Research Findings

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Effect of Graded Doses of Potassium on Yield, Profitability and Nutrient Content of Vegetable Crops in the Central Plain Zone of Uttar Pradesh, India

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Abstract

Field experiments were carried out at the vegetable research farm, Kalyanpur, Kanpur Nagar, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, during the rabi seasons of 2011-12 and to 2012-13 to evaluate the potassium (K) requirement of four vegetable crops i.e. cauliflower, cabbage, brinjal (aubergine) and tomato on a soil moderately supplied in K. Five rates of K application 0, 40, 60, 80 and 100 kg K_2O ha^{-1} were tested with recommended doses of nitrogen (N) and phosphorus (P) of 120 kg N ha^{-1} and 60 kg P_2O_5 ha^{-1} for all four crops. Significant responses in increasing yield occurred for all four vegetables, the lowest yield for all crops being found in the treatment without K application. Yields and net profit from added potash to cauliflower, brinjal and tomato increased to the maximum level

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of K applied (100 kg K_2O ha^{-1}), while that for brinjal was achieved with less K applied, at 80 kg ha^{-1}. These yield responses indicate that even though the soil was moderately well supplied with K, it was inadequate to meet the K demands required to obtain the maximum yield in any of the four crops. In all four crops, the benefit cost ratio (BCR) due to potash application was very high, and varied between 25 to 69 presenting a very low financial risk for potash application. N, P and K concentration in the dry matter of all crops tested increased significantly up to 60 kg K_2O ha^{-1}, indicating a higher nutrient use efficiency (NUE) of N and P. Nutrient balance calculations showed that N was insufficiently provided to cauliflower and cabbage, resulting in a negative balance. Similarly, in all crops, except tomato, levels of applied K were not sufficient to avoid a negative K balance. We conclude that potash application to the crops tested was highly profitable with very little risk in this investment, especially in brinjal and tomato crops. The N levels applied to cauliflower and cabbage were not sufficient to realize full yield potential, however, increasing rates of K applied raised the NUE of N and P. Additional experiments in these crops are needed with increased levels of N and K to test for further possible potential yield increases.

Introduction

Potassium (K), an essential macronutrient taken up by the plant in very large quantities, plays a fundamental role in plant physiology and biochemistry (Marschner, 2012; Mengel and Kirkby, 2001). It is an exceptional nutrient in that it is not metabolized and is present within the plant almost exclusively as a univalent cation. It is highly mobile throughout the plant and associated with the transport of inorganic anions and metabolites. It activates more than 60 enzymes, has a direct function in protein synthesis, exerts an outstanding influence on plant water relations and is essential in the process of growth and development of cells. Potassium also plays a major role in photosynthesis in both the light and dark reactions culminating in the formation of sugar via the reduction of carbon dioxide. Potassium is also essential for the loading and transport of the sugar produced to developing fruits and roots, processes of extreme importance in the production of fruits and vegetables. It also enhances crop resistance to biotic and abiotic stresses including insects, pests and various diseases, as well as drought and frost (Cakmak, 2005) and is beneficial in extending the keeping quality of crop produce.

On many soils the application of K fertilizers is needed to increase yields and quality of crops. The aim of the work presented here was to establish the effects of increasing rates of application of muriate of potash (KCl) in a field experiment over a two year period on yields and nutrient uptake in four vegetable crops (cauliflower, cabbage, brinjal (aubergine) and tomato) growing in the soil conditions of the central plain of Uttar Pradesh, India. Our objective was also to use the data obtained to provide information in recommending K application rates for vegetable crops in the region. Additionally, the work was initiated to establish the benefit cost ratio (BCR), in relation to likely increased yields and the most profitable return to farmers when taking into account the fertilizer cost and crop sale value.

Soil fertility is very closely dependent on the presence of adequate supplies of mineral plant nutrients. Many soils, however, are unable to meet nutrient demands, particularly those supporting high yielding crops, so fertilizers have to be applied to the soil. In this work we therefore also draw up simple balance sheets relating the known increasing rates of K to the four vegetable crops (supplied together with the fixed recommended rates of N and P) and the removal of these nutrients in the harvested crops.

