International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
www.chemijournal.com
IJCS 2020; 8(2): 2958-2963

Received: 04-01-2020
Accepted: 06-02-2020

NB More
All India Co-Ordianted Research Project for Dryland Agriculture, Solapur, Maharashtra, India

VM Amrutsagar
All India Co-Ordianted Research Project for Dryland Agriculture, Solapur, Maharashtra, India

AB Pawar
All India Co-Ordianted Research Project for Dryland Agriculture, Solapur, Maharashtra, India

GR Charry
Project Coordinator & I/C Director, CRIDA, Hyderabad, Telangana, India

Corresponding Author:
NB More
M.Sc. Student, College of Agriculture, Latur. Dist. Latur, Maharashtra, India

Potash fertilization for enhancing the productivity of pearlmillet-safflower sequence under dryland condition

NB More, VM Amrutsagar, AB Pawar and GR Charry

DOI: https://doi.org/10.22271/chemi.2020.v8.i2at.9201

Abstract
Indian *Rainfed* and Dryland agriculture is predominantly dependant on monsoon rainfall accounts for 72% in India of the net cultivated area in India and plays an important role in country's economy. Generally farmers takes only one crop, either sorghum or safflower on medium deep black soils in scarcity zone of Maharashtra. However, taking double or sequence cropping may be one of the alternative for doubling the farmers income. Keeping such aspects in view the present investigation on potash fertilizer management in dryland field crops viz. pearlmillet- safflower sequence is undertaken, with objectives i.e. i) To Maintain higher potassium status in soil and ii) To study the effects of potassium levels on yield and moisture use efficiency and monetary returns of sequence crops. The field experiments with different potash fertilizer levels for pearlmillet-safflower was undertaken at AICRPDLA, Solapur for three years (2015-2016 to 2017-18) with three replications in randomized block design for *kharif* crop and split plot design for *rabi* crop. In the sequence cropping of pearlmillet – safflower showed significantly higher yield and MUE of *kharif* pearlmillet with application of 50 kg K_2O ha^{-1}, rabi safflower and *Rabi* safflower with 20 kg K_2O ha^{-1} respectively. The non-exchangeable K increased with increase in potassium application to both crops, which could be maintained the exchangeable and water soluble K in soil solution, which might be contributed to significantly higher uptake of K and moisture use efficiency by both the crops as compared to farmers practice.

Keywords: Potash fertilization, pearlmillet-safflower sequence, potassium fractions, dryland

Introduction
The dryland field crops *viz.* pearlmillet and safflower are important crops generally grown in semi-arid conditions of western Maharashtra. However the production of pearlmillet and safflower are low. The productivity of pearlmillet and safflower are 6.95 q ha^{-1} and 5.75 q ha^{-1} respectively in Maharashtra. Generally, farmers are taking only one crop, either sorghum or safflower on medium deep black soil in scarcity zone of Maharashtra. Taking double or sequence cropping might be one of the alternative for doubling the farmers income. About 50% of food grains and 65 % oil seed productions are coming from rainfed and Dryland agriculture. In India 72 % area in general and 82 % area in particular of Maharashtra State comes under rainfed and Dryland agriculture. Recently from the year 2010 it is observed that every year there is aberrant weather situation *i.e.* early onset of monsoon followed by immediate prolonged dry spell, delayed onset of monsoon and early cessation of rains or extended of monsoon. There is occurrence of drought every year in part of scarcity zone of Maharashtra, there by yield of different crops are adversely affected due to dry spells in *kharif* as well as in *rabi.* Under such situations, potassium (K) play an important role for dryland field crops, especially during dry spells a large quantity of K being taken up by plants from soil during their life cycle. Dryland soils are rich in available potassium (450 to 950 kg ha^{-1}). However, water soluble potassium in soils and their availability to growing crops are very less may be due to large differences in soil moisture parent materials and that the effect of weathering of potassium bearing minerals. The majority of dryland soils are in *Vertisol* and *Inceptisol*, which are dominant in smectite and associated groups of clays *viz.*, Smectite + vermiculite, smectite + montmorillonite. These clays fix K when soils became dry because K is trapped between the layers in the clay minerals. Despite of significant addition of plant nutrients through fertilizers, there exists a vast gap between the nutrient removal by crops and

