7% higher than inbred paddy grown plot (132.57 mg kg^{-1}). However, the interaction between variety and split application of K was not significant.

Table 3: Effect of K fertilization on available K (mg kg^{-1}) in soil at tillering and panicle stage

Treatment	Tillering stage			Panicle stage		
	Inbred	Hybrid	Mean	Inbred	Hybrid	Mean
Control	107.27	117.85	112.56	89.67	92.40	91.03
NP(-K)	109.83	120.18	115.01	92.82	97.58	95.20
NP + K (100% as basal)	130.60	148.23	139.42	102.18	109.25	105.72
NP + K (50% as basal + 50% at tillering)	139.17	156.27	147.72	109.67	119.55	114.61
NP + K (50% as basal + 50% at panicle)	135.22	151.83	143.53	113.92	123.22	118.57
NP + K (50% as basal + 25% at tillering + 25% at panicle)	135.72	147.25	141.48	111.83	119.82	115.83
Mean	126.30	140.27		103.35	110.30	
	S.Em ±	CD(P=0.05)	CV (%)	S.Em ±	CD(P=0.05)	CV(%)
V	1.03	6.27		0.94	5.76	
K	4.27	12.62	7.86	3.50	10.33	8.03
V X K	6.05	NS		4.95	NS	

V= Variety, K= Potassium

Available K in soil (0-15 cm) at harvesting stage

Available K in post harvest soil was non-significantly affected by variety and potassium fertilization (Table 4). The mean available K in post harvest soil range from 75.76 and 83.18 mg kg^{-1} in NP(-K) and K treated plots with three split doses (50% as basal + 25% at tillering + 25% at panicle), respectively. The highest mean available K content (83.18 mg kg^{-1}) was observed in the treatment receiving K in three splits, 50% as basal + 25% at tillering + 25% at panicle. However, the effect of available K in soil due to treatment and variety was non-significant.

The available K content in soil decreased as the growth of crop advances towards physiological maturity and this may be due to K uptake by plants and leaching losses. These results corroborate with the findings of Mani and Ramanathan (1980) [7]. The treatment which received split application of K recorded highest available K at all the periods of observation and this may be due to reduction in leaching losses of K due to split application. This is in conformity with the reports of Nanjundappa (2002) [8]. The amount of potassium present in the soil solution is often smaller than the crop requirement for potassium. Thus, continuous renewal of potassium in the soil solution for adequate nutrition of high yielding varieties of paddy and wheat is obvious. Similarly, exchangeable potassium component has to be continuously replenished through the release of fixed potassium and weathering of potassium minerals. Hence, potassium availability to crops is a function of the amounts of different forms of potassium in soil, their rates of replenishment and the degree of leaching (Singh *et al.*, 2003) [9].

The variability in available K in soils estimated at different growth stages of paddy is presented in figure 1. The available K was found to decrease from tillering to panicle stage and again increased from panicle to milking stage and again decreased from milking to maturity stage. The decrease in available K from tillering to panicle stage was might be due to accumulation of K in root zone soil as there was less requirement of K by the sink *i.e.* shoot, leaves and reproductive parts. Again, the decrease in available K until maturity was might be due to conversion of available K in to other forms like non-exchangeable form etc.

Table 4: Effect of K fertilization on available K (mg kg^{-1}) in soil milking and harvesting stage

Treatment	Milking stage			Harvesting stage		
	Inbred	Hybrid	Mean	Inbred	Hybrid	Mean
Control	115.95	127.70	121.83	76.52	76.10	76.31
NP(-K)	118.40	129.88	124.14	75.44	76.08	75.76
NP + K (100% as basal)	136.73	149.72	143.23	79.49	78.76	79.12
NP + K (50% as basal + 50% at tillering)	139.77	157.87	148.82	81.05	80.41	80.73
NP + K (50% as basal + 50% at panicle)	142.67	155.65	149.16	81.62	82.13	81.87
NP + K (50% as basal + 25% at tillering + 25% at panicle)	141.88	151.67	146.78	83.38	82.98	83.18
Mean	132.57	145.41		79.58	79.41	
	SE(m) ±	CD(P=0.05)	CV	SE(m) ±	CD(P=0.05)	CV
V	1.48	9.05		0.81	NS	
K	4.26	12.59	7.52	2.85	NS	8.78
V X K	6.03	NS		4.03	NS	

V= Variety, K= Potassium

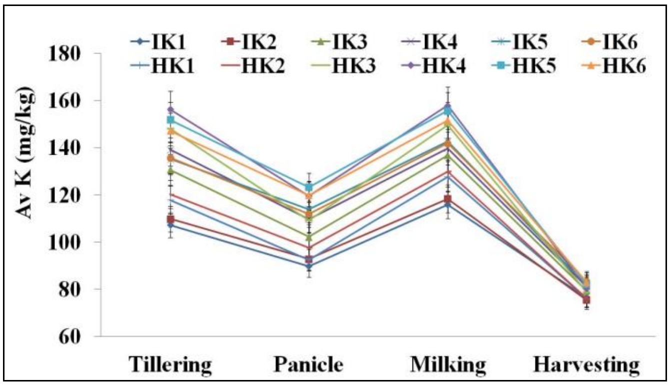

Fig 1: Changes in available K Content in soil at different growth stages of paddy

Conclusion

It may be concluded that full dose of nitrogen, phosphorus and half dose of potassium as basal application and remaining dose of potassium at panicle initiation stage increases available potassium in the soil which helps in different growth stages of paddy.

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