Research Findings

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Enhanced Potassium Application Improves Yield and Profitability of Various Vegetable Crops in Jharkhand, India

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Abstract

A series of experiments were conducted in farmers' fields in different locations of Jharkhand with medium to high fertility status of available potassium (K) to study the response of selected vegetable crops viz. French bean (*Phaseolus vulgaris*), brinjal (*Solanum melongena* L.), cucumber (*Cucumis sativus*), bitter gourd (*Momordica charantia*), potato (*Solanum tuberosum*), bottle gourd (*Lagenaria siceraria*), ridge gourd (*Luffa acutangula*), green chili pepper (*Capsicum annuum* L.), and sweet pepper (*Capsicun annuum var. glossum*) to different K regimes. Five K treatments were tested: 1) K-free, farmers' fertilization practice (FFP); 2) recommended dose (100%), basal application; or, 3) split into basal and a second application at bloom; 4) enhanced (150%), basal application; or 5) enhanced, split as above. Nitrogen (N) and phosphorus (P) were uniformly

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applied according to recommendations. All nine crops displayed a significant increase (average - 31%) in yields in response to K application at recommended dose, as compared to FFP. The enhanced dose gave rise to a smaller yield increase, only 22% above the recommended dose, on average, which was also characterized by large variation between crops. Split K applications improved the yield of most crops, but to a much lesser extent. The differences among crop species regarding the linkage between crop K requirements in terms of life span and phenological phases, cropping patterns, and K and carbohydrate contents in harvested organs, are discussed. In conclusion, K application is essential, if exploiting the potential of vegetable crops and seeking to enhance the net return to farmers. For most crop species tested, recommended K dose should be revisited and upgraded. The positive response to split K dose may indicate that it is beneficial to distribute K application along the cropping season.

Map 1. Ranchi district, Jharkhand state, India. (By Joy1963. Own work, inset based on image: India Jharkhand locator map.svg. Licensed under CC BY-SA 3.0 via Wikimedia Commons. http://commons.wikimedia.org/wiki/File:JharkhandRanchi.png#/media/File:JharkhandRanchi.png).

Introduction

Soils are usually incapable of replenishing the loss of nutrients demanded by crops year after year (Mengel and Kirkby, 1987). Therefore, fertilization is essential to maintain soil productivity and fertility. Successive harvests remove large quantities of nutrients from soils; if their nutritional status is not tested regularly and sufficiently restored by balanced fertilization when found to be inadequate, soils become poor. Among the major plant nutrients (NPK), potassium (otherwise known as K or potash) requirements in vegetable crops are fairly high compared to grain crops. Potassium deficiency can bring about a drastic reduction in production and quality as well as shelf-life (Geraldson, 1985; Usherwood, 1985).

Potassium is an activator of various enzymes responsible for plant processes such as energy metabolism, starch synthesis, nitrate reduction and carbohydrate source-sink relationships and allocation. It is extremely mobile in the plant and is involved in plant water status, regulating stomatal conductance in the leaves, as well as water uptake in the roots. Potassium enhances the formation and development of fruit and tubers, and supports crop resistance against certain fungal and bacterial diseases. Soils with poor available K content usually fail to

French bean (*Phaseolus vulgaris*). Photo by IPI.

Brinjal (*Solanum melongena* L.). Photo by IPI.

Cucumber (*Cucumis sativus*). Photo by IPI.

support satisfactory crop yields (Engels *et al.*, 2012; Hawkesford *et al.*, 2012).

Jharkhand state in north-east India (Map. 1) has the potential to significantly increase its vegetable crop production by adoption of improved management practices. In general, soils in Jharkhand vary between low and medium status of available K. About 51% of the soils have medium K content and about 18% display low available K content. Thus, improving potash application practices, in context with other nutrients, would be among the first steps to further develop vegetable production in Jharkhand.

Potash application is usually carried out at the time of sowing/planting (basal application), which ensures the establishment of the crop and some subsequent K supply throughout the whole crop cycle. However, K availability in the soil is very labile; in sandy soils, it is easily leached from the root zone, while in heavy black soils, it might be fixed strongly to the soil surface. Therefore, splitting the dose along the cropping season would be a reasonable measure to ensure K availability when required by the crop.

While most of the farmers in the region tend to apply N and P, sometimes at a dosage higher than necessary, they underestimate or even ignore crop K requirements. The objectives of the present study were, therefore: 1) to quantify the yield response of various vegetable crops to doses and regimes of K application; 2) to demonstrate and thus promote the use of K fertilizer in vegetables crops in Jharkhand, India; and, 3) to initiate educated practices of K application.

Materials and methods

Field experiments were conducted during 2011 to 2014 on various major vegetable crops in farmers' fields situated at different provinces: Kanke (23°17'226"N 85°19'282"E), Pithoria (23°31'261"N 85°17'924"E), Ormanjhi (23°27'883"N 85°28'201"E), and Patratu (23°37'629"N 85°17'372"E) in Ranchi district, Jharkhand state, India (Map. 1). The soils were sandy-loam (52-63.7% sand, 20.7-28.21% silt and 15.6-18.8% clay) with organic carbon content (3.94-6.51 g kg^{-1}), pH (5.6-6.6), medium in 0.32% alkaline $KMnO_4$-oxidizable N (180-278 kg ha^{-1}), high in Bray-P1 extractable P (35-88 kg ha^{-1}) and medium to high in 1N neutral ammonium acetate extractable-K (121-480 kg ha^{-1}).

Vegetable crops examined were: French bean (*Phaseolus vulgaris* var. Arka Komal), brinjal (*Solanum melongena* L. var. Swarna Shakti), cucumber (*Cucumis sativus* var. Swarna Ageti), bitter gourd (*Momordica charantia* var. Combitore Long Green), potato (*Solanum tuberosum*) var. Pokhraj), bottle gourd (*Lagenaria siceraria* var. Victoria), ridge gourd (*Luffa acutangula* var. Swarna Manjari), green chili pepper (*Capsicum annuum* L. var. NP-46), and Shimla mirch or sweet pepper (*Capsicum annuum* L. var. California Wonder).

Farmers' fields were categorized as medium- or high-soil available K status. French bean and capsicum were grown in the medium-, while the rest of the vegetable crops were grown in the high-soil available K status. Crop seedlings were raised in a nursery/polytunnel and transplanted 15-20 days after sowing. A uniform dose of N and P was applied according to state recommendations for individual crops. Di-ammonium phosphate, urea and muriate of potash (MOP, KCl) were the sources of N, P and K, respectively.

All experiments comprised five treatments, as follows: 1) farmer fertilization practice (FFP), normally without K (K_0); 2) recommended K dose as basal ($K_{100\%}$); 3) recommended K dose split into 50% as basal, and 50% at bloom ($K_{(50+50)\%}$); 4) enhanced (150%) K dose, applied as basal ($K_{150\%}$); and, 5) enhanced (150%) K dose, split evenly into a basal application and a late one, at bloom ($K_{(75+75)\%}$). A detailed description of the fertilization regimes applied to each crop is given in Table 1. Each farmer's field was treated as a replicate. Experiments were carried out over one or two years, and the number of replicates for an experiment varied between three and six (Table 1).

Bitter gourd (*Momordica charantia*). Photo by IPI.

Potato (*Solanum tuberosum*). Photo by IPI.

Bottle gourd (*Lagenaria siceraria*). Photo by IPI.

Table 1. Detailed description of the experimental design, basic soil K availability, annual nitrogen (N) and phosphorus (P) dose, and the dose and regime of K application according to treatments and crops. Whenever split, K was applied as basal and at bloom, half and half. FFP – farmers' fertilization practice.

Crop	French bean	Brinjal	Cucumber	Bitter gourd	Potato	Bottle gourd	Ridge gourd	Green chili	Sweet pepper
Years	2	1	1	2	1	1	2	2	2
Exp. plots	3	3	3	3	3	4	3	3	3
	----------*kg ha^{-1}*----------								
Basal soil available K	121-258	140-225	284-480	297-416	284-416	284-417	284-322	284-416	297-258
Basal N	40	200	80	80	100	80	80	100	100
Basal P	80	150	40	40	150	40	40	60	150
Treatment	----------*K dosage and regime (kg ha^{-1})*----------								
FFP (K_0)	0	0	0	0	0	0	0	0	0
$K_{100\%}$	40	100	40	40	100	40	40	50	100
$K_{(50+50)\%}$	20+20	50+50	20+20	20+20	50+50	20+20	20+20	25+25	50+50
$K_{150\%}$	60	150	60	60	150	60	60	75	150
$K_{(75+75)\%}$	30+30	75+75	30+30	30+30	75+75	30+30	30+30	38+37	75+75

Results and discussion

Is K availability a factor limiting the accomplishment of high vegetable yield and quality? Indicators which answer this fundamental question may arise from several directions. The first one may be the basic fertility of the soil in terms of K availability, which indicates the potential of the soil to supply crop K requirements. Field data from the present study indicated medium to high K availability in all cases, ranging from 121 to 480 kg K ha^{-1} (Table 1). However, exploiting this soil potential depends largely on the extent to which the root system explores the relevant soil volume. Factors like water availability over dimensions of soil and time strongly restrict root expansion and function. Thus, very small portions of the theoretical soil mineral availability are practically exploited and, therefore, active fertilization should be considered also in fertile soils.

The crop response to elevated K application provides much better indications; a prompt and significant increase in yield would definitely demonstrate the dependency of crop development on K supply. This is in agreement with previous studies (Balasubramanian *et al.*, 1991; Hassan *et al.*, 1994; Patil *et al.*, 1996; Imas and Bansal, 1999; Deka *et al.*, 2000; Wuzhong, 2002; Umamaheshwarappa *et al.*, 2003; Bidari *et al.*, 2004; Thakre *et al.*, 2005; and Hari *et al.*, 2007), and was the case with all nine vegetable crops examined here, comparing the yields of K-free (K_0 as FFP) to those of $K_{100\%}$, where the officially recommended dosage was applied as basal fertilizer (Table 2; Fig. 1). Yield increases averaged 31%, ranging between 15% for ridge gourd, the least responsive crop, to about 51% for the most responsive one at that level - bottle gourd. The average consequent rise in net income was about 45 KRs ha^{-1}, ranging between 11 (ridge gourd) to 96 KRs ha^{-1} (brinjal). The average relative increase in net return was 49%, ranging from 18.5% (ridge gourd) up to 118% (potato) (Table 3). These results clearly express the significant contribution of basic K fertilization to farmer's income, for almost any vegetable crop tested, and in spite of the apparently good K status of the soils.

Nevertheless, there were significant differences among crops regarding the response rates (Fig. 1). Small or no response may indicate that factors other than K requirement, such as inadequate availability of water or other nutrients, or non-optimal temperature regime, might limit crop growth and development. Increased K application appears ineffective in such circumstances,

Table 2. Effect of K dose and regime on mean annual yields of nine vegetable crops grown in Ranchi district, Jharkhand state, India.

Crop	French bean	Cucumber	Bitter gourd	Ridge gourd	Chili pepper	Brinjal	Potato	Bottle gourd	Sweet pepper
Treatment	----------*Mg ha^{-1}*----------								
FFP (K_0)	7.3	9.4	7.5	8.0	7.1	50.6	9.2	9.2	21.8
Rec. ($K_{100\%}$)	9.6	12.4	9.2	9.2	8.5	67.1	13.3	13.9	29.1
Rec. split ($K_{(50+50)\%}$)	10.0	13.8	9.3	9.9	8.1	73.2	16.2	15.5	33.7
Enhanced ($K_{150\%}$)	10.5	15.4	10.6	10.8	10.1	76.8§	17.8	17.1	42.1
Enhanced split ($K_{(75+75)\%}$)	10.8	16.0	11.2	11.5	10.0	81.8	23.3	18.8	37.7
LSD (P=0.05)	1.88	2.19	1.74	2.22	2.06	14.9	4.81	1.58	11.1

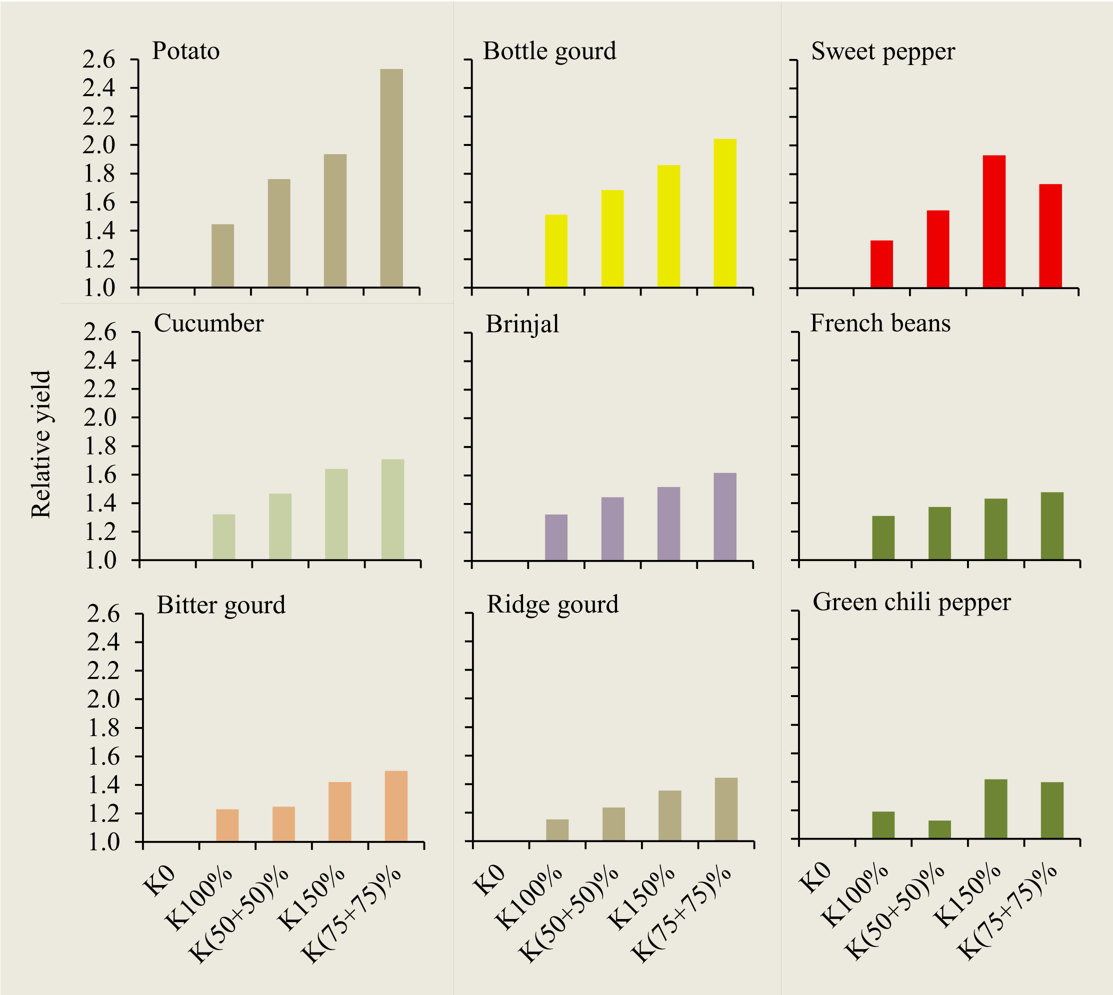

Fig. 1. Yield increment of nine vegetable crops in response to K dose and application regime. Data represent the relative yield compared to that of the K-free (K_0) farmers fertilization practice (FFP). $K_{100\%}$ = the recommended dose, applied once upon planting; $K_{(50+50)\%}$ = similar dose split into two uniform portions, applied upon planting and at bloom; $K_{150\%}$ = enhanced dose applied once upon planting; $K_{(75+75)\%}$ = enhanced dose split as described above.

Table 3. Net return to the farmer as a function of the current market price and the yield obtained by each crop species in response to K dose and regime. Data are presented by 1,000 Rs ha^{-1} (K Rs ha^{-1}).

Crop	French bean	Cucumber	Bitter gourd	Ridge gourd	Chili pepper	Brinjal	Potato	Bottle gourd	Sweet pepper
	Current market price (Rs kg^{-1})								
	15	10	15	10	20	6	15	10	12
Treatment	*Net return (K Rs ha^{-1})*								
K_0	69.2	58.6	76.3	59.5	106.2	227.6	49.7	66.2	204.3
$K_{100\%}$	101.9	87.5	100.7	70.5	131.8	323.5	108.3	111.9	288.7
$K_{(50+50)\%}$	108.6	101.3	102.8	77.0	123.0	359.8	151.8	128.6	343.9
$K_{150\%}$	114.5	116.7	121.4	85.9	163.4	380.5	174.2	143.6	443.1
$K_{(75+75)\%}$	119.1	123.0	130.1	93.1	160.6	409.9	257.3	160.1	390.3

before the active limiting problem is resolved. Alternatively, a weak response to elevated K application may indicate that K requirements are actually fulfilled. To distinguish between these two options, a rough estimate of crops' K requirements was carried out. Obviously, plant K content at harvest provides a minimum threshold estimate of K removal from the soil during crop growth and development. While this kind of measurement was beyond the scope of the present study, data regarding fruit or tuber K content is available from public web sources (USDA National Nutrient Database for Standard Reference, http://ndb.nal.usda.gov/ndb/search/list). Multiplying the yield by K content resulted in K removal by each crop and treatment (Table 4) (assuming that fruit K content is not directly affected by K soil status). Potassium is deeply involved in sugar translocation and metabolism (Engels *et al*., 2012), which may significantly affect crop K requirements. Therefore, special attention was also paid to differences among crops in regard to carbohydrate accumulation in fruit or tubers (Table 5).

Ridge gourd provided an excellent example for a very low recovery (in the fruit) of K inputs - less than 15% (Table 4). Yield response to increased K input was positive but quite poor compared to some other crops (Fig. 1). It seems that in the case of ridge gourd, K was not the ultimate factor limiting yield improvement. French bean, cucumber, bitter gourd, chili pepper, and bottle gourd comprise a group of crops, the K removal by the fruit of which was around 50% of K inputs. Assuming a rough harvest index of 0.5, K requirements by the crop met K inputs. Together with their positive significant yield response to elevated K (Fig. 1), the availability of this nutrient seems to dominate crop development. These results support updating the recommended dosage by at least 50% or more. Brinjal, potato, and sweet pepper comprise the most interesting group of vegetable crops in the present study. Their fruit or tubers remove large quantities of K, which is sometimes more than supplied by fertilizers (Table 4), and they also accumulate significant rates of carbohydrate (Table 5). Potato and sweet pepper yields displayed the largest response to increased K input (Fig. 1), indicating a significant dependency on K availability. Potato tubers removed 60-75% of the K supplied and accumulated up to 4 Mg ha^{-1} starch. In sweet pepper, K quantities removed by fruit alone were equivalent to those applied (Table 4). Furthermore with brinjal, the heavy yields of which always removed K quantities significantly higher than applied. In addition to 3-5 Mg ha^{-1} carbohydrate accumulated in the fruit, these results strongly indicate that K availability is crucial for this crop (Hochmuth *et al*., 1993). The relatively smaller response of brinjal yield to increased K input (Fig. 1) definitely strengthens the point that the dose range in the present study was far below real K requirements. This may be true also for potato and sweet pepper.

Splitting the recommended K dosage between basal and later application at bloom ($K_{(50+50)\%}$) brought about less significant effects on yields (Fig. 1). On average, yields increased by only 8%,

Table 4. Potassium removal from the soil by the fruit or tubers of nine vegetable crops grown under different K fertilization regimes. Seeds were not included, assuming that products are consumed as fresh vegetables, before seed maturation. In parentheses, the seasonal K dose per treatment for each crop.

Crop	French bean	Cucumber	Bitter gourd	Ridge gourd	Chili pepper	Brinjal	Potato	Bottle gourd	Sweet pepper
	K content in fruit or tubers (g K kg^{-1})								
	2.1	1.5	3.2	0.6	3.2	2.3	4.2	1.5	1.75
Treatment	*K removal by yield (kg K ha^{-1})*								
K_0	15.4 (0)	14.1 (0)	23.8 (0)	4.8 (0)	22.8 (0)	116.4 (0)	38.6 (0)	13.8 (0)	38.2 (0)
$K_{100\%}$	20.1 (40)	18.6 (40)	29.3 (40)	5.5 (40)	27.2 (50)	154.3 (100)	55.9 (100)	20.9 (40)	50.9 (50)
$K_{(50+50)\%}$	21.1 (40)	20.7 (40)	29.8 (40)	5.9 (40)	25.8 (50)	168.4 (100)	68.0 (100)	23.3 (40)	59.0 (50)
$K_{150\%}$	22.0 (60)	23.1 (60)	33.9 (60)	6.5 (60)	32.4 (75)	176.6 (150)	74.8 (150)	25.7 (60)	73.7 (75)
$K_{(75+75)\%}$	22.7 (60)	24.1 (60)	35.7 (60)	6.9 (60)	31.9 (75)	188.1 (150)	97.9 (150)	28.2 (60)	66.0 (75)

Table 5. Carbohydrate input in the fruit or tuber yields of nine vegetable crops grown under different K fertilization regimes. Seeds were not included, assuming that products are consumed as fresh vegetables, before seed maturation.

Crop	French bean	Cucumber	Bitter gourd	Ridge gourd	Chili pepper	Brinjal	Potato	Bottle gourd	Sweet pepper
	Carbohydrate content in fruit or tubers (%)								
	7	3.6	4.3	2	8.8	5.9	17.5	3.4	4.6
Treatment	*Carbohydrate removal by yield (Mg ha^{-1})*								
K_0	0.512	0.338	0.320	0.160	0.627	2.985	1.610	0.313	1.003
$K_{100\%}$	0.670	0.447	0.394	0.184	0.747	3.959	2.328	0.473	1.339
$K_{(50+50)\%}$	0.703	0.497	0.400	0.197	0.708	4.319	2.835	0.527	1.550
$K_{150\%}$	0.732	0.555	0.455	0.216	0.890	4.531	3.115	0.581	1.937
$K_{(75+75)\%}$	0.755	0.577	0.480	0.231	0.877	4.826	4.078	0.639	1.734


Ridge gourd (*Luffa acutangula*). Photo by IPI.


Chili pepper (*Capsicum annuum* L.). Photo by IPI.


Sweet pepper (*Capsicun annuum var. glossum*).Photo by IPI.

and crop response varied considerably. Chili was the sole crop where the yield declined. Yield increase of below 10% were recorded for bitter gourd, French bean, brinjal, and ridge gourd (1.5, 5%, 5%, and 7%, respectively), while more significant yield addition occurred in cucumber, bottle gourd, sweet pepper, and potato (11, 12, 16, and 22%, respectively). Splitting the enhanced K dose ($K_{(75+75)\%}$) resulted in an even smaller average increase in yield, less than 6%. Here, sweet pepper exhibited a significant yield decline; chili remained stable; French bean, brinjal, cucumber, bitter gourd, ridge gourd, and bottle gourd increased by less than 10%; while potato yield surged by 31%, in comparison to its yield at a single enhanced K application.

The idea of splitting the K dosage into several applications arises from two basic reasons: 1) the relatively high K mobility, particularly in the sandy-loam soils typical to the region of the experiment in Jharkhand; and, 2) the considerably dynamic changes in the requirements for K during plant life cycle. Successive applications of K along the growing season are assumed to ensure its availability to the plant whenever required. The results of the present study show that this assumption is generally valid. Consequently, the net return to the farmer increased in most cases (Table 3). However, K application should be adapted to an individual vegetable crop according to the altering demands through its phenological phases and to its cropping pattern. Some of the vegetable crops examined here differed significantly in these aspects.

In cucurbits, yield is a function of plant biomass at the occurrence of the first female flower, and the ratio between male and female flowers. Adequate basal N supply ensures sufficient plant biomass, whereas balanced N:K ratio (1:1-2, respectively) along the season provides optimal flower ratio, fruit set, development, and quality (Swiader *et al.*, 1994). Splitting the basal dose into two applications may be quite beneficial, as shown here for cucumber and bottle gourd. Nevertheless, additional value may emerge from dividing the same dose into several applications (Lin *et al.*, 2004). Some revision of the N and P fertilization practices might assist in improving the yields of the other cucurbit crops.

Also brinjal and French beans, which are characterized by a continuous cropping pattern, would benefit from the distribution of K application along the season, as indicated by the yield response to the split K dose. Yet, as mentioned above, the ultimate limiting factor in French beans seemed not to be to K, at least here. Brinjal requires significant upgrading of K dosage before solid conclusions can be made.

Potato, the most responsive crop in this experiment, appears to have a great potential for further improvement in yields. While significant basal N application is essential to establish sufficient vegetative biomass to support later tuber development, the application of this nutrient should be significantly reduced once tubers emerge, being replaced by considerable K application in order to sustain the massive carbohydrate translocation from leaves to tubers. Also here, the treatments with split K dose showed substantial benefits, but the whole fertilization practice should be reconsidered.

Sweet pepper and chili pepper provide an interesting comparison between two crops of the same species, *Capsicum annuum*. The difference might shed light on the role of phenology determining crop K requirements. Chili plants produce many tiny fruit that emerge and develop continuously along the plant life span. In this case, the reproductive effort displays a relatively constant but very small demand on K, hence no significant benefit in splitting the K dose could be observed. On the contrary, sweet pepper plants produce much larger fruit with considerable carbon sink demands. Fruit set displays an undulating pattern, which might influence current K requirements (Marcelis *et al.*, 2004). Therefore, splitting the K dose may have positive effects on yield, but the timing or synchronization with fruit set should be considered. This may provide an explanation for the inconsistent response of sweet pepper to the split K dose. Also here, revