Research Findings

Experimental plot with pigeon pea crop at the Fertilizer Research Station Uttari Pura, Univ. of Agric. & Tech., Kanpur. Photo by E. Sokolowski.

Effect of Potassium Application on Yield and Quality Characteristics of Pigeon Pea *(Cajanus cajan)* and Mustard *(Brassica juncea* L. *Czern)* Crops in Central Plain Zone of Uttar Pradesh

Tiwari, D.D.[(1)(2)], S.B. Pandey[(2)], and M.K. Dubey[(2)]

Abstract

To investigate the effect of five levels of potassium at 0 (control), 20, 40, 60 and 80 K_2O kg ha^{-1} applied as muriate of potash on pigeon pea and mustard, as pulse and oil seed crops respectively, field experiments were conducted at the Fertilizer Research Station Uttari Pura, of C.S.A. University of Agriculture & Technology, Kanpur during 2007 to 2011. The experimental field had available 195 kg ha^{-1} K_2O and was sandy loam in nature. Nitrogen, phosphorus, sulphur and zinc were also applied in amounts determined by soil analysis to provide adequate supply.

Increasing doses of potassium up to 60 kg K_2O ha^{-1} significantly increased grain and stover yields of pigeon pea and mustard crops. Mean yields of pigeon pea grain and stover were raised from 1,358 to 1,764 and 5,647 to 6,594 kg ha^{-1} respectively, and that of mustard grain and stover from 1,645 to 2,257 and 4,041 to 5,077 kg ha^{-1} respectively.

Likewise, protein and oil content were also increased significantly by K application to pigeon pea and mustard respectively. Protein content in pigeon pea grain increased from 21.01 percent in the control to 21.95 percent at the highest K treatment, K_{80}. Mean oil content in mustard seed was raised from 37.01 percent (control) to a maximum of 40.98 percent in the K_{60} treatment.

[(1)] Corresponding author: tiwardi_csa@indiatimes.com
[(2)] Department of Soil Science and Agricultural Chemistry, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur 208002, Uttar Pradesh, India

Experimental plot with mustard crop at the Fertilizer Research Station Uttari Pura, Univ. of Agric. & Tech., Kanpur. Photo by E. Sokolowski.

Table 1. Area, production and productivity of pigeon pea and mustard crops in India and the state of Uttar Pradesh (2009-2010).

Crop		India	Uttar Pradesh
Pigeon pea	Area (million ha)	3.86	0.31
	Production (million mt)	2.9	0.20
	Productivity (kg ha^{-1})	751	662
Mustard	Area (million ha)	6.51	0.61
	Production (million mt)	7.67	0.68
	Productivity (kg ha^{-1})	1,179	1,113

Source: Directorate of Economics and Statistics, Department of Agricultur and Cooperation, Ministry of Agriculture, Government of India.

K content increased from 1.53 to 1.58 and 2.51 to 2.56 percent in grain and stover of pigeon pea, and 0.88 to 0.99 percent in mustard seed. No clear increase in K concentration due to K application was found in mustard stover.

Increasing levels of K application lowered the negative balance of K in the soil. Removal of K from the soil by pigeon pea and mustard crops progressively increased from 163 to 194 and 143 to 184 kg K_2O ha^{-1} respectively between the 0 to 80 kg K_2O ha^{-1} levels. For the same levels of increasing rates of K_2O application the negative balance of K_2O kg ha^{-1} was lowered from 163 to 114 under pigeon pea, and 143 to 104 under mustard.

Introduction

A substantial proportion of the Indian population has a vegetarian diet in which plant oil and protein make up the principal sources of dietary lipid and protein. The major sources of oil and protein are oilseeds and pulses respectively. Pulses are grown for proteins as a target product and oilseeds provide both oil and protein because oils are stored and synthesized in protein rich tissues. Of the pulses and oilseeds, pigeon pea *(Cajanus cajan)* and mustard *(Brassica juncea* L. *Czern)* are the major crops of the state of Uttar Pradesh in terms of area of cultivation, as well as production and productivity (Table 1). The nutrient requirements of these two crops are similar to rice and wheat and they thrive under varied edaphic regimes. In general, farmers apply low rates of nitrogen (N) and phosphorus (P), but potassium (K) is frequently absent from their fertilizer schedule. This lack of K is responsible for low yields and poor crop quality because, apart from other major physiological and biochemical requirements in plant growth, K is a key nutrient element in the biosynthesis of oil in oilseeds and protein in pulse crops.