those added to the soil. Patil *et al.* (2001) studied the plant nutrient mining in different agro-climatic zones of Maharashtra and reported that there is a vide gap in addition of K in soil and their removal by crops. Although about 1,77,191 t $year^{-1}$ of K was added, but its removal was 20,95,939 t $year^{-1}$ i.e. 20 times more removal than addition, which leaves the negative balance of K in soil (Anonymous, 2011). Scrutiny of the estimates on K status over four decades showed that there is a gradual decline in K status in soils of Maharashtra (Motsara, 2002) [2]. If proper management strategies are not undertaken, the problem of potassium mining will be worst causing minimizing the crop productivity considerably. It is, therefore, to increase the production and productivity of state it is necessary to give more emphasis on rainfed and dryland field crops. Keeping such aspects in view the present investigation on potash fertilizer management in dryland field crops for maintaining higher potassium status in soil with higher yield and monetary returns.

Materials and methods

The field experiment on sequence cropping of pearlmillet-safflower was undertaken at Mulegaon Farm, AICRPDLA, Solapur for three years (2015-2016 to 2017-18) with three replications. Experiment was conducted in randomized block design for kharif crop and split plot design for rabi crop. Crop varieties taken for pearlmillet *Dhanshakti* and safflower- SSF-748. The treatment tried for pearlmillet – safflower were A) Main (Pearlmillet) P_1.05:00:00 (Farmers Practice), P_2.50:25:00, P_3.50:25:25, P_4. 50:25:50 and P_5.50:25:75 N:P_2O_5:K_2O kg ha^{-1} respectively. B) Sub (*Safflower*) S_1.00:00:00 (Farmers Practice), S_2.50:25:00, S_3.50:25:10, S_4.50:25:20 and S_5.50:25:30 N:P_2O_5:K_2O kg ha^{-1} respectively.

Result and Discussion

Yield (*Kharif* Pearlmillet)

The significantly higher grain and stover yields (16.71 and 32.70 q ha^{-1}) are observed in treatment receiving 75 kg K_2O ha^{-1}(P_5) which is on par with the treatment receiving 50 kg K_2O ha^{-1} i.e. P_4 (16.51 and 32.54 q ha^{-1}). It is clearly indicated that 50 kg K_2O ha^{-1} applied to *kharif* pearlmillet along with recommended dose of N and P_2O_5 is beneficial in terms of grain and Stover yield with maximum MUE (3.74 kg grain ha^{-1} mm^{-1}). Subba Rao *et al*., (2011) [9] reported that the significant increase in yield of pearlmillet was obtained due to K application and this is expected since *regur* soil series contains very little biotite, they also reported that, maize crop responded to K application upto 30 to 60 kg K_2O ha^{-1} .

Potassium fractions before sowing of pearl millet

Application of 50:25:75 kg N: P_2O_5 : K_2O ha^{-1} recorded significantly higher soil solution K (14.25 $mgkg^{-1}$) and non exchangeable K(894 $mgkg^{-1}$), but it was on par with 50:25:50 kg N:P_2O_5 K_2O ha^{-1} for soil solution K (13.25 mg kg^{-1}) and 50:25:25 kg N: P_2O_5 K_2O ha^{-1} for non exchangeable K. Where as application of 50:25:25 kg N: P_2O_5 K_2O ha^{-1} recorded significantly higher fractions of exchangeable K(437 $mgkg^{-1}$) and it was on par with 50:25:50 (382 $mgkg^{-1}$) kg N: P_2O_5 K_2O ha^{-1} (Table 2).

