Indian Journal of Fertilisers **15** (7) : 758-764, July 2019

Potash Management in Black Gram-Sorghum Sequence on Dryland Soils of Maharashtra

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Received : 17/05/2019 Accepted : 07/06/2019

Abstract

Field experiments were conducted on dryland soils of AICRPDLA, Solapur for three years (2015-2016 to 2017-18) to evaluate the influence of different levels of potassium on *kharif* black gram-*rabi* sorghum cropping sequence in the randomized block design (RBD) for *kharif* black gram and split plot design for *rabi* sorghum. Grown in a sequence, *kharif* black gram and *rabi* sorghum responded significantly to the application of 20 and 50 kg K_2O ha^{-1}, respectively. Potassium application to both the crops sustained optimum levels of water soluble, exchangeable and non-exchangeable K in the soil which enhanced the K uptake and improved the moisture use efficiency over the farmers' practice which exclude the application of K. Inclusion of K in fertilization schedule gave 38 and 9.5% higher yield in *kharif* black gram and *rabi* sorghum crops, respectively. Higher monitory returns and B:C ratio over the farmers' practice were associated with application of potassic fertilizers.

Key words: Potassium, fertilization, black gram – sorghum sequence, potassium fractions

Introduction

Sorghum and black gram are two important crops generally grown under semi-arid conditions of western Maharashtra. In general, there is an aberrant weather situation every year in terms of early onset of monsoons followed by immediate prolonged dry spell, delayed onset of monsoons, early cessation of rains and extended monsoons etc. and drought invariably every after 2-3 years. Even though the excess rainfall than normal might be received, yet the crop growth and yields of different crops are adversely affected due to dry spells in *kharif* and *rabi* and uneven distribution of rainfall, climate variable pattern and identified sinusoidal pattern of rainfall in the region. Potassium (K) is an important nutrient for dryland field crops, especially during dry spells where a large quantity of K is taken up by plants from soil to complete their life cycle. Black soils formed under dryland condition generally show richness in available K (450 to 950 kg ha^{-1}). However, water soluble potassium in the soil and its availability to growing crops is very less due to wetting and drying conditions and large differences in the parent material which differentially affects the weathering of K-bearing minerals.

Majority of dryland soils are Vertisols and Inceptisols dominated by smectite and associated groups of clays *viz.*, smectite + vermiculite, smectite + montmorillonite. These clays fix K upon drying because of K getting trapped in the interlayers of clay minerals. Despite significant additions of plant nutrients through fertilizers, there still exists a vast gap between the nutrient removal by crops and their additions to the soil. Situation is more precarious in case of dryland soils (Patil et al., 2001). Compilation made by IPNI showed that although about 1,77,191 t of K was added annually to the dryland soils, its removal by the crops was whopping 20,95,939 t, leaving an astronomically large negative K balance (Anonymous, 2011). Over a period of time, there has been a gradual decline in the available K status of the soils of Maharashtra (Motsara, 2002). Unless immediate steps are undertaken to arrest this K mining, unsustainability in the crop productivity and degradation of soil health will have catastrophic effects.

About 50% of food grains and 65% of oilseeds are contributed from the rainfed and dryland regions. Seventy-two per cent of the country's area in general, and 82% area in particular of Maharashtra, comes under rainfed and dryland agriculture. To increase the production and productivity of Maharashtra, more emphasis needs to be placed on rainfed and dryland field crops. Keeping this in

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mind, this project on potash fertilizer management in dryland field crops was undertaken.