For the work reported in this paper, we tested in a field experiment over four growing seasons, the effect of increasing rates of K fertilization on yield and quality of pigeon pea and mustard adequately fertilized with other plant nutrients. The yield and K content was measured for the seed and stover of both crops. Protein content is used as a measure of quality of pigeon pea and oil for mustard seeds. The K uptake by the crops and K balance between the crop and soil is also reported.

Materials and methods

The field experiments were carried out at the Fertilizer Research Station, Uttaripura, of the Chandra Shekhar Azad (CSA) University of Agriculture & Technology, Kanpur, during 2007 to 2011. Pigeon pea in Kharif and mustard in Rabi seasons were used as test crops. Five levels of potassium at 0, 20, 40, 60 and 80 kg K_2O ha^{-1} were applied to both the crops as a basal dressing in the form of muriate of potash. N, P, sulphur (S) and zinc (Zn) in the forms of urea, diammonium phosphate (DAP), gypsum and zinc sulphate were applied uniformly in required amounts based on soil chemical analysis. Plot size of the experimental field was 40 m^2. The experimental soils were neutral in reaction (pH 7.3), low in organic carbon (0.41), and deficient in S (16.3 kg ha^{-1}) and available Zn (0.51 mg kg^{-1}). The available N, P_2O_5 and K_2O of the experimental fields were 180, 12.5 and 195 kg ha^{-1}, respectively.

All necessary agronomic practices were followed, when and where required. At maturity, the crops were harvested and grain and stover yields were recorded as per treatments.

Soil pH, EC, organic carbon and available NPK were analyzed using standard procedures (Jackson, 1973).

Available soil S was determined by the turbidimetric procedure (Chesnin and Yein, 1951) after extraction with Morgan's reagent, and available soil Zn was determined by AAS after extraction with DTPA (Lindsay and Norvell, 1978).

Grain N content was determined by the micro Kjeldahl method and protein in pigeon pea was estimated by multiplying the N content by 6.25. Oil in mustard seed was extracted by the soxhlet method. Grain and straw K contents were estimated by flame photometry following nitric and perchloric acid digestion of the samples (Jackson, 1973).

Table 2. Effect of treatments on grain and stover yield (kg ha^{-1}) of pigeon pea.

Treatments	Kharif 2007		Kharif 2008		Kharif 2009		Kharif 2010		Mean		Response over control (grain)	AE_K * (grain)
	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover		
kg K_2O ha^{-1}	*kg ha^{-1}*										*%*	*kg kg^{-1}*
K_0	1,206	5,462	1,395	5,875	1,380	5,547	1,450	5,810	1,358	5,674	-	-
K_{20}	1,400	5,906	1,480	6,095	1,450	5,756	1,530	6,120	1,465	5,969	7.9	5.35
K_{40}	1,575	6,269	1,585	6,290	1,520	5,897	1,620	6,310	1,575	6,192	15.9	5.42
K_{60}	1,744	6,500	1,750	6,750	1,710	6,207	1,810	6,570	1,754	6,507	29.2	6.60
K_{80}	1,750	6,631	1,765	6,745	1,720	6,398	1,820	6,600	1,764	6,594	29.8	5.07
CD (p = 0.05)	87	308	120	320	65	175	78	170	-	-	-	-

*AE_K = Agronomic efficiency of potassium

Table 3. Effect of treatments on grain and stover yield (kg ha^{-1}) of mustard.