Potassium fractions after harvest of pearlmillet

Application of 50:25:75 kg N: P_2O_5 K_2O ha^{-1} recorded significantly higher soil solution K(18.25 $mgkg^{-1}$), non exchangeable K(814 $mgkg^{-1}$), but only soil solution K was on par with dose of K_2O @ 0, 25 and 50 $kgha^{-1}$ and non exchangeable K was significantly superior over rest of potash levels. Where as in case of exchange K application of 50:25:25 kg N: P_2O_5 K_2O ha^{-1} recorded significantly higher value (440 $mgkg^{-1}$K) and it was on par with potash levels of 0, 50 and 75 $kgha^{-1}$ (Table 2).

Nutrient uptake

The data in terms of uptake of N & K are depicted in Table 3. Application of 50:25:75 kg N: P_2O_5 K_2O ha^{-1} recorded significantly higher uptake of N(72.13 $kgha^{-1}$) and K(83.01 $kgha^{-1}$) and they were significantly superior over rest of potash levels.

Rabi Safflower

Main treatments

The grain and fodder yield of safflower is depicted in Table 4. The significantly highest mean grain and stover yield is observed in treatment P_5 (15.33 and 65.16 q ha^{-1}) which is on par with the treatment P_4 (15.09 and 64.13 q ha^{-1}). From this result, it is indicated that application potash @ 50 $kgha^{-1}$ to pearl millet is economical to safflower.

Sub treatments

From the results, it is clear that, there is significant increase in the grain and stover yield of safflower with increase in the level of potash (0 to 30 kg K_2O ha^{-1}) application. The significantly higher grain and stover yield is observed in treatment receiving 30 kg K_2O ha^{-1} (S_5) (15.13 and 63.47 q ha^{-1}) which is on par with the treatment receiving 20 kg K_2O ha^{-1} i.e. S_4 (14.67 and 61.56 q ha^{-1}). It indicates that the application of potassium @ 20 kg K_2O ha^{-1} along with recommended dose of N and P_2O_5 to *rabi* safflower is beneficial in terms of grains and stover yields.

From the above results, it is observed that the potash application @ 50 kg K_2O ha^{-1} to pearlmillet and 20 kg K_2O ha^{-1} to safflower is beneficial for grain and stover yield.

Potassium fractions after harvest of safflower

Main treatment

Application of 50 kg K_2O ha^{-1} along with RD N and P_2O_5 recorded significantly higher exchangeable K(477 $mgkg^{-1}$) and non exchangeable K(636 $mgkg^{-1}$) and they were significantly superior over rest of potash levels (Table 4). Where as in case of soil solution K application of 25 kg K_2O ha^{-1} along with RD N and P_2O_5 recorded significantly higher value of K (16.70 $mgkg^{-1}$) and it was superior over rest of potash levels. Dhar et al, (2009) reported that application of fertilizer K at 49.8 kg ha^{-1} helped in preventing the depletion of non exchangeable K resolves in *Alfisol,* further he also showed that higher dose of applied K (i.e. 166 kg K ha^{-1}) helped in minimizing the mining of soil K from its original status.

Sub treatment

Application of 30 kg K_2O ha^{-1} along with RD of N and P_2O_5 recorded significantly higher soil solution K(20.15 $mgkg^{-1}$) exchangeable K(386 $mgkg^{-1}$) and non exchangeable K (616 $mgkg^{-1}$) and they were significantly superior over rest of potash levels.

Interaction

The soil solution K was significantly higher (25.25 mg kg^{-1}) when K_2O was given @ 25 kg ha^{-1} along with RD N and P_2O_5 followed by *rabi* safflower fertilized with 30 kg K_2O ha^{-1}along with RD of N and P_2O_5 . Where as in case of exchangeable K potash applied @ 50 kg ha^{-1} along with RD N and P_2O_5 followed by safflower crop with no nitrogen, phosphorous and potash fertilizer recorded significantly higher value (560.0 mg kg^{-1}). The non exchangeable K was significantly higher (744 mg kg^{-1}) when 50 kg K_2O ha^{-1} along with RD N and P_2O_5 was given to pearl millet crop followed by safflower with 10 kg K_2O along with RD N and P_2O_5 kgha^{-1}. (Table 5). This results indicates that non exchangeable K might be contributed for total plant uptake and minimum solution K seems a good indication of application of fertilizer K. Similar type of observations are also reported by Srinivasrao and Khera, (1994) [6] and Srinivasrao *et al* (1998 and 2000) [7, 8].

Nutrient uptake

Interaction

Results in terms of N uptake, found non significant while in case of phosphorous uptake application of potash @ 75 and 30 kg ha^{-1} along with RD N and P_2O_5 to pearlmillet and safflower respectively recorded significantly higher uptake (58.09 kg ha^{-1}) but it was on par with 0 and 50 kg K_2O ha^{-1} (55.92 and 54.76 kg ha^{-1} respectively). In terms of potassium uptake application of potash @ 75, 10 and 20 kg ha^{-1} along with RD N and P_2O_5 to pearlmillet and safflower respectively (Table 6) recorded significantly higher values (112.97 and 105.05 kgha^{-1} respectively). Srinivasrao *et al*. (1998 and 2000) [7, 8] showed that plant K removal from soil and contribution of non-exchangeable K to K uptake are almost synonymous and accounts for upto 90-95 per cent of the total plant uptake. The total K uptake increased significantly in five different varieties of groundnut (Patil *et al*. 2003) [5]. This shows that fresh K fertilization has a significant impact on K supply or availability in these soils.

Correlation Studies

The soil solution K was positively and significantly correlated with grain (r= 0.968**) and stover yield (r= 0.946*) at harvest of pearlmillet. The exchangeable K was also positively and significantly correlated with grain (r=0.900*) and stover yield (r= 0.889*) after harvest of pearlmillet. The non exchangeable K was positively and significantly correlated with grain (r= 0.798 and 0.878*) and stover (r=0.869 and 0.893*) yield at sowing and harvest of pearlmillet respectively. Correlation was positive but non significant for total K uptake with grain and stover yield (Table 7). Subba Rao *et al*. (2011) [9] also reported significant positive correlation were recorded with exchangeable K and non exchangeable K in all the soil types indicating the dynamic equilibration between two soil K fractions. For millet crops in Anantpur area it is need to immediate attention on K nutrition as those soils contain low amount of exchangeable and non exchangeable K.

The soil solution K was positively and significantly correlated with grain (r= 0.618**) and stover (r=0.595**) yield. The non exchangeable -K was also positively and significantly correlated with grain (r=0.538**) and stover yield (r= 0.551**). The total K uptake was positively and significantly correlated with grain (r= 0.895**) and stover (r= 0.902**) yield. (Table 8)

Economics

The net monitory returns and B:C ratio of pearlmillet – safflower (Table 9 and 10) are higher with application of 50 kg K_2O ha^{-1} to pearlmillet followed by 20 kg K_2O ha^{-1} to safflower under Dryland condition. Mujumdar *et al*. 2018 also reported return on investment on applied potassium in rice, wheat and maize where Rs. 5.5, 4.4 and 3.2 respectively per rupee invested on K.