Materials and methods

Field experiments were carried out at the vegetable research farm, Kalyanpur, Kanpur Nagar, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur, in the central plain zone of Uttar Pradesh, India. Four vegetable crops i.e. cauliflower, cabbage, brinjal and tomato were grown over two years during the rabi seasons of 2011-12 to 2012-13 to test their response to

Cauliflower crop in the experiment. Photo by E. Sokolowski.

K application on yield and nutrient uptake. Five doses were compared 0, 40, 60 80 and 100 kg K_2O ha^{-1} in the form of muriate of potash given as a basal application. The recommended rates of N and P application of 120 kg N ha^{-1} and 60 kg P_2O_5 ha^{-1} were supplied as urea and diammonium phosphate (DAP) respectively. All the DAP and half the urea was applied as a basal dressing, with the remaining half of the urea being applied in two equal splits as top dressing. The five treatments for the four crops were replicated three times, giving a total of 60 plots with a plot size of 40 m^2.

Soil samples were collected randomly from the top soil (0-15 cm) and analyzed for physico-chemical properties prior to the onset of the experiment. The experimental soil was alkaline in reaction (pH 7.3) and low in organic carbon (C) (0.41%). Available N, P and K values obtained from sampling the experimental fields were 173.5, 11.92 and 171.5 kg ha^{-1} respectively, indicating a deficiency in N and medium levels of available P and K. During the experiments all necessary agronomic practices were followed when and where required. At maturity, the crops were harvested and fresh and dry matter yields determined as per treatment. Soil pH, EC, and available NPK were analyzed by standard procedures (Jackson, 1973). Organic C was measured using the Walkley and Black (1934) method. N, P and K concentrations in the vegetables (% dm) were determined as follows: N by the micro Kjeldahl method, and P and K by wet digestion using a (9:4) mixture of nitric:perchloric acid followed by suitable dilution. P was estimated colorimetrically as phosphomolybdate and K by flame photometry. The NPK concentrations of vegetables under test were expressed on a dry matter basis and the values computed.

Results and discussion

Yields

All four vegetable crops responded to a varying extent to K application as shown in Table 1 and Fig 1. In cauliflower and brinjal, fresh weight yield significantly increased up to 80 kg K_2O ha^{-1} from 21.8 to 27.85 t ha^{-1}, an increase of 27%, and from 27.8 to 43.35 t ha^{-1}, an increase of 59%, respectively. The lesser effect of K in cauliflower may be explained by an insufficiency of applied N, as evident from the negative N balance (Fig. 2). In cabbage, fresh weight yield increased up to only 60 kg K_2O ha^{-1} from 23.10 to 29.80 t ha^{-1}, a 29% increase. N applied to this crop was also probably insufficient in meeting only half of the crop's requirement (Fig. 3), with a large negative N balance at higher rates of

Table 1. Effect of K application on fresh weight yield, profit and BCR in vegetables (mean over two years).

K doses	Cauliflower			Cabbage			Brinjal			Tomato		
	Yield	Added net profit	BCR	Yield	Added net profit	BCR	Yield	Added net profit	BCR	Yield	Added net profit	BCR
kg K_2O ha^{-1}	*t ha^{-1}*	*US$ ha^{-1}*		*t ha^{-1}*	*US$ ha^{-1}*		*t ha^{-1}*	*US$ ha^{-1}*		*t ha^{-1}*	*US$ ha^{-1}*	
K_0	21.80	-	-	23.10	-	-	27.80	-	-	22.10	-	-
K_{40}	24.55	458	25	26.40	550	29	33.50	950	51	26.35	708	38
K_{60}	27.15	892	32	29.80	1,117	40	40.00	2,033	73	32.60	1,750	62
K_{80}	27.75	992	27	29.75	1,108	30	43.35	2,583	69	34.70	2,100	56
K_{100}	27.90	1,017	22	30.05	1,158	25	43.05	2,542	54	35.75	2,275	49
CD (P=0.05)	0.42			0.25			0.23			0.85		

Note: Calculation based on exch. rate USD=Rs.60; cost of vegetables 166.67 US$ t^{-1}; cost of potash 466.67 US$ t^{-1}.

