Chapter 4

Response of crops to applied potassium

4.1 Decade old studies

The response of crops to applied potassium depends upon the potassium status in soil. The results of the more than 800 experiments conducted at the Department of Soils, Punjab Agricultural University, Ludhiana from 1961 through 1995 showed a variable response to potassium application (Table 15). Out of 296 experiments conducted on wheat, 115 on paddy, and 118 on maize, the response of more than 100 kg grains ha^{-1} was obtained in 61 percent in wheat, 71 percent in paddy and 57 percent in maize. On an average, the application of K at the rate of 60 kg K_2O ha^{-1} gave response of 3.6 kg wheat grain, 7.8 kg paddy, and 3.3 kg maize grain per kg of applied K_2O. Since, the experiments were conducted on all types of soils - testing low to high in available potassium – it was inferred that the extent of response was varying.

Table 15. Extent of response to soil application of potassium by wheat, paddy, and maize crops in Punjab (1961 through 1995).

Extent of response: Grain yield (kg ha^{-1})	Number of experiments *		
	Wheat	Paddy	Maize
< 100	115 (39)*	33 (29)	51 (43)
101-300	86 (29)	28 (24)	37 (32)
301-500	52 (18)	18 (16)	18 (15)
>500	43 (14)	36 (31)	12 (10)
Total	296 (100)	115 (100)	118 (100)

* Figures in parenthesis represent percent of total.

When the data on 115 experiments on wheat, and 41 experiments on paddy that were conducted between 1961 and 1995, and data on 21 experiments on sunflower, and 18 experiments on cotton that were conducted recently were compiled on the basis of soil test values of low, medium, and high categories of available potassium, it was observed that crops responded to the application of potassium not only on soils testing low (< 137 kg K_2O ha^{-1}) but also on soils testing medium (137 to 337 kg K_2O ha^{-1}) in available potassium. The response, however, decreased as the available K status of the soil increased (Fig. 5). Since farmers apply no potassium to crops (except potato) it is discernable that the K

application may help in breaking the yield barriers, a barrier that is increasingly being realized in recent past as yield of most of the crops are stagnant over years. Such results emphasize the need for fresh look at soil fertility limits used for categorizing soils into low, medium and high with respect to available K.

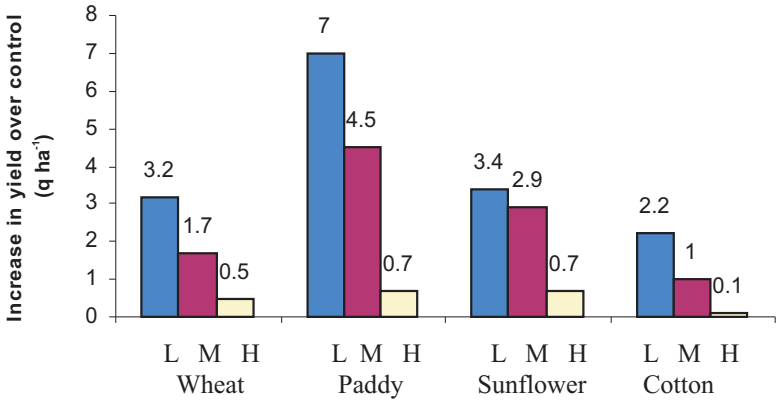


Fig. 5. Increase in yield of wheat (115 experiments), paddy (41 experiments), sunflower (21 experiments) and cotton (18 experiments) with potassium application on soils testing low (<137 kg K_2O ha^{-1}), medium (137 to 337 kg K_2O ha^{-1}) and high (>337 kg K_2O ha^{-1}) in available (NH_4OAC extractable) potassium

The studies conducted during 1970's showed significant response of applied K to wheat up to 25 kg K ha^{-1} in the soils of low-available K, but no significant increase was observed in soils testing medium to high in available K in Punjab (Sharma et al., 1978). Rana et al. (1985) observed that rice responded to 50 kg K ha^{-1} on soils testing low and medium in available K, but no significant response to applied K was observed in soils testing high in available K. Experiments carried out by Kapur et al. (198O) revealed that wheat responded up to a dose of 75 kg K ha^{-1} on low K soils and up to 50 kg K ha^{-1} on medium and high K soils. Azad et al. (1993) observed that whereas wheat yield increased significantly up to 75 kg K ha^{-1} on soils testing low in available K, significant increase in wheat yield was observed only at 25 kg K ha^{-1} on soils testing medium as well as high in available K. Tandon and Sekhon (1988) concluded that response of high yielding varieties of rice and wheat to K application in soils rated medium in available K were only marginally lower than responses in low K soils.

Field experiments conducted at different locations in Punjab showed that rice responded more to applied K in north-eastern districts (Gurdaspur, Amritsar, Kapurthala and Hoshiarpur) than in central and south-west districts (Ludhiana,

Bathinda, Sangrur, Ferozepur) (Singh and Bhandari, 1995). A 6-year study conducted at two locations showed that both rice and wheat responded significantly to K application up to 50 kg K ha^{-1} in loam soils at Gurdaspur, whereas no significant increase in rice yields was observed on sandy loam soil at Ludhiana (Yadvinder-Singh et al., 2002). Brar et al. (1986) made a similar inference, and opined that within a series, texture and rate of release could be driving criteria to demystify K dynamics in the soils of Punjab. Incidentally, wheat started responding to K application at Ludhiana two years after the initiation of the former experiments. Although soils at both the locations were low in NH_4OAc-K, higher response at Gurdaspur was due to high K-fixation capacity and slow K-release rate of the loam soil. These results suggest that K supplying capacity of different soils is governed by pools of K rather than water soluble plus exchangeable K (Brar and Sekhon, 1986; Brar et al., 1986; Bijay Singh and Yadvinder Singh, 2006).