Materials and Methods

Field experiments were conducted on Vertisols of Mulegaon Farm, AICRPDLA, Solapur for three years (2015-2016 to 2017-18) to evaluate the influence of potassium (K) fertilization in *kharif* black gram - *rabi* sorghum cropping sequence. Soil properties before sowing of *rabi* sorghum were 178 kg ha^{-1} available nitrogen (N), 11.07 kg ha^{-1} available phosphorus (P), 362 kg ha^{-1} available K, 10.00 mg kg^{-1} water soluble K, 698 mg kg^{-1} exchangeable K, and 548 mg kg^{-1} non-exchangeable K. Experiment was conducted in a randomized block design (replicated thrice) for *kharif* crop of black gram and in split plot design for *rabi* sorghum. Crop varieties taken for experimentation included TAU-1 for black gram and Phule Anuradha for sorghum. Treatments for *kharif* black gram (which have been subsequently referred to as main treatments) included: B_1 (control) - 00:00:00, B_2 (farmers' practice) – 25 kg N + 50 kg P_2O_5 + 10 kg K_2O ha^{-1}, B_3 - 25 kg N + 50 kg P_2O_5 + 20 kg K_2O ha^{-1}, and B_4 - 25 kg N + 50 kg P_2O_5 + 30 kg K_2O ha^{-1}. In the *rabi* season, each main plot was subdivided to accommodate five sub-treatments namely, S_1 (farmers' practice) -- 40 kg N + 0 kg P_2O_5 + 0 kg K_2O ha^{-1}, S_2 - 50 kg N + 25 kg P_2O_5 + 0 kg K_2O ha^{-1}, S_3 - 50 kg N + 25 kg P_2O_5 + 25 kg K_2O ha^{-1}, S_4- 50 kg N + 25 kg P_2O_5 + 50 kg K_2O ha^{-1}, and S_5- 50 kg N + 25 kg P_2O_5 + 75 kg K_2O ha^{-1}. Crops were raised following the standard package of practices recommended by MPKV, Rahuri. Soil samples collected after the harvest of *kharif* black gram and *rabi* sorghum were analysed for available, water soluble, exchangeable and non-exchangeable K contents.

Result and Discussion

Results are presented and discussed crop-wise.

Black Gram

Crop Yields

There occurred a significant increase in the grain and stover yields of black gram with increase in rate of K from 0 to 30 kg K_2O ha^{-1} (**Table 1**). Significantly higher grain (534 kg ha^{-1}) and stover (1249 kg ha^{-1}) yields were obtained in the B_3 treatment receiving 20 kg K_2O ha^{-1}; these were statistically at par with the yields obtained with 30 kg K_2O ha^{-1}(B_4) (553 and 1308 kg ha^{-1} grain and stover yields, respectively). It establishes the usefulness of applying 20 kg K_2O ha^{-1} with recommended dose of N and P_2O_5 in black gram. In this study, 38% increase in the grain yield over the farmers' practice was obtained. Majumdar et al. (2011) reported that the grain yield response to fertilizer K which is highly variable is influenced by soil, crop and management practices and as such skipping application of K could cause significant yield and economic losses. Bansal et al. (2018) also observed a significant increase in rice productivity (ranging from 6 to 15%) in six states *viz*. Andhra Pradesh, Chhattisgarh, Madhya Pradesh, Telangana, Uttar Pradesh and West Bengal.

Potassium Fractions under Black Gram Cultivation

Variable doses of K applied to black gram did not significantly influence the water soluble and exchangeable K content in the post-harvest samples. However, application of 30 kg K_2O ha^{-1} along with the recommended doses of N and P was associated with highest non-exchangeable K (714.0 mg kg^{-1}); it was significantly superior to the rest of K treatments (**Table 2**). Srinivasarao and Khera (1994) and Srinivasarao et al. (1998, 2000) reported that in the absence of K application, initially exchangeable K in the soil contributes to plant K nutrition, but with the prolonged cropping, exchangeable K falls to a certain minimum critical level. Thereafter, K removal by plants from the soil is largely from the non-exchangeable K pool. Under these conditions 90-95% of K uptake is from this pool which is often termed as non-exchangeable but useful K. This pool, determined by the amount and nature of clay minerals in the soil, gives a good index of soil K fertility.

Table 1. Effect of potash levels on yield, and nutrient uptake of black gram

Treatments (kg ha^{-1})			Grain (kg ha^{-1})	Stover (kg ha^{-1})	MUE (kg grain ha^{-1} mm^{-1})	Nutrient uptake (kg ha^{-1})		
N	P_2O_5	K_2O				N	P	K
0	0	0	384	686	0.94	19.36	2.75	11.62
25	50	10	401	855	0.94	24.23	4.39	17.29
25	50	20	534	1249	1.18	39.83	6.36	24.66
25	50	30	553	1308	1.16	44.39	9.38	27.33
S.E.±			6	16	—	0.76	0.48	0.54
CD (P = 0.05)			22	54	—	2.62	1.65	1.87

Table 2. Effect of potash levels on different K fractions (mg kg^{-1}) before sowing and after harvest of black gram

Treatments ($kg\ ha^{-1}$)			Water soluble K (mg kg^{-1})		Exchangeable K (mg kg^{-1})		Non-exchangeable K (mg kg^{-1})	
N	P_2O_5	K_2O	Before sowing	After harvest	Before sowing	After harvest	Before sowing	After harvest
0	0	0	12.3	16.3	306	402	530	548
25	50	10	12.8	18.3	353	430	640	650
25	50	20	18.8	20.5	394	438	624	634
25	50	30	14.5	17.3	454	444	722	714
S.E.$_{\pm}$			1.1	0.9	4	18	23	20
CD (P = 0.05)			3.9	NS	14	NS	80	68

Nutrient Uptake

Uptake of N, P and K by black gram was highest (44.39, 9.38 and 27.33 kg ha^{-1}, respectively) in the plots receiving 30 kg K_2O ha^{-1} along with the recommended N and P rates. It was significantly superior to the rest of the treatments (**Table 1**).

***Rabi* Sorghum**

Yield

Influence of K applied to black gram in *kharif* season (main treatments) on the grain and fodder yield of *rabi* sorghum is depicted in **Table 3**. Highest mean grain (1391 kg ha^{-1}) and fodder (3247 kg ha^{-1}) yields of *rabi* sorghum were observed in the treatment B_4 and these were statistically at par with the yields obtained under B_3 treatment (1361 and 3170 kg ha^{-1}, respectively). Influence of sub-plot treatments *i.e.*, K applied directly to sorghum crop on the grain and fodder yields is depicted in **Table 3**. Results on mean yields indicated a significant increase in the grain and stover yields (1172 and 2863 kg ha^{-1}) of sorghum under nil application of K to 1303 and 3231 kg ha^{-1} with application of 75 kg K_2O ha^{-1}. Significantly higher mean grain and fodder yields obtained in the treatment receiving 75 kg K_2O ha^{-1} (S_5) (1303 and 3231 kg ha^{-1}) was, however, on par with the treatment receiving 50 kg K_2O ha^{-1} *i.e.* S_4 (1283 and 3199 kg ha^{-1}). It can be concluded from these results that the application 50 kg K_2O ha^{-1} along with recommended doses of N and P_2O_5 is beneficial as this caused 9.5% increase in the grain yields of sorghum. In similar studies with rice and potato, usefulness of K application was demonstrated (Bansal et al., 2018, 2019). Average rice yields increased between 6-15% in six states *viz*., Andhra Pradesh, Chhattisgarh, Madhya Pradesh, Telangana, Uttar Pradesh and West Bengal

Table 3. Effect of potash levels on grain and fodder yield of *rabi* sorghum and potassium fractions in soil at harvest

	Yield (kg ha^{-1})		MUE	Potassium fractions (mg kg^{-1})		
	Grain	Fodder	(kg grain ha^{-1} mm^{-1})	Water soluble	Exchangeable	Non-exchangeable
Main treatments						
B_1	1066	2892	4.81	11.1	380	422
B_2	1128	3025	5.40	12.3	389	535
B_3	1361	3170	5.23	14.9	387	570
B_4	1391	3247	3.96	14.3	383	527
SE$_{\pm}$	10	23	—	0.7	29	8
CD (P = 0.05)	36	79	—	2.5	NS	27
Sub treatments						
S_1	1172	2863	4.65	9.0	312	421
S_2	1181	3014	4.66	11.8	342	474
S_3	1243	3105	4.90	13.8	417	547
S_4	1283	3199	4.92	14.7	434	546
S_5	1303	3231	5.11	16.4	418	580
SE$_{\pm}$	9	21	—	0.6	11	12
CD (P = 0.05)	26	60	—	1.6	32	35
Interaction						
SE$_{\pm}$	18	42	—	1.1	22	24
CD (P = 0.05)	NS	NS	—	NS	NS	69

Table 4. Effect of potash levels on non-exchangeable K content (mg kg^{-1}) after harvest of *rabi* sorghum

Sub/Main	S_1	S_2	S_3	S_4	S_5	Mean
B_1	426	428	470	362	422	422
B_2	450	488	528	600	608	535
B_3	452	486	608	622	684	570
B_4	356	494	580	598	606	527
Mean	421	474	547	546	580	—
	B	*S*	*B × S*			
SE±	8	12	24			
CD (P = 0.05)	27	35	69			

(Bansal et al., 2018). In case of potato, increase was 10.9% in the states of West Bengal and Jammu & Kashmir (Bansal et al., 2019). Sorghum responded to K application at Akola and Sirguppa under rainfed conditions (Pillai et al. 1987).

Potassium Fractions in Post-harvest Soil Samples after Rabi Sorghum

Data on K fractions in **Table 3** showed that the soil receiving B_3 treatment recorded highest soil solution K (14.9 mg kg^{-1}) and non-exchangeable K (570 mg kg^{-1}) contents; values of soil solution K under B_3 were statistically on par with those under B_4 (14.3 mg kg^{-1}). Influence of rates of K applied to *kharif* black gram on exchangeable K at the time of sorghum harvest was non-significant (**Table 3**).

Application of 75 kg K_2O ha^{-1} to sorghum resulted in highest soil solution K (16.4 mg kg^{-1}) at the harvest (**Table 3**). Highest value of 434 mg kg^{-1} of exchangeable K was recorded in a treatment receiving 50 kg K_2O ha^{-1}; however, it was statistically on par with that obtained with application of 25 and 75 kg K_2O ha^{-1} (417 and 418 mg kg^{-1}, respectively). Non-exchangeable K content exhibited a significant rise with application of 25 kg K_2O ha^{-1} to sorghum; subsequent increase in this fraction with rise in K application rates to 75 kg K_2O ha^{-1} was statistically non-significant.

Interaction effects on the soil solution K and exchangeable K were non-significant. Effects on non-exchangeable K were significant (**Table 4**). Application of 20 kg K_2O ha^{-1} to black gram followed by 75 kg K_2O ha^{-1} to *rabi* sorghum recorded the highest value of 684 mg kg^{-1}; it was on par (622 mg kg $^{-1}$) with that obtained under B_3S_4.

Nutrient Uptake

Uptake of N, P and K by sorghum under varying treatments is depicted in **Table 5**. Application of 30 kg K_2O ha^{-1} to *kharif* black gram recorded highest uptake of N (41.41 kg ha^{-1}) and K (61.31 kg ha^{-1}) by sorghum; highest uptake of P (11.78 kg ha^{-1}) was observed where 20 kg K_2O ha^{-1} had been applied to the preceding *kharif* black gram crop. Manjunatha

Table 5. Effect of potash levels on available nutrient content in the soil and uptake after harvest of *rabi* sorghum

	Available nutrient content (kg ha^{-1})			Nutrient uptake by sorghum (kg ha^{-1})		
	N	P	K	N	P	K
Main treatment						
B_1	249	39.7	876	32.15	7.20	44.28
B_2	219	33.8	898	32.40	10.51	52.14
B_3	240	44.1	899	40.55	11.78	56.36
B_4	229	31.9	889	41.41	11.44	61.31
SE±	5	1.7	63	0.15	0.06	0.67
CD (P = 0.05)	17	5.9	NS	0.52	0.22	2.32
Sub - treatment						
S_1	223	26.0	718	28.69	7.58	42.64
S_2	234	38.6	792	33.33	9.95	49.66
S_3	237	39.0	964	37.67	9.33	52.15
S_4	236	45.7	1006	39.81	11.22	59.35
S_5	242	37.6	974	43.63	13.07	63.81
SE±	6	2.0	25	0.19	0.071	1.08
CD (P = 0.05)	NS	5.8	72	0.54	0.205	3.11
Interaction						
SE±	11	3.99	50.27	0.38	0.14	2.16
CD (P = 0.05)	32	NS	NS	1.09	0.41	6.22

Table 6. Interaction effect of potash levels on nutrient uptake by sorghum

SubMain	S_1	S_2	S_3	S_4	S_5	Mean
			Nitrogen uptake (kg ha^{-1})			
B_1	24.59	28.47	34.66	34.09	38.93	32.15
B_2	27.79	30.34	30.33	36.26	37.27	32.40
B_3	29.43	37.70	43.88	43.79	47.98	40.55
B_4	32.97	36.80	41.82	45.07	50.37	41.41
Mean	28.69	33.33	37.67	39.81	43.63	-
	B × S	-	-	-	-	-
SE$_{\pm}$	0.38	-	-	-	-	-
CD (P = 0.05)	1.09	-	-	-	-	-
			Phosphorus uptake (kg ha^{-1})			
B_1	5.68	7.35	7.26	7.37	8.31	7.20
B_2	8.57	10.00	8.34	13.10	12.50	10.51
B_3	8.42	11.01	11.43	12.60	15.45	11.78
B_4	7.64	11.45	10.28	11.79	16.01	11.44
Mean	7.58	9.95	9.33	11.22	13.07	-
	B × S	-	-	-	-	-
SE$_{\pm}$	0.14	-	-	-	-	-
CD (P = 0.05)	0.41	-	-	-	-	-
			Potassium uptake (kg ha^{-1})			
B_1	35.93	39.41	40.81	48.33	56.90	44.28
B_2	39.11	55.00	52.99	57.86	55.73	52.14
B_3	45.14	49.25	58.11	63.44	65.84	56.36
B_4	50.36	54.96	56.67	67.79	76.76	61.31
Mean	42.64	49.66	52.15	59.35	63.81	-
	B × S	-	-	-	-	-
SE$_{\pm}$	2.16	-	-	-	-	-
CD (P = 0.05)	6.22	-	-	-	-	-

et al. (2011) also reported a significant increase in K uptake by *rabi* rice with N, P, and K fertilization of the *kharif* crop.

Application of 75 kg K_2O ha^{-1} along with the recommended doses of N and P_2O_5 to sorghum produced the highest uptake of N (43.63 kg ha^{-1}), P (13.07 kg ha^{-1}) and K (63.81 kg ha^{-1}); these were significantly superior to those obtained under the rest of the treatments. Jat et al. (2011) reported data for maize from 36 locations in Bihar and West Bengal. In their study, maize yield with full dose of N, P and K ranged from 4,020 to 9,420 kg ha^{-1} with a mean value of 6343 kg ha^{-1}.

Interaction effects were significant. Highest uptake of N (50.37 kg ha^{-1}), P (16.01 kg ha^{-1}) and K (76.76 kg ha^{-1}) was recorded in the treatment comprising of application of 30 kg K_2O ha^{-1} to *kharif* black gram followed by addition of 75 kg K_2O ha^{-1} to *rabi* sorghum (**Table 6**).

Correlation Studies

All the K fractions were positively and significantly correlated with grain and stover yields of sorghum with the sole exception of exchangeable K *vs.* grain yield (**Table 7**). Soil solution K was positively and significantly correlated with grain (r = 0.733**) and stover (r = 0.918**) yield. Exchangeable K was significantly correlated only with the stover yield (r = 0.610**). The non-exchangeable K was positively

Table 7. Correlation of forms of K with yield of *rabi* sorghum

Parameters	Soil Solution-K	Exchangeable-K	Non-exchangeable K	Total K uptake
Grain yield	0.733**	0.268	0.620**	0.749**
Stover yield	0.918**	0.610**	0.799**	0.929**

N= 20, * = Significance at 5% (0.443), ** = significance at 1% (0.561)

Table 8. Effect of potash levels on yield of grain, fodder and economics of *kharif* black gram

Treatments ($kg\ ha^{-1}$) N	P_2O_5	K_2O	Grain yield ($kg\ ha^{-1}$)	Stover yield ($kg\ ha^{-1}$)	Gross monetary returns ($kg\ ha^{-1}$)	Net monetary returns ($Rs.\ ha^{-1}$)	Benefit: cost ratio ($Rs.\ Re^{-1}$)
0	0	0	384	686	18,186	2,186	1.14
25	50	10	401	855	19,407	3,407	1.21
25	50	20	534	1249	26,175	10,175	1.64
25	50	30	553	1308	27,150	11,150	1.70
S.E.±			6	16	-	-	-
CD (P = 0.05)			22	54	-	-	-

Table 9. Effect of potash levels on yield of grain, fodder and economics of *rabi* sorghum

Treatments	Grain yield ($kg\ ha^{-1}$)	Fodder yield ($kg\ ha^{-1}$)	Gross monetary returns ($Rs.\ ha^{-1}$)	Net monetary returns ($Rs.\ ha^{-1}$)	Benefit: cost ratio ($Rs.\ Re^{-1}$)
Main-treatment					
B_1	1066	2892	57,554	32,454	2.29
B_2	1128	3025	60,655	35,555	2.42
B_3	1361	3170	69,825	44,725	2.78
B_4	1391	3247	71,414	46,314	2.85
S.E.±	10	23	-	-	-
CD (P = 0.05)	36	79	-	-	-
Sub - treatment					
S_1	1172	2863	61,061	35,961	2.43
S_2	1181	3014	62,433	37,332	2.49
S_3	1243	3105	65,240	40,138	2.60
S_4	1283	3199	67,298	42,195	2.68
S_5	1303	3231	68,222	43,118	2.72
S.E.±	9	21	-	-	-
CD (P = 0.05)	26	60	-	-	-
Interaction					
S.E.±	0.18	0.42	-	-	-
CD (P = 0.05)	NS	NS	-	-	-

and significantly correlated with both grain (r = 0.620**) and stover (r = 0.799**) yields. It is evident that the grain as well as stover yields increased with improvement in the different K fractions in the soil. Total K uptake was positively and significantly correlated with grain (r = 0.749**) and stover (r = 0.929**) yields.

Economics

Data presented in **Tables 8** and **9** shows that the application of 30 kg K_2O ha^{-1} to *kharif* black gram followed by 75 kg K_2O ha^{-1} to *rabi* sorghum under dryland conditions gave the highest gross and net monetary returns and benefit: cost ratios. Mujumdar et al. (2011) reported returns of Rs. 5.5, 4.4 and 3.2 in rice, wheat and maize, respectively on a single rupee investment on the potassic fertilizer.

Conclusions

This study shows that the application of 20 kg K_2O ha^{-1} is optimum for obtaining higher yields of *kharif* black gram on dryland soils of Solapur. Fifty kg K_2O ha^{-1} needs to be added to maximize the productivity of *rabi* sorghum. Potassium application to both the crops was useful in increasing the non-exchangeable K content of the soil, and in return this helped in sustaining and maintaining the exchangeable and water soluble K. Effect was reflected in terms of optimum uptake of K and higher moisture use efficiency exhibited by the plants.

Acknowledgements

Authors thank the Director of Research and Head, Soil Science and Agril. Chemistry, MPKV, Rahuri for providing valuable guidance and accorded approval for conducting the field experiments at AICRPDLA, Solapur. Authors express gratefulness to Potash for Life and Indian Potash Limited, New Delhi and ICL fertilizers, Israel for help and financial assistance.

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