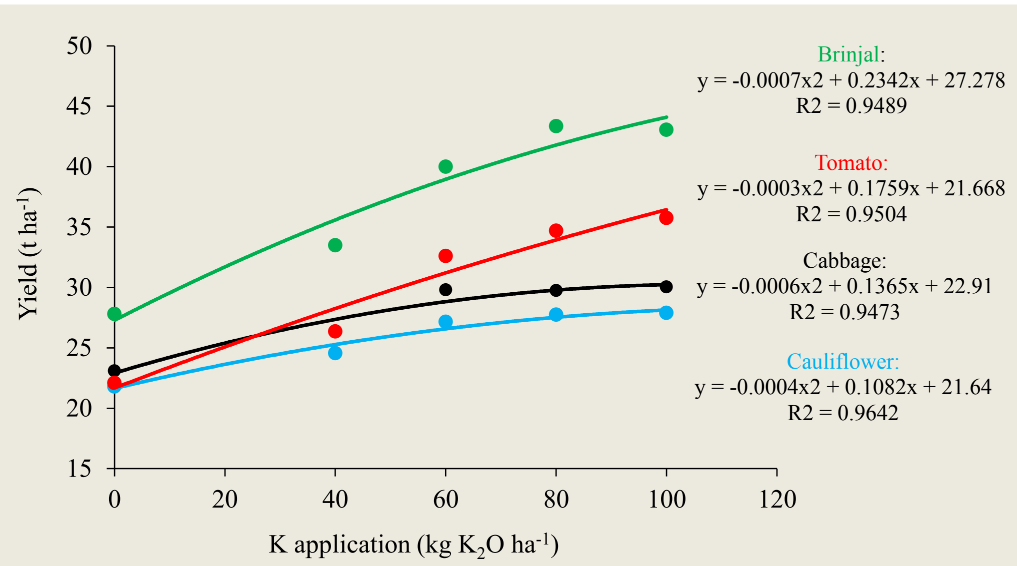


Fig. 1. Response of fresh weight vegetable yield to K application.

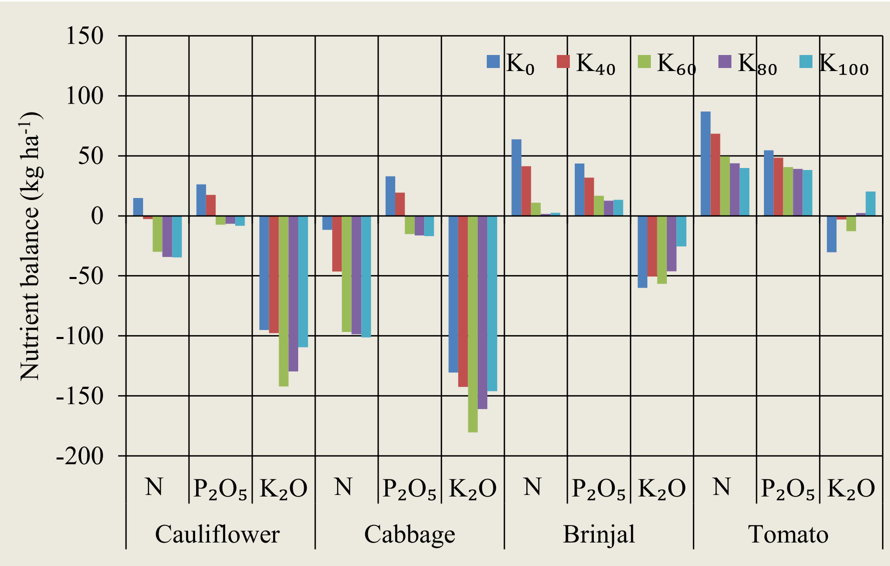


Fig. 2. Nutrient balance in crops.

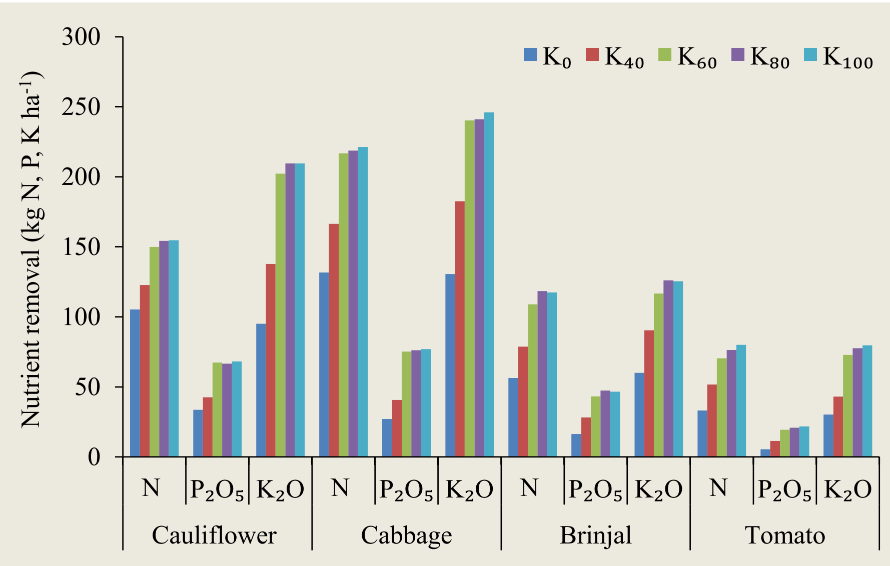


Fig. 3. Nutrient removal by crop with increased K application.

Table 2. Effect of K application on dry matter yield of various vegetables (mean over two years).

K doses	Cauliflower	Cabbage	Brinjal	Tomato
kg K_2O ha^{-1}		--------------$t\ ha^{-1}$--------------		
K_0	3.71	3.47	1.39	0.88
K_{40}	4.17	3.96	1.68	1.05
K_{60}	4.62	4.47	2.00	1.30
K_{80}	4.72	4.46	2.17	1.39
K_{100}	4.74	4.51	2.15	1.43

Note: Dry matter yield calculated on the basis of 17, 15, 5 and 4% dry matter in cauliflower, cabbage, brinjal and tomato respectively.

K supply (Fig. 2). The greatest response at 100 kg K_2O ha^{-1} occurred in tomato with a yield increase of 13.65 t ha^{-1}, a 61.76% increase. The fresh yield response curves of the four vegetables against the rate of K_2O application (Fig. 1) illustrate the response order in terms of fresh yield produced: brinjal (aubergine) > tomato > cabbage > cauliflower. From this data, we also assume that the tomato crop might have increased further with applications higher than 100 kg K_2O ha^{-1}. The response of increasing yield to K application above the zero application for all four vegetable crops provides evidence of an inadequate supply of available K in the farm soil for the growth and development of all of these crops. It is interesting that the order of fresh weight yield for the four crops as shown above differs markedly from the dry weight yield order of: cauliflower > cabbage > brinjal (aubergine) > tomato. This difference is dependent on the large variation in dry matter weights (of 17, 15, 5 and 4% for the four crops respectively - see Table 2).

Nutrient removal and balance

The concentrations of all three nutrients, N, P and K, in the dry matter were lowest in the treatment which did not receive any K fertilizer for all four vegetables (Table 3). This result provides further evidence that, despite the presence of adequate amounts of N and P fertilizer, the unamended soil K, although of medium status, was an insufficient source of K and restricted the uptake of all three nutrients by the crops. This observation also reflects the high K requirement in all four crops. Comparing the various rates of K application, K concentrations in the dry matter varied between the four crops. Brinjal, showed the highest K concentration above tomato and cabbage (with somewhat similar figures), followed by cauliflower with by far the lowest K concentration (about 25% lower than brinjal, Table 3). These differences may, to some extent, reflect differences in K requirement between the crops. Additionally, however, from a physiological viewpoint, fruits (brinjal

Table 3. Effect of graded doses of K on percent nutrient concentration in the dry matter of vegetables (mean over two years).

K doses	Cauliflower			Cabbage			Brinjal			Tomato		
	N	P	K	N	P	K	N	P	K	N	P	K
kg K_2O ha^{-1}	---% of DM---											
K_0	2.84	0.40	2.14	3.80	0.34	3.14	4.05	0.52	3.60	4.20	0.27	2.85
K_{40}	2.94	0.45	2.75	4.20	0.45	3.84	4.70	0.74	4.50	4.90	0.48	3.40
K_{60}	3.25	0.64	3.65	4.85	0.74	4.48	5.45	0.95	4.86	5.40	0.65	4.65
K_{80}	3.27	0.62	3.70	4.90	0.75	4.50	5.46	0.96	4.85	5.50	0.66	4.66
K_{100}	3.26	0.63	3.68	4.91	0.75	4.55	5.46	0.95	4.86	5.60	0.67	4.65
CD (P=0.05)	0.08	0.04	0.52	0.35	0.09	0.61	0.58	0.19	0.34	0.45	0.18	0.44

Table 4. Effect of K application on removal and balance of N by vegetables (mean over two years).

K doses	Cauliflower		Cabbage		Brinjal		Tomato	
	Removal	Balance	Removal	Balance	Removal	Balance	Removal	Balance
kg K_2O ha^{-1}	---*kg N ha^{-1}*---							
K_0	105.23	+14.77	131.70	-11.70	56.30	+63.70	33.12	+86.88
K_{40}	122.74	-2.74	166.35	-46.35	78.70	+41.30	51.64	+68.36
K_{60}	149.94	-29.94	216.75	-96.75	109.00	+11.00	70.40	+49.60
K_{80}	154.19	-34.19	218.70	-98.70	118.35	+1.65	76.32	+43.68
K_{100}	154.70	-34.70	221.25	-101.25	117.50	+2.50	80.08	+39.92

Note: Calculation based on 120 kg N ha^{-1} application.

Table 5. Effect of K application on removal and balance of P_2O_5 by vegetables (mean over two years).

K doses	Cauliflower		Cabbage		Brinjal		Tomato	
	Removal	Balance	Removal	Balance	Removal	Balance	Removal	Balance
kg K_2O ha^{-1}	---*kg P_2O_5 ha^{-1}*---							
K_0	33.72	26.28	27.02	32.98	16.42	43.58	5.47	54.53
K_{40}	42.64	17.36	40.70	19.30	28.27	31.73	11.49	48.51
K_{60}	67.44	-7.44	75.24	-15.24	43.32	16.68	19.33	40.67
K_{80}	66.67	-6.67	76.27	-16.27	47.42	12.58	20.88	39.12
K_{100}	68.22	-8.22	76.95	-16.95	46.63	13.37	21.80	38.20

Note: Calculation based on 60 kg P_2O_5 ha^{-1} application.

Table 6. Effect of K application on removal and balance of K_2O by vegetables (mean over two years).

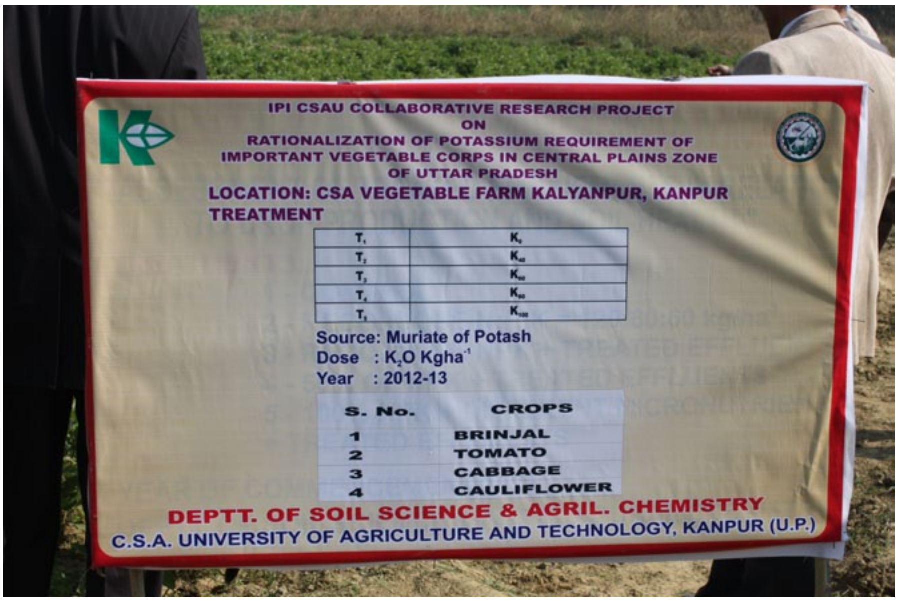
K doses	Cauliflower		Cabbage		Brinjal		Tomato	
	Removal	Balance	Removal	Balance	Removal	Balance	Removal	Balance
kg K_2O ha^{-1}	---*kg K_2O ha^{-1}*---							
K_0	95.06	-95.06	130.50	-130.50	60.06	-60.06	30.24	-30.24
K_{40}	137.70	-97.70	182.52	-142.52	90.42	-50.42	43.01	-3.01
K_{60}	202.16	-142.16	240.30	-180.30	116.64	-56.64	72.77	-12.77
K_{80}	209.51	-129.51	241.02	-161.02	126.12	-46.12	77.62	2.38
K_{100}	209.51	-109.51	246.06	-146.06	125.52	-25.52	79.78	20.22

and tomato) as K sinks in the plant might be expected to contain higher concentrations of K than leafy vegetables. Phosphorus concentrations of the dry matter were particularly high in brinjal followed by cabbage, tomato and cauliflower (Table 3).

The effects of K application on the four vegetable crops on the removal and balance of the three nutrients are shown for N (Table 4), P_2O_5 (Table 5) and K_2O (Table 6). The results are also expressed graphically (Fig. 2 and 3). A negative balance of N (Table 4) was recorded in all the K treatments for cauliflower and cabbage (except the controls) indicating that a lack of N probably limited plant growth. The positive balance of phosphorus (Fig. 2 and Table 5) was noted in all four vegetables (cauliflower, cabbage, brinjal and tomato), except at the higher rates of K application with cauliflower and cabbage. The negative balance of K was found in all crops regardless of K levels applied, except for tomato (Fig. 2, Table 6) for which a positive K balance was recorded at each level of K application. In all crops tested, NUE, e.g. increasing removal of N and P (Fig. 3) increased with K application over that without K use.

Profit and benefit cost ratio

Increased yield and profit with no risk to the farmer are not synonymous. To determine profit, the added costs for potash application were deducted from the additional income (Table 1, added net profit). Benefit cost ratio (BCR) reflects the risk by presenting the ratio between the added profit and the cost of the input (KCl in this case). It is factors such as net profit (USD ha^{-1}) and BCR that farmers take into account. The effect of K application on the net profit in each crop is described in Table 1 and Fig. 4. The highest additional net profit was achieved in brinjal and tomato, at USD 2,583 and USD 2,275 per ha while in cauliflower and cabbage it was only half of this amount. The high profitability of brinjal and tomato is also supported by a very high BCR of well over 50, while that of cauliflower and cabbage varies between 30 to 40. While maximum BCR was recorded at applications of 60 kg K_2O ha^{-1} for all four vegetables, the decision for which K application rate is needed, especially



Field board with the experiment set-up. Photo by E. Sokolowski.

at such high BCR values which pose no risk to farmers, brings into account the additional net profit.

Conclusions

On the basis of two years results of a vegetable research farm trial using cauliflower, cabbage, brinjal and tomato as test vegetables in their response to K fertilization as KCl, it was concluded that brinjal and tomato crops responded significantly in yield up to 80 and 100 kg K_2O ha^{-1} with maximum additional net income of over USD 2,000 ha^{-1}, and cauliflower and cabbage responded significantly in yield up to 80 and 60 kg K_2O ha^{-1} respectively, with maximum additional net income of over USD 1,000 ha^{-1}. These substantial responses, which were observed on a soil of medium K supply, indicate the high K requirements by all four vegetable crops and the

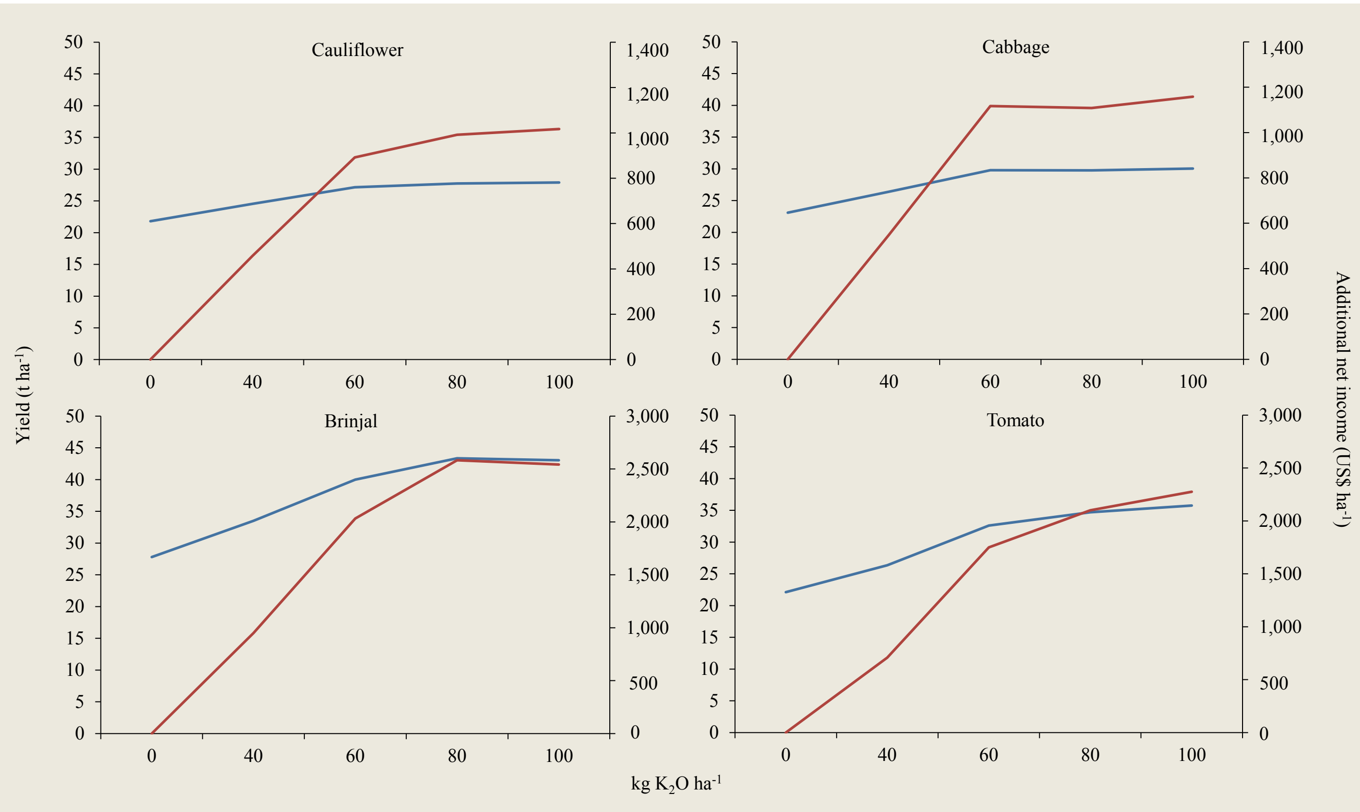


Fig. 4. Effect of increasing levels of K application on fresh weight yield (blue) and net profit of vegetables.

need for fertilizer application. High K applications must be accompanied by appropriate N levels, to avoid yield stagnation due to N deficiency, as reported here for cauliflower and cabbage crops. More experiments are required to optimize rates of N and K application to reduce or eliminate negative N and K nutrient balances and possible loss of fertility. Considering the BCR, which takes into account the cost of fertilizer and the value of the crop, K application offers little risk and therefore should be widely adopted.

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