4.2 Recent studies

It has now been established that larger number of soils in the north-eastern part of the state are deficient in the status of available potassium than the soils of other parts of the state. Also due to scarcity of ground water for irrigation, farmers of Hoshiarpur and Nawanshar districts are shifting their cultivation from rice-wheat system to sunflower-maize-peas system. To study the response to applied potassium by these crops, the experiments were conducted at farmers' fields for five years from 2003 through 2007 under an adhoc research project funded by the International Potash Institute, Switzerland. The salient results are reported in the following paragraphs:

Yield and yield parameters of sunflower: The data of 21 experiments conducted at farmers' fields showed that at most of the places, significant response was obtained up to an application of 60 kg K_2O ha^{-1}. However, at some places, the response was up to 90 kg K_2O ha^{-1} application; the highest level of K applied in these experiments (Table 16). These variations could be due to intricacies in soil resources, especially mineralogical make-up and state of weathering of soil minerals. On an average, both grain and straw yields increased with increase in the level of applied potassium (Fig. 6).

The increase in yield of sunflower was obtained because of application of potassium that at first led to the increase in head yield, which was as a result of increases in head weight and head diameter (Table 17; Fig. 7). The data also showed that the application of potassium has significantly increased the grain weight. The increase in grain to head ratio with the application of potassium further indicated that potassium application has more favourable effect on increase in grains over the total head weight.

Table 16. Effect of fertilizer treatments on yield and yield parameters of sunflower

Treatments	Year					Average
	2003 (6*)	2004 (5*)	2005 (4*)	2006 (3*)	2007 (3*)	
			Grain yield (q ha^{-1})			
$N_{60}P_0K_0$	9.0	7.6	9.7	19.3	24.1	13.9
$N_{60}P_{30}K_0$	10.0	10.5	11.5	20.8	25.6	15.7
$N_{60}P_{30}K_{30}$	10.9	12.9	15.0	22.6	26.8	17.6
$N_{60}P_{30}K_{60}$	12.0	14.6	16.7	22.1	28.1	18.7
$N_{60}P_{30}K_{90}$	12.5	15.3	18.0	23.1	34.9	20.8
CD (5%)	1.4	1.9	1.5	NS	4.9	
			Straw yield (q ha^{-1})			
$N_{60}P_0K_0$	38.8	33.6	41.9	37.2	38.0	37.9
$N_{60}P_{30}K_0$	39.7	41.5	45.6	42.8	44.9	42.9
$N_{60}P_{30}K_{30}$	41.0	41.5	48.3	45.4	51.9	45.6
$N_{60}P_{30}K_{60}$	43.8	44.1	51.3	48.1	50.1	47.5
$N_{60}P_{30}K_{90}$	47.6	48.6	47.6	47.9	52.8	48.9
CD (5%)	NS	7.2	NS	NS	8.3	
			Fresh head yield (q ha^{-1})			
$N_{60}P_0K_0$	141	135	153	161	324	183
$N_{60}P_{30}K_0$	161	146	158	170	346	196
$N_{60}P_{30}K_{30}$	189	171	195	213	346	223
$N_{60}P_{30}K_{60}$	186	192	218	192	373	232
$N_{60}P_{30}K_{90}$	178	198	230	222	386	243
CD (5%)	33	17	21	36	NS	

* Data in parenthesis show total number of experiments conducted at different sites.

Potassium application has a favourable effect on height of plant (Table 18). The plants that were dressed with potassium were taller than plants, which did not receive any K. Plant height alone may not be a good indicator of yields, until and unless it is accompanied by strength and thickness. The data indicate that potassium application not only increased the height but also thickness of the sunflower plant (Table 19), thus making it strong enough to withstand lodging.

Total leaf area is considered as one of the important factors contributing to crop yields by increasing the rate of photosynthesis. Higher the leaf area, higher will be the photosynthetic activity, and higher formation of photosynthates. The data in Table 20 indicate that potassium application has significantly increased the leaf area of sunflower, which might have contributed to the yield gain.

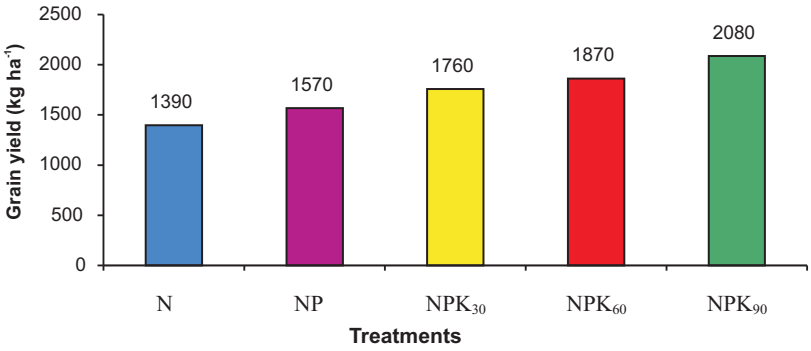
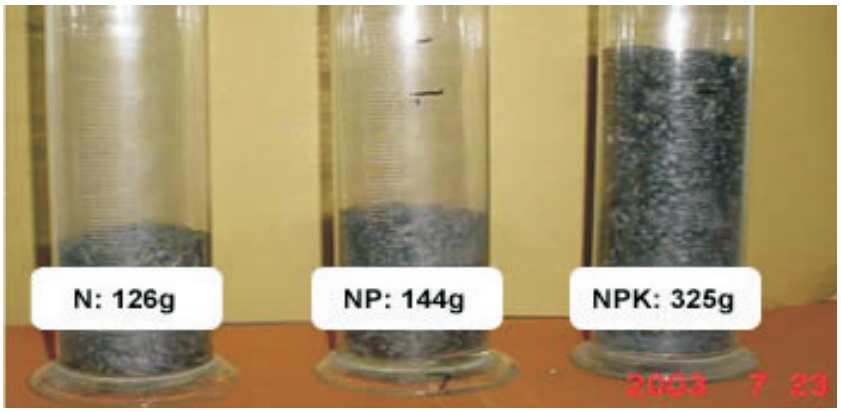


Fig. 6. Effect of different treatments on grain yield (kg ha^{-1}) of sunflower

(a)



(b)

Fig. 7. Effect of potassium application on (a) size of head of sunflower and thickness of stem, and (b) grain weight of flower head.

Table 17. Effect of fertilizer treatments on yield parameters of sunflower

Treatments	Year					Average
	2003 (6*)	2004 (5*)	2005 (4*)	2006 (3*)	2007 (3*)	
			Weight per head (g)			
$N_{60}P_0K_0$	331	214	264	210	324	247
$N_{60}P_{30}K_0$	399	304	275	292	346	293
$N_{60}P_{30}K_{30}$	469	330	332	285	346	319
$N_{60}P_{30}K_{60}$	519	360	362	271	373	341
$N_{60}P_{30}K_{90}$	430	362	389	377	386	353
CD (5%)	98	40	70	NS	NS	
			Head diameter (cm)			
$N_{60}P_0K_0$	14.7	17.8	15.3	15.7	16.8	16.1
$N_{60}P_{30}K_0$	16.7	20.2	16.4	17.4	17.7	17.7
$N_{60}P_{30}K_{30}$	17.6	22.0	17.5	17.7	17.4	18.4
$N_{60}P_{30}K_{60}$	18.0	22.1	17.3	17.5	18.2	18.6
$N_{60}P_{30}K_{90}$	18.8	22.2	18.6	18.6	18.0	19.2
CD (5%)	2.1	1.4	1.1	NS	NS	
			Thousand grain weight (g)			
$N_{60}P_0K_0$	34.4	31.8	47.8	34.8	32.2	36.2
$N_{60}P_{30}K_0$	38.5	34.5	49.7	36.2	33.6	38.5
$N_{60}P_{30}K_{30}$	40.0	34.8	51.6	41.9	39.7	41.6
$N_{60}P_{30}K_{60}$	41.8	38.2	56.6	39.3	39.4	43.1
$N_{60}P_{30}K_{90}$	41.2	43.4	60.0	47.3	40.5	46.5
CD (5%)	3.3	4.9	5.1	7.5	5.9	
			Grain:Head ratio			
$N_{60}P_0K_0$	0.58	0.54	0.51	0.58	0.53	0.55
$N_{60}P_{30}K_0$	0.62	0.60	0.57	0.59	0.62	0.60
$N_{60}P_{30}K_{30}$	0.62	0.62	0.55	0.62	0.59	0.60
$N_{60}P_{30}K_{60}$	0.65	0.63	0.62	0.69	0.66	0.65
$N_{60}P_{30}K_{90}$	0.64	0.63	0.66	0.63	0.60	0.63
CD (5%)	0.03	0.04	0.05	NS	0.07	

* Figures in parenthesis indicate total numbers of experiments conducted at different sites.

Table 18. Effect of fertilizer treatments on height of sunflower plant

Treatments	Year					Average
	2003 (6*)	2004 (5*)	2005 (4*)	2006 (3*)	2007 (3*)	
	Plant height (cm) at 45 days after sowing					
$N_{60}P_0K_0$	28.8	21.4	26.2	28.0	39.8	28.8
$N_{60}P_{30}K_0$	30.5	26.9	31.9	31.7	40.0	32.2
$N_{60}P_{30}K_{30}$	33.0	28.1	30.8	34.4	44.2	34.1
$N_{60}P_{30}K_{60}$	33.6	28.1	32.8	33.6	44.4	34.5
$N_{60}P_{30}K_{90}$	31.7	27.7	35.1	34.8	43.9	34.6
CD (5%)	NS	3.04	5.53	NS	NS	
	Plant height (cm) at 75 days after sowing					
$N_{60}P_0K_0$	129	148	163	199	160	160
$N_{60}P_{30}K_0$	139	163	164	204	165	167
$N_{60}P_{30}K_{30}$	136	164	164	203	168	167
$N_{60}P_{30}K_{60}$	141	165	171	202	172	170
$N_{60}P_{30}K_{90}$	140	166	177	211	175	174
CD (5%)	NS	NS	8.48	NS	NS	
	Plant height (cm) at 100 days after sowing					
$N_{60}P_0K_0$	159	157	173	198	194	176
$N_{60}P_{30}K_0$	167	167	174	208	213	186
$N_{60}P_{30}K_{30}$	168	172	177	210	216	189
$N_{60}P_{30}K_{60}$	166	174	179	211	238	194
$N_{60}P_{30}K_{90}$	164	174	187	219	244	198
CD (5%)	NS	9.03	5.99	NS	10.56	

* Figures in parenthesis indicate total number of experiments conducted at different locations.

Table 19. Effect of fertilizer treatments on girth of sunflower plant

Treatments	Year					Average
	2003 (6*)	2004 (5*)	2005 (4*)	2006 (3*)	2007 (3*)	
	Plant girth (cm) at 45 days after sowing					
$N_{60}P_0K_0$	3.48	3.66	4.45	5.53	6.03	4.63
$N_{60}P_{30}K_0$	3.88	4.42	5.14	5.87	6.16	5.09
$N_{60}P_{30}K_{30}$	4.37	4.74	5.39	6.43	6.31	5.45
$N_{60}P_{30}K_{60}$	4.50	4.46	6.04	6.77	7.55	5.86
$N_{60}P_{30}K_{90}$	4.55	4.86	6.17	6.30	6.75	5.73
CD (5%)	0.45	0.37	0.81	NS	NS	
	Plant girth (cm) at 75 days after sowing					
$N_{60}P_0K_0$	6.85	7.32	6.74	14.67	9.64	9.04
$N_{60}P_{30}K_0$	7.00	8.28	7.29	14.07	9.94	9.32
$N_{60}P_{30}K_{30}$	7.27	8.72	8.48	14.43	10.11	9.80
$N_{60}P_{30}K_{60}$	7.52	9.10	9.33	14.40	11.17	10.30
$N_{60}P_{30}K_{90}$	7.72	8.82	9.16	14.07	10.78	10.11
CD (5%)	0.58	0.70	0.96	NS	NS	
	Plant girth (cm) at 100 days after sowing					
$N_{60}P_0K_0$	7.85	7.54	8.67	14.43	13.67	10.43
$N_{60}P_{30}K_0$	8.22	8.50	9.00	13.83	14.00	10.71
$N_{60}P_{30}K_{30}$	8.78	9.44	9.62	14.13	14.27	11.25
$N_{60}P_{30}K_{60}$	8.90	9.46	9.95	14.13	15.28	11.54
$N_{60}P_{30}K_{90}$	9.38	9.06	10.42	13.70	15.33	11.58
CD (5%)	0.76	0.56	0.63	NS	1.09	

* Figures in parenthesis indicate total number of experiments conducted at different locations.

Table 20. Effect of fertilizer treatments on leaf area of sunflower

Treatments	Year					Average
	2003 (6*)	2004 (5*)	2005 (4*)	2006 (3*)	2007 (3*)	
	Leaf area (cm) - 45 days after sowing					
$N_{60}P_0K_0$	1109	1298	1391	1624	2130	1510
$N_{60}P_{30}K_0$	1122	1863	1530	1807	2554	1775
$N_{60}P_{30}K_{30}$	1483	2316	1681	2039	2585	2021
$N_{60}P_{30}K_{60}$	1362	2415	1949	2223	2780	2146
$N_{60}P_{30}K_{90}$	1300	2372	2096	1946	2984	2140
CD (5%)	NS	496	280	NS	296	
	Leaf area (cm) - 75 days after sowing					
$N_{60}P_0K_0$	4535	5338	8921	10231	8863	7578
$N_{60}P_{30}K_0$	4638	6805	9139	11197	9199	8196
$N_{60}P_{30}K_{30}$	6098	8355	9373	11166	9337	8866
$N_{60}P_{30}K_{60}$	5716	8448	9916	10554	9893	8905
$N_{60}P_{30}K_{90}$	5234	8767	9838	10690	10294	8965
CD (5%)	NS	1697	442	NS	NS	
	Leaf area (cm^2) - 100 days after sowing					
$N_{60}P_0K_0$	3649	7212	9581	9480	8917	7768
$N_{60}P_{30}K_0$	4497	9034	9739	10119	9606	8599
$N_{60}P_{30}K_{30}$	5267	10918	9912	10351	9863	9262
$N_{60}P_{30}K_{60}$	5575	12491	10137	10589	9696	9698
$N_{60}P_{30}K_{90}$	6084	11772	10224	10666	10080	9765
CD (5%)	1300	1939	355	NS	NS	

* Figures in parenthesis show total number of experiments conducted at different locations.

Oil content and oil yield of sunflower: Sunflower is an important oilseed crop. Therefore, it is pertinent to study the effect of potassium application on the content and total yield of oil. The data in Table 21 show that application of potassium has increased oil content. As a consequence of increase in percent oil content accompanied by grain-yield there was significant increase in total oil yield, which is a key component of an oilseed crop.

Table 21. Effect of fertilizer treatments on oil content and oil yield of sunflower

Treatments	Year					Average
	2003 (6*)	2004 (5*)	2005 (4*)	2006 (3*)	2007 (3*)	
			Oil content (%)			
$N_{60}P_0K_0$	38.4	31.9	40.3	35.7	32.3	35.7
$N_{60}P_{30}K_0$	40.2	30.5	35.7	35.6	39.1	36.2
$N_{60}P_{30}K_{30}$	37.4	33.7	36.8	37.3	39.3	36.9
$N_{60}P_{30}K_{60}$	38.7	33.8	36.7	36.5	40.3	37.2
$N_{60}P_{30}K_{90}$	40.6	36.1	38.4	39.7	37.8	38.5
CD (5%)	NS	NS	NS	NS	3.80	
			Oil yield (q ha^{-1})			
$N_{60}P_0K_0$	334	244	392	688	780	488
$N_{60}P_{30}K_0$	394	330	413	735	1003	575
$N_{60}P_{30}K_{30}$	402	448	564	819	1052	657
$N_{60}P_{30}K_{60}$	467	500	625	803	1127	704
$N_{60}P_{30}K_{90}$	509	555	696	878	1313	790
CD (5%)	61	94	107	NS	207	

* Figures in parenthesis indicate total number of experiments conducted at different locations.

Content and uptake of K by Sunflower: Potassium application has increased the content of potassium both in grain and straw (Table 22). The content of potassium was more in straw than in grain. Simultaneously, the application of K has improved its uptake by grain and straw of sunflower.

Table 22. Effect of fertilizer treatments on contents and uptakes of K in seeds and straw of sunflower

Treatments	Year					Average
	2003 (6*)	2004 (5*)	2005 (4*)	2006 (3*)	2007 (3*)	
			K content (%) in grain			
$N_{60}P_0K_0$	1.15	1.18	1.57	1.17	1.30	1.27
$N_{60}P_{30}K_0$	1.31	1.22	1.64	1.22	1.55	1.39
$N_{60}P_{30}K_{30}$	1.41	1.42	1.82	1.38	1.53	1.51
$N_{60}P_{30}K_{60}$	1.53	1.50	1.84	1.36	1.69	1.58
$N_{60}P_{30}K_{90}$	1.44	1.48	1.98	1.44	1.79	1.63
CD (5%)	0.12	0.19	0.26	0.08	0.20	
			K uptake (kg ha^{-1}) in grains			
$N_{60}P_0K_0$	10.4	8.9	15.2	22.3	31.3	17.6
$N_{60}P_{30}K_0$	13.3	13.0	19.3	24.9	39.8	22.1
$N_{60}P_{30}K_{30}$	15.8	19.2	27.7	30.6	40.8	26.8
$N_{60}P_{30}K_{60}$	18.5	22.8	30.0	29.7	47.7	29.7
$N_{60}P_{30}K_{90}$	17.9	23.3	35.4	33.3	61.9	34.4
CD (5%)	2.54	5.44	4.02	NS	7.86	
			K content (%) in straw			
$N_{60}P_0K_0$	2.40	2.12	2.24	2.87	2.61	2.45
$N_{60}P_{30}K_0$	2.43	2.22	2.46	2.97	2.84	2.58
$N_{60}P_{30}K_{30}$	2.58	2.25	2.50	3.18	3.18	2.74
$N_{60}P_{30}K_{60}$	2.55	2.41	2.72	3.50	3.78	2.99
$N_{60}P_{30}K_{90}$	2.78	2.42	2.98	3.75	4.00	3.19
CD (5%)	0.16	0.18	NS	0.39	0.64	
			K uptake (kg ha^{-1}) in straw			
$N_{60}P_0K_0$	93.0	71.0	86.9	110.0	99.5	92.1
$N_{60}P_{30}K_0$	96.8	92.3	76.5	120.2	126.2	102.4
$N_{60}P_{30}K_{30}$	105.7	93.8	112.0	141.7	166.4	123.9
$N_{60}P_{30}K_{60}$	111.6	106.3	132.5	167.5	187.7	141.1
$N_{60}P_{30}K_{90}$	132.6	117.9	135.5	173.4	211.8	154.2
CD (5%)	20.9	21.3	38.6	31.1	36.3	

* Figures in parenthesis indicate total number of experiments conducted at different locations.

Yield and yield parameters of maize: Maize is primarily grown in the Hoshiarpur and Nawanshahr districts in Punjab. The experiments were conducted to study the effect of potassium application on yield and yield parameters of maize at farmers' fields from 2003 through 2007. The data presented in Table 23 show that both grain and straw yields increased with the application of potassium. The increase in levels of potassium increased the yield. The overall mean of all the experiments (Fig. 8) showed that increase in grain yield was significant up to the addition of 60 kg K_2O ha^{-1}, although the response to the application of 90 kg K_2O ha^{-1} was also obtained at some locations.

Table 23. Effect of fertilizer treatments on grain and straw yields of maize

Treatments	Year					Average
	2003 (4*)	2004 (3*)	2005 (4*)	2006 (4*)	2007 (3*)	
	Grain yield (q ha^{-1})					
$N_{125}P_0K_0$	24.4	35.7	27.0	46.6	57.2	38.2
$N_{125}P_{60}K_0$	26.4	40.0	33.5	47.8	56.9	40.9
$N_{125}P_{60}K_{30}$	30.3	47.4	34.1	49.4	59.5	44.1
$N_{125}P_{60}K_{60}$	33.8	52.2	34.3	51.6	65.4	47.5
$N_{125}P_{60}K_{90}$	33.0	51.2	38.6	60.3	61.0	48.8
CD (5%)	4.9	5.6	6.5	5.3	NS	
	Straw yield (q ha^{-1})					
$N_{125}P_0K_0$	73.4	107.7	74.2	58.6	60.4	74.9
$N_{125}P_{60}K_0$	75.2	114.3	95.1	63.9	67.6	83.2
$N_{125}P_{60}K_{30}$	69.3	108.9	99.7	60.0	72.4	82.1
$N_{125}P_{60}K_{60}$	69.3	107.4	97.8	66.0	78.7	83.8
$N_{125}P_{60}K_{90}$	74.2	115.6	111.3	66.2	74.0	88.3
CD (5%)	NS	NS	NS	NS	10.8	

* Figures in parenthesis indicate total number of experiments conducted at different locations.

To study the effect of potassium application on yield parameters, the observations were recorded for cob length, cob girth, number of lines per cob, and thousand-grain weight (Table 24; Fig. 9). Potassium application at the rate of 60 kg ha^{-1} improved all yield parameters by increasing the length and girth of the cobs, number of grains, and weight of the grains of maize. All these factors contributed in increase in yield of maize.

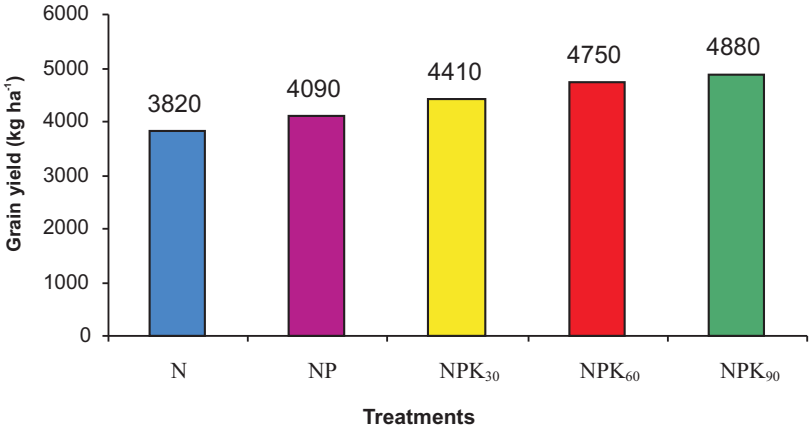


Fig. 8. Effect of different treatments on grain yield (kg ha^{-1}) of maize

Fig. 9. Effect of potassium application on size of cob and grains per cob

Fig. 10. Potassium application protected the maize crop from lodging

Table 24. Effect of fertilizer treatments on yield parameters of maize

Treatments	Year					Average
	2003 (4*)	2004 (3*)	2005 (4*)	2006 (4*)	2007 (3*)	
			Cob length (cm)			
$N_{125}P_0K_0$	17.2	18.8	21.4	19.4	19.8	19.3
$N_{125}P_{60}K_0$	18.1	20.5	21.1	19.7	20.6	20.0
$N_{125}P_{60}K_{30}$	19.0	22.7	21.4	19.1	20.7	20.6
$N_{125}P_{60}K_{60}$	20.2	23.0	21.7	20.2	20.6	21.1
$N_{125}P_{60}K_{90}$	19.9	21.8	22.2	21.5	21.4	21.4
CD (5%)	0.9	1.3	NS	1.1	NS	
			Cob girth (cm)			
$N_{125}P_0K_0$	13.1	13.7	14.6	14.5	14.3	14.0
$N_{125}P_{60}K_0$	13.3	14.6	14.5	14.5	15.1	14.4
$N_{125}P_{60}K_{30}$	13.7	15.0	14.6	14.5	15.0	14.6
$N_{125}P_{60}K_{60}$	14.0	15.4	14.8	14.7	15.1	14.8
$N_{125}P_{60}K_{90}$	14.1	15.3	15.0	15.0	15.0	14.9
CD (5%)	0.53	0.46	NS	0.39	NS	
			Number of grain lines per cob			
$N_{125}P_0K_0$	12	12	13	13	13	12.6
$N_{125}P_{60}K_0$	13	13	13	13	13	13.0
$N_{125}P_{60}K_{30}$	13	13	13	13	14	13.2
$N_{125}P_{60}K_{60}$	14	14	13	13	14	13.6
$N_{125}P_{60}K_{90}$	14	13	13	14	14	13.6
CD (5%)	0.9	1.1	NS	NS	NS	
			Thousand grain weight (g)			
$N_{125}P_0K_0$	215	221	208	229	234	221
$N_{125}P_{60}K_0$	220	224	230	229	271	235
$N_{125}P_{60}K_{30}$	226	229	241	230	264	238
$N_{125}P_{60}K_{60}$	231	242	253	253	268	249
$N_{125}P_{60}K_{90}$	232	248	277	255	256	254
CD (5%)	NS	12	14	15	22	

* Figures in parenthesis indicate total number of experiments conducted at different locations.

Application of potassium not only increased the length of the plant but also improved its strength by increasing the girth of the plant (Table 25). It was observed that incidence of lodging of plants was lesser in K treated plants than in untreated plants (Fig. 10). This was

Table 25. Effect of fertilizer treatments on growth parameters of maize

Treatments	Year					Average
	2003 (4*)	2004 (3*)	2005 (4*)	2006 (4*)	2007 (3*)	
			Plant height (cm)			
$N_{125}P_0K_0$	224.5	261.2	233.7	172.8	225.2	223.5
$N_{125}P_{60}K_0$	222.2	258.5	238.5	192.3	236.7	229.6
$N_{125}P_{60}K_{30}$	231.5	258.3	238.2	203.2	239.3	234.1
$N_{125}P_{60}K_{60}$	234.8	263.3	247.8	209.9	244.6	240.1
$N_{125}P_{60}K_{90}$	235.3	265.2	244.1	222.1	244.7	242.3
CD (5%)	NS	NS	NS	24.5	NS	
			Plant girth (cm)			
$N_{125}P_0K_0$	5.02	7.07	7.32	3.42	6.79	5.92
$N_{125}P_{60}K_0$	5.18	7.13	8.32	3.47	7.60	6.34
$N_{125}P_{60}K_{30}$	6.72	7.60	7.92	3.80	7.53	6.71
$N_{125}P_{60}K_{60}$	6.95	8.17	8.65	3.75	7.46	7.00
$N_{125}P_{60}K_{90}$	7.21	7.87	8.27	3.77	7.63	6.95
CD (5%)	1.17	0.75	NS	0.27	0.39	
			Leaf area (cm^2)			
$N_{125}P_0K_0$	5645	7962	4339	4569	4753	5454
$N_{125}P_{60}K_0$	5715	8640	4357	5047	4585	5669
$N_{125}P_{60}K_{30}$	5905	9115	4707	5099	5005	5966
$N_{125}P_{60}K_{60}$	6016	9368	4702	5466	4905	6091
$N_{125}P_{60}K_{90}$	6225	9018	4804	6160	5464	6334
CD (5%)	NS	859	243	957	NS	

* Figures in parenthesis indicate total number of experiments conducted at different locations.

due to the improvement in the strength of the plant caused by the potassium application. Total leaf area improved significantly with the application of potassium and increase was up to the maximum application of potassium at the rates of 90 kg K_2O ha^{-1}.

Content and uptake of K in maize: The content of potassium increased with the increased levels of potassium application (Table 26). The contents and uptakes of K were smaller in grains than in straw.

Table 26. Effect of fertilizer treatments on K content and uptake by maize

Treatments	Year					Average
	2003 (4*)	2004 (3*)	2005 (4*)	2006 (4*)	2007 (3*)	
	K content (%) in grain					
$N_{125}P_0K_0$	0.33	0.24	0.34	0.36	0.68	0.39
$N_{125}P_{60}K_0$	0.32	0.26	0.34	0.42	0.76	0.42
$N_{125}P_{60}K_{30}$	0.41	0.27	0.38	0.40	0.76	0.44
$N_{125}P_{60}K_{60}$	0.46	0.30	0.39	0.44	0.74	0.47
$N_{125}P_{60}K_{90}$	0.48	0.32	0.40	0.55	0.77	0.50
CD (5%)	0.07	0.05	0.02	0.06	NS	
	K content (%) in straw					
$N_{125}P_0K_0$	0.66	0.52	1.23	0.95	0.78	0.83
$N_{125}P_{60}K_0$	0.67	0.58	1.30	1.16	0.82	0.91
$N_{125}P_{60}K_{30}$	0.72	0.87	1.27	1.43	0.80	1.02
$N_{125}P_{60}K_{60}$	0.71	0.87	1.39	1.48	0.88	1.07
$N_{125}P_{60}K_{90}$	0.83	0.89	1.55	1.56	0.97	1.16
CD (5%)	NS	NS	0.20	0.21	NS	
	K uptake (kg ha^{-1}) in grain					
$N_{125}P_0K_0$	8.1	8.5	9.4	17.1	39.7	16.6
$N_{125}P_{60}K_0$	8.4	10.3	11.9	22.2	44.1	19.4
$N_{125}P_{60}K_{30}$	12.4	13.0	13.1	20.1	45.9	20.9
$N_{125}P_{60}K_{60}$	15.7	14.9	13.7	23.3	48.4	23.2
$N_{125}P_{60}K_{90}$	15.7	16.5	15.6	34.6	51.8	26.8
CD (5%)	2.6	3.6	2.7	5.4	NS	
	K uptake (kg ha^{-1}) in straw					
$N_{125}P_0K_0$	48.7	55.3	84.7	57.2	47.0	58.6
$N_{125}P_{60}K_0$	50.4	65.2	117.2	73.5	54.7	72.2
$N_{125}P_{60}K_{30}$	50.0	84.6	116.7	85.8	58.3	79.0
$N_{125}P_{60}K_{60}$	49.2	87.2	138.9	97.4	69.1	88.4
$N_{125}P_{60}K_{90}$	61.5	95.0	171.6	101.7	71.7	100.3
CD (5%)	NS	NS	35.0	17.3	12.0	

***** Figures in parenthesis indicate total number of experiments conducted at different locations.

Yield and yield parameters of peas: Under intensive cropping system, with three crops in a year (i.e., 300% cropping intensity) farmers of Punjab are growing maize-peas (green)-sunflower in a sequence. The peas are sold as green pods, and farmers get a good

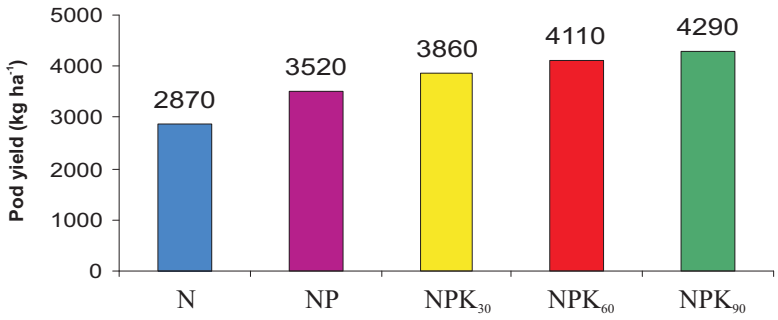


Fig. 11. Effect of treatments on fresh pod yield (kg ha^{-1}) of peas

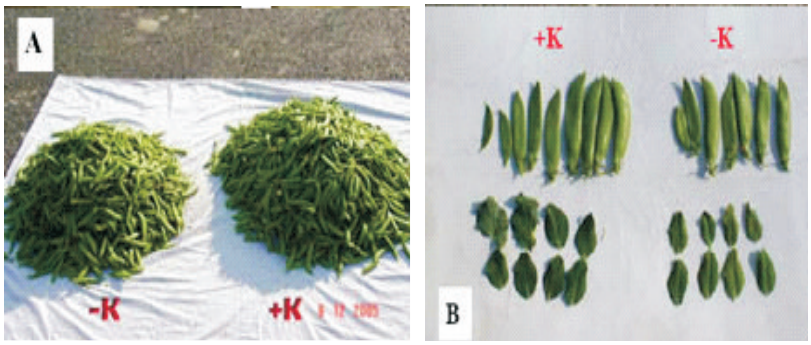


Fig. 12. Effect of potassium application on pods of peas

return in a short span. There was a substantial increase in the yield of fresh pods with the application of potassium (Fig. 11). In most of the experiments the significant response was limited up to the application of 60 kg K_2O ha^{-1}. However, in few experiments response was obtained up to the application of 90 kg K_2O ha^{-1}. The potassium application increased the yield due to the increase in pod weight, pod length, as well as increase in grain weight (Table 27). The plots that received 60 kg ha^{-1} of K_2O produced heavier pods than plots that received no potassium (Fig. 12). The grains in the K applied plots were bolder and heavier than their counterparts.

These studies clearly indicated that in North-eastern part of the state, all crops in sunflower-maize-peas cropping sequence respond significantly to the application of potassium. In addition to N and P

Table 27. Effect of fertilizer treatments on yield and yield parameters of peas

Treatments	Year					Average
	2003 (3*)	2004 (5*)	2005 (3*)	2006 (3*)	2007 (3*)	
	Fresh pod yield (q ha^{-1})					
$N_{50}P_0K_0$	38.5	42.0	28.9	17.6	16.4	28.7
$N_{50}P_{60}K_0$	43.8	53.0	33.4	24.6	21.2	35.2
$N_{50}P_{60}K_{30}$	50.3	55.4	39.2	27.4	20.5	38.6
$N_{50}P_{60}K_{60}$	51.9	61.0	42.6	28.0	22.0	41.1
$N_{50}P_{60}K_{90}$	49.6	61.3	46.2	34.5	22.8	42.9
CD (5%)	8.1	7.2	10.7	4.6	4.1	
	Weight of 100 pods (g)					
$N_{50}P_0K_0$	508	479	568	366	254	435
$N_{50}P_{60}K_0$	520	519	631	361	326	471
$N_{50}P_{60}K_{30}$	555	531	691	395	359	506
$N_{50}P_{60}K_{60}$	542	567	782	409	365	533
$N_{50}P_{60}K_{90}$	524	525	776	422	353	520
CD (5%)	19	25	NS	42	49	
	Pod length (cm)					
$N_{50}P_0K_0$	8.07	8.28	8.07	7.09	7.31	7.76
$N_{50}P_{60}K_0$	8.17	8.48	8.10	7.34	7.76	7.97
$N_{50}P_{60}K_{30}$	8.43	8.44	8.08	7.57	7.80	8.06
$N_{50}P_{60}K_{60}$	8.43	8.58	8.44	7.79	7.94	8.24
$N_{50}P_{60}K_{90}$	8.23	8.68	8.36	7.67	8.01	8.19
CD (5%)	NS	0.14	0.24	NS	0.39	
	Thousand grain weight (g)					
$N_{50}P_0K_0$	371	372	388	299	228	332
$N_{50}P_{60}K_0$	402	395	437	300	250	357
$N_{50}P_{60}K_{30}$	447	401	438	322	296	380
$N_{50}P_{60}K_{60}$	469	414	437	346	297	393
$N_{50}P_{60}K_{90}$	477	391	424	345	334	394
CD (5%)	NS	20	28	27	50	

* Figures in parenthesis indicate total number of experiments conducted at different sites.

the application of K seems to be beneficial for obtaining the optimum yields of these crops.

Content and uptake of potassium by peas: The potassium application also increased content and K uptake of K by peas (Table

Table 28. Effect of fertilizer treatments on K content and K uptake by peas

Treatments	Year					Average
	2003 (3*)	2004 (5*)	2005 (3*)	2006 (3*)	2007 (3*)	
	K content (%) in grain					
$N_{50}P_0K_0$	1.46	1.54	1.52	1.52	1.77	1.56
$N_{50}P_{60}K_0$	1.43	1.76	1.61	1.74	1.88	1.68
$N_{50}P_{60}K_{30}$	1.68	1.76	1.67	1.88	1.93	1.78
$N_{50}P_{60}K_{60}$	1.63	1.86	1.69	1.97	2.02	1.83
$N_{50}P_{60}K_{90}$	1.54	1.86	1.83	2.21	2.05	1.90
CD (5%)	0.17	0.15	0.19	NS	0.13	
	K content (%) in hull					
$N_{50}P_0K_0$	2.08	1.83	1.87	2.33	1.58	1.94
$N_{50}P_{60}K_0$	2.18	1.87	1.92	2.30	1.65	1.98
$N_{50}P_{60}K_{30}$	2.36	2.09	2.02	2.51	1.75	2.15
$N_{50}P_{60}K_{60}$	2.25	2.12	1.99	3.12	1.92	2.28
$N_{50}P_{60}K_{90}$	2.35	2.22	2.04	3.11	2.02	2.35
CD (5%)	0.09	0.16	0.06	0.35	0.12	
	K uptake (kg ha^{-1}) in grain					
$N_{50}P_0K_0$	4.45	5.12	3.44	2.20	2.22	3.49
$N_{50}P_{60}K_0$	4.97	7.44	4.29	3.00	3.10	4.56
$N_{50}P_{60}K_{30}$	6.45	7.76	5.24	4.31	3.13	5.38
$N_{50}P_{60}K_{60}$	6.42	9.17	5.74	4.30	3.36	5.80
$N_{50}P_{60}K_{90}$	5.81	9.03	6.67	5.83	3.65	6.20
CD (5%)	0.81	1.21	1.29	1.33	0.82	
	K uptake (kg ha^{-1}) in hull					
$N_{50}P_0K_0$	9.68	9.21	6.60	6.73	3.03	7.05
$N_{50}P_{60}K_0$	11.51	12.20	7.87	10.47	3.98	9.21
$N_{50}P_{60}K_{30}$	14.17	13.99	9.67	11.75	4.14	10.74
$N_{50}P_{60}K_{60}$	13.95	15.46	10.39	13.37	4.67	11.57
$N_{50}P_{60}K_{90}$	13.94	16.15	11.23	18.40	5.37	13.02
CD (5%)	2.41	1.92	2.14	2.48	1.12	

* Figures in parenthesis indicate total number of experiments conducted at different locations.

28). Increase in K content boosted utilization of nitrogen apart from meeting K requirement of the crop.