Treatments	Rabi 2007/8		Rabi 2008/9		Rabi 2009/10		Rabi 2010/11		Mean		Response over control (grain)	AE_K* (grain)
	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover		
kg K_2O ha^{-1}	*kg ha^{-1}*										*%*	*kg kg^{-1}*
K_0	1,763	4,040	1,650	3,940	1,675	3,983	1,490	4,200	1,645	4,041	-	-
K_{20}	2,100	5,403	1,735	4,120	1,890	4,200	1,670	4,310	1,849	4,508	12.4	10.2
K_{40}	2,315	6,045	1,890	4,340	2,035	4,440	1,820	4,490	2,015	4,828	22.5	9.3
K_{60}	2,467	6,458	2,185	4,520	2,250	4,650	2,100	4,680	2,251	5,077	36.8	10.1
K_{80}	2,468	6,461	2,190	4,515	2,260	4,630	2,110	4,700	2,257	5,077	37.2	7.7
CD (p = 0.05)	133	375	125	170	140	180	135	109	-	-	-	-

*AE_K = Agronomic efficiency of potassium

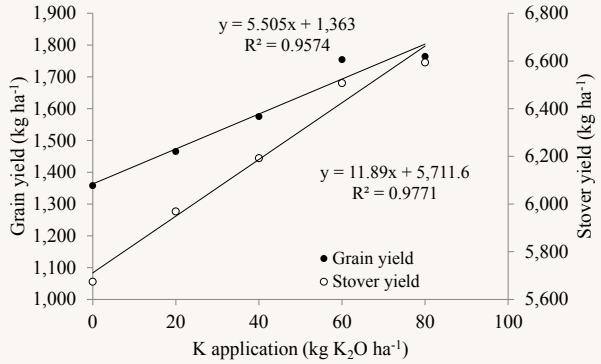

Fig. 1. Effect of treatments on grain and stover yields of pigeon pea (average of four years, 2007-2010).

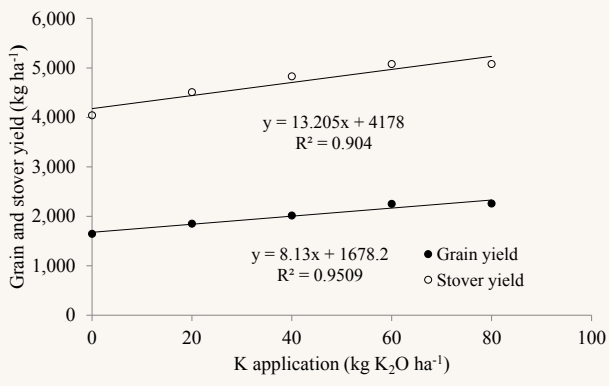

Fig. 2. Effect of K-doses on grain and stover yields of mustard (average of four years, 2007/08-2010/11) .

Results and discussion

Yield

Application of K up to 80 kg K_2O ha^{-1} significantly increased grain and stover yield of pigeon pea during each year of the experiment (Table 2). On average, with the high K application (80 kg K_2O ha^{-1}), a 29.8 percent increase in grain yield over the control was achieved. With stable yields through the four years of the experiment, the response to K was significant in every year.

The response to K application was significant to both grain and stover (R_2 >0.95; Fig. 1), implying that higher levels of K might have increased yields further. This increase in yield is in accordance with essential requirement for K in plant biochemistry and physiology, in processes including photosynthesis, water relationships, protein synthesis and the requirement for K in at least 60 different enzyme systems within the plant. Similar results showing the benefit of K on crop yield have also been reported by Prasad *et al.* (1993).

Agronomic Efficiency of Potassium (AE_K) varied from 5.07-6.60 kg/kg of K in pigeon pea with the maximum at K application of 60 kg ha^{-1}.

Application of K up to 60 kg K_2O ha^{-1} also significantly increased grain and stover yields of mustard during each year of the experiment (Table 3). On average, with the high K application (80 kg ha^{-1}), a 37.2 percent increase in grain yield was achieved. As with the yield of pigeon pea, with mustard yields stable through the four years of the experiment, the response to K was significant in every year.

Table 4. Effect of treatments on percent K content in pigeon pea (Kharif 2007-2010) and removal of K by the crop (kg K_2O ha^{-1}).

Treatments	Kharif 2007		Kharif 2008		Kharif 2009		Kharif 2010		Mean				
	K concentration										Removal of K		
	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover	Total
kg K_2O ha^{-1}	----------					*%*					----------	*kg K_2O ha^{-1}*	----------
K_0	1.42	2.17	1.72	2.64	1.44	2.34	1.56	2.87	1.53	2.51	20.8	142.4	163.2
K_{20}	1.50	2.15	1.74	2.72	1.51	2.47	1.65	3.00	1.55	2.56	22.7	152.8	175.5
K_{40}	1.57	2.21	1.73	2.70	1.48	2.40	1.67	2.98	1.56	2.54	24.6	157.3	181.8
K_{60}	1.56	2.32	1.80	2.68	1.55	2.41	1.73	2.84	1.58	2.55	27.7	165.9	193.8
K_{80}	1.51	2.33	1.79	2.68	1.51	2.45	1.75	2.84	1.57	2.52	27.7	166.2	193.9

Table 5. Effect of treatments on percent K content in mustard (Rabi 2007/08-2010/11) and removal of K by the crop (kg K_2O ha^{-1}).

Treatments	Rabi 2007/08		Rabi 2008/09		Rabi 2009/10		Rabi 2010/11		Mean				
	K concentration										Removal of K		
	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover	Total
kg K_2O ha^{-1}	----------					*%*					----------	*kg K_2O ha^{-1}*	----------
K_0	1.04	3.05	1.04	3.15	1.04	3.14	1.00	3.07	0.88	3.18	14.5	128.5	143.0
K_{20}	1.05	3.19	1.03	3.20	1.04	3.25	1.01	3.12	0.91	3.11	16.8	140.2	157.0
K_{40}	1.05	3.34	1.09	3.23	1.09	3.25	1.02	3.09	0.91	3.15	18.3	152.1	170.4
K_{60}	1.05	3.46	1.20	3.22	1.22	3.17	1.09	3.10	0.99	3.18	22.3	161.4	183.7
K_{80}	1.06	3.31	1.20	3.24	1.20	3.18	1.08	3.13	0.98	3.19	22.1	162.0	184.1

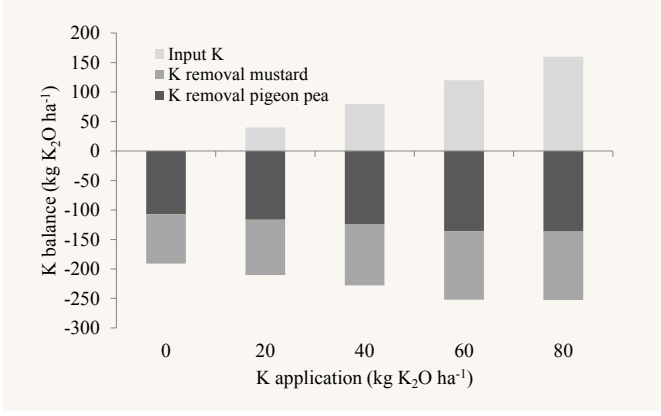

Fig. 3. K balance in pigeon pea - mustard crop rotation (average of four years, 2007-2010).

The response to K application was significant for both grain and stover (R_2 >0.9; Fig. 2), implying that higher levels of K might have increased yields further.

AE_K was high and varied from 7.7-10.2 kg/kg of K in mustard seeds, with a maximum at K application of 20 kg ha^{-1}.

Potassium content

K content in grain and stover of pigeon pea increased with the use of K over the control. K content ranged from 1.53 to 1.58 percent in the grain but only from 2.51 to 2.56 percent in the stover (Table 4). The removal of K increased as yield increased, up to 194 kg K_2O ha^{-1} (Table 4). Similarly, in the mustard crop, K content increased in grain (from 0.88 to 0.99 percent) but not for stover (Table 5). The removal of K increased mainly by the increased yield, up to a level of 184 kg K_2O ha^{-1} (Table 5).