Table 1: Effect of potash levels on yield of pearlmillet (q ha^{-1})

Sr. No.	Treatments	Grain	Stover	MUE (kg grain ha^{-1} mm^{-1})
1	05:00:00 N:P_2O_5:K_2O kg/ha (Farmers Practice)	6.91	17.80	1.82
2	50:25:00 N:P_2O_5:K_2O kg/ha	13.65	26.29	3.23
3	50:25:25 N:P_2O_5:K_2O kg/ha	14.81	30.36	3.49
4	50:25:50 N:P_2O_5:K_2O kg/ha	16.51	32.54	3.74
5	50:25:75 N:P_2O_5:K_2O kg/ha	16.71	32.70	4.45
	SE±	0.17	0.27	--
	CD@5%	0.54	0.88	--

Table 2: Effect of potash levels on different potassium fractions (mg kg^{-1}) before sowing and after harvest of pearlmillet

Sr. No.	Treatments	WSK		Exch. K		Non Exch. K	
		BS	AH	BS	AH	BS	AH
1	05:00:00 N:P_2O_5:K_2O kg/ha (Farmers Practice)	10.50	10.25	318	363	651	530
2	50:25:00 N:P_2O_5:K_2O kg/ha	11.00	15.25	359	419	672	632
3	50:25:25 N:P_2O_5:K_2O kg/ha	12.25	15.25	437	440	868	700
4	50:25:50 N:P_2O_5:K_2O kg/ha	13.25	16.25	382	424	824	684
5	50:25:75 N:P_2O_5:K_2O kg/ha	14.25	18.25	370	421	894	814
	SE±	0.57	1.25	20.06	14.87	19.93	17.04
	CD@ 5%	1.87	4.07	65.42	48.51	65.00	55.58

BS= Before sowing AH= After harvest

Table 3: Effect of potash levels on available nutrient content and uptake after harvest of pearlmillet.

Sr. No.	Treatments	Available Nutrients (kg ha^{-1})		Nutrient Uptake (kg ha^{-1})	
		N	K	N	K
1	05:00:00 N:P_2O_5:K_2O kg/ha (Farmers Practice)	222.67	836.08	29.07	30.42
2	50:25:00 N:P_2O_5:K_2O kg/ha	229.00	972.72	48.05	47.05
3	50:25:25 N:P_2O_5:K_2O kg/ha	225.67	1019.76	60.18	67.72
4	50:25:50 N:P_2O_5:K_2O kg/ha	224.00	986.16	66.56	59.06
5	50:25:75 N:P_2O_5:K_2O kg/ha	218.67	1235.00	72.13	83.01
	SE±	8.54	31.18	0.49	0.49
	CD@ 5%	N.S.	101.69	1.59	1.60

Table 4: Effect of potash levels on yields and potassium fractions after harvest of Safflower

Particulars	Yield (q ha^{-1})		MUE (kg grain ha^{-1} mm^{-1})	Forms of potassium (mg ha^{-1})		
	Grain	Fodder		Soil Solution K	Exch-K	Non-Exch-K
Main treatment						
P1	11.11	45.56	3.30	14.95	333	395
P2	12.40	51.46	3.66	14.00	350	510
P3	13.65	57.32	3.82	16.70	380	571
P4	15.09	64.13	4.51	15.75	477	636
P5	15.33	65.16	4.79	16.25	332	568
SE ±	0.23	0.99	-	0.033	0.33	0.34
CD @ 5%	0.77	3.23	-	0.108	1.07	1.11
Sub - treatment						
S1	11.34	47.62	3.54	12.15	396	511
S2	12.67	53.17	3.55	13.45	365	566
S3	13.77	57.80	4.17	15.15	347	498
S4	14.67	61.56	4.28	16.75	378	490
S5	15.13	63.47	4.53	20.15	386	616
SE ±	0.43	1.81	-	0.030	0.34	0.37
CD @ 5%	1.23	5.16	-	0.086	0.98	1.07

Table 5: Interaction effect of potash levels for *kharif* and *rabi* crops on potassium fractions after harvest of Safflower

Main \ Sub	S_1	S_2	S_3	S_4	S_5	Mean
Soil solution K (mg kg^{-1})						
P_1	12.25	15.25	12.00	18.00	17.25	14.95
P_2	10.25	11.25	16.25	13.25	19.00	14.00
P_3	12.00	14.25	16.00	16.00	25.25	16.70
P_4	12.00	12.25	16.25	20.25	18.00	15.75
P_5	14.25	14.25	15.25	16.25	21.25	16.25
Mean	12.15	13.45	15.15	16.75	20.15	-
	P	S	P x S			
SE±	0.33	0.030	0.068			
CD @ 5%	0.108	0.086	0.193			
Exchangeable K (mg kg^{-1})						
P_1	344	315	323	342	342	333
P_2	323	342	342	371	371	350
P_3	501	342	346	402	308	380
P_4	560	500	424	493	408	477
P_5	250	323	301	284	502	332
Mean	396	365	347	378	386	-
	P	S	P x S			
SE±	0.33	0.34	0.77			
CD @ 5%	1.07	0.98	2.20			
Non exchangeable K (mg kg^{-1})						
P_1	353	342	385	411	484	395
P_2	507	391	493	504	658	510
P_3	542	691	484	431	707	571
P_4	651	664	744	504	618	636
P_5	502	740	384	600	613	568
Mean	511	566	498	490	616	-
	P	S	P x S			
SE±	0.34	0.37	0.84			
CD @ 5%	1.11	1.07	2.39			

Table 6: Interaction effect of potash levels on nutrient uptake (kg ha^{-1}) of safflower

Main \ Sub	S_1	S_2	S_3	S_4	S_5	Mean
Nitrogen						
P_1	36.12	43.14	50.76	55.63	63.87	49.91
P_2	50.55	65.05	73.79	86.95	96.35	74.54
P_3	43.07	59.39	69.96	98.39	110.24	76.21
P_4	47.83	63.50	74.98	80.54	102.02	73.77
P_5	73.35	79.57	93.20	98.52	127.64	94.46
Mean	50.19	62.13	72.54	84.01	100.02	-
	B x S	-	-	-	-	-
SE±	5.25	-	-	-	-	-
CD @ 5%	NS	-	-	-	-	-

Potassium						
P_1	24.94	29.15	41.23	52.16	57.44	40.99
P_2	21.28	28.14	37.09	52.40	60.14	39.81
P_3	50.64	61.25	75.95	85.07	93.95	73.37
P_4	55.05	77.54	82.21	85.08	105.05	80.99
P_5	80.00	88.96	112.97	118.23	78.51	95.73
Mean	46.38	57.01	69.89	78.59	79.02	-
	P x S	-	-	-	-	-
SE±	4.84	-	-	-	-	-
CD @ 5%	13.83	-	-	-	-	-

Table 7: Correlation: *Kharif* pearlmillet

Parameters	Soil Solution -K		Exch-K		Non Exch-K		Total K uptake
	BS	AH	BS	AH	BS	AH	
Grain Yield	0.835	0.968**	0.668	0.900*	0.798*	0.878*	0.863
Stover Yield	0.877	0.946*	0.711	0.889*	0.869*	0.893*	0.893

N= 5, * = significance at 5% (0.878), ** = significance at 1% (0.958)

Table 8: Correlation: *Rabi* safflower

Parameters	Soil Solution -K	Exch-K	Non Exch-K	Total K uptake
Grain Yield	0.618**	0.241	0.538**	0.895**
Stover Yield	0.595**	0.255	0.551**	0.902**

N= 25, * = significance at 5% (0.396), ** = significance at 1% (0.505)

Table 9: Effect of potash levels on yield and economics of pearlmillet (q ha^{-1})

Sr. No.	Treatments	Grain	Stover	GMR (Rs/ha^{-1})	NMR (Rs/ha^{-1})	B:C ratio
1	05:00:00 N:P_2O_5:K_2O kg/ha (Farmers Practice)	6.91	17.80	18176	2176	1.14
2	50:25:00 N:P_2O_5:K_2O kg/ha	13.65	26.29	32356	16356	2.02
3	50:25:25 N:P_2O_5:K_2O kg/ha	14.81	30.36	35840	19840	2.24
4	50:25:50 N:P_2O_5:K_2O kg/ha	16.51	32.54	39432	23432	2.46
5	50:25:75 N:P_2O_5:K_2O kg/ha	16.71	32.70	39816	23816	2.49
	SE±	0.17	0.27	-	-	-
	CD@5%	0.54	0.88	-	-	-

Table 10: Effect of potash levels on yields of grain and fodder and economics of Safflower

	Yield (q ha^{-1})		GMR (Rs/ha^{-1})	NMR (Rs/ha^{-1})	B:C ratio
	Grain	Straw			
Main treatment					
P1	11.11	45.56	45775	26975	2.43
P2	12.40	51.46	51212	32412	2.72
P3	13.65	57.32	56509	37709	3.01
P4	15.09	64.13	62623	43823	3.33
P5	15.33	65.16	63621	44821	3.38
SE ±	0.23	0.99	-	-	-
CD @ 5%	0.77	3.23	-	-	-
Sub - treatment					
S1	11.34	47.62	46946	28146	2.50
S2	12.67	53.17	52445	33645	2.79
S3	13.77	57.80	57001	38201	3.03
S4	14.67	61.56	60723	41923	3.23
S5	15.13	63.47	62623	43823	3.33
SE ±	0.43	1.81	-	-	-
CD @ 5%	1.23	5.16	-	-	-

Conclusion
The significantly higher yields of dryland crops viz. pearlmillet and safflower were recorded with application of 50 kg K_2O $ha^{-1}$and 20 kg K_2O ha^{-1}respectively along with recommended N and P_2O_5dose. The potassium application to both the crops maintained the optimum level of water soluble, exchangeable and non-exchangeable K in soil which helped in higher uptake of K and moisture use efficiency as compared to farmers practice.

Acknowledgement
Authors are express gratefulness to Dr. S. K. Bansal and Dr. Patricia Imas, Potash Research Institute of India, Gurgaon, Haryana and ICL Fertilizer Beer Sheva, Israel for help and financial assistance. Grateful thanks are also to MD, IPL-Chairman PFL for all the supports, kid advice and guidance in successful implementation of the project activities.

References
1. Dhar AA, Debhnath, Sanyal SK. Planning judicious potassium fertilization for maintaining native soil potassium reserves in an Ultic Paleustalf in relation to its uptake by rice and potato. Journal Indian Society of Soil Science. 2019; 57:58-61.
2. Motsara MR. Available NPK status of Indian soils as depicted by soil fertility maps. Fertilizer News. 2002; 47(8):15-21.
3. Mujmadar K, Anil Kumar, Shahi V, Satyanarayana T, Jat ML, Dilip Kumar *et al*. Indian J Fert. 2011; 8(5):44-53.
4. Pillai KG, Sushila Devi L, Sholapurkar MV, Jagannath MK. Effect of continuous cropping and manuring in selected cropping systems. Fertilizer News. 1987; 32:31-37.
5. Patil PS, Polara JV, Babaria NB. Potassium uptake of different varieties of groundnut under varying K levels. Journal of Potassium Research. 2003; 19:78-81.
6. Srinivasrao Ch, Khera MS. Effects of exhaustive cropping on various potassium forms. Journal of Potassium Research. 1994; 10:109-116.

7. Srinivasrao Ch, Pal DK, Takkar PN. Mathematical models to study the kinetics of potassium release from swell-shrink soils of central India in relation to their mineralogy. Journal of Plant Nutrition and soil Science. 1998; 161:67-71.
8. Srinivasrao Ch, Rupa TR, Subba Rao A, Bansal SK. Potassium fixation characteristics of major benchmark soils of India. Journal of the Indian Society of soil Science. 2000; 48:220-228.
9. Subbarao A, Srinivasrao Ch, Srivastava S. Potassium Status and Crop Response to Potassium on the Soils of Agroecological Regions of India. IPI Research Topics. 2011; 20:94.