K balance calculation for pigeon pea – mustard crop rotation system was based on the removal of K in grain (seeds) and stover (fully removed from the field) using the average annual removal rates of four years (Fig. 3, based on data of Tables 4 and 5). Removal rates of the two crops in this cropping system are very similar, at approximately 100 kg K_2O ha^{-1} $year^{-1}$, for each crop (Tables 4 and 5). However, the mustard crop is unique in that the removal of K by the seeds is larger than that by the stover (Table 5). K fertilizer was calculated as the only K input, and K output with regard to removal by crop (Fig. 3). Results show that K balance in all treatments was negative, ranging from almost 200 (K=0) to 100 (K=80) kg K_2O $year^{-1}$. It also indicates that even at the high rate of K application, there is still significant K mining from soil.

Protein content in pigeon pea and oil in mustard

Protein levels in pigeon pea grain increased significantly over the control in all years of the experiment, reaching approximately 22 percent (Table 6). The protein content varied from 21 to 22.15 percent, with a minimum in the control and a maximum at 80 kg K_2O ha^{-1}. This increase in grain protein content might be due to enhanced N use efficiency as a consequence of increased K application. Pathak *et al.* (1999) and Tiwari *et al.* (2009) also reported similar results.

Oil content in mustard grain increased significantly with the application of K up to 60 kg K_2O ha^{-1} in each year of the experiment (Table 6). The highest oil content (40.98 percent) was obtained at

Table 6. Concentration of protein and oil in pigeon pea and mustard seeds respectively.

Treatments	Pigeon pea					Mustard				
	2007	2008	2009	2010	Mean	2007/8	2008/9	2009/10	2010/11	Mean
	----------*Protein (%)*----------					----------*Oil (%)*----------				
K_0	21.20	20.90	20.95	21.00	21.01	37.52	36.90	37.55	36.10	37.01
K_{20}	21.57	21.15	21.20	21.25	21.29	38.82	38.10	38.70	37.75	38.34
K_{40}	21.74	21.20	21.55	22.00	21.62	40.26	39.15	39.85	38.40	39.41
K_{60}	21.75	21.75	22.05	22.10	21.91	41.00	41.25	41.20	40.50	40.98
K_{80}	21.85	21.70	22.10	22.15	21.95	41.18	41.10	41.15	40.30	40.93
CD (p = 0.05)	0.19	0.20	0.24	0.21		0.67	0.75	0.80	0.85	

60 kg K_2O ha^{-1} which was about 16 percent higher than the control, without any K application. This finding is in agreement with the observations of Kushwaha and Ali (1999).

Conclusions

Grain yield and quality of pigeon pea and mustard seed increased significantly with the application of K up to 60 kg K_2O ha^{-1}. At this rate of application, yield of pigeon pea increased 29 percent, while that of mustard seed 37 percent. The agronomic efficiency of potash applied to pigeon pea and mustard (6.6 and 10.2 respectively) provides a stable economic return.

Removal rates of K were increased with K application mostly from higher yield, but also as K concentration in grain and stover increased with increasing K application. The applied K in this experiment was insufficient to prevent a significant K negative balance for the cropping system of approximately 100 kg K_2O $year^{-1}$.

K application significantly increased protein content in pigeon pea and oil content in mustard seeds, bringing higher economic value to the harvested crop.

Based on the results of this four year experiment in which we produced stable responses year after year, we conclude that 60 kg K_2O ha^{-1} is the recommended amount of K for achieving high yield of pigeon pea and mustard in medium K-soils of Uttar Pradesh. However, based on the data shown in Fig. 1 and 2, the nature of response implies that there is still scope for higher inputs of K which may generate additional yield, as well as reduce the calculated negative K balance.

Farmers' meeting at the Fertilizer Research Station Uttari Pura, Univ. of Agric. & Tech., Kanpur. Photo by E. Sokolowski.

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The paper "Effect of Potassium Application on Yield and Quality Characteristics of Pigeon Pea *(Cajanus cajan)* and Mustard *(Brassica juncea* L. *Czern)* Crops in Central Plain Zone of Uttar Pradesh" also appears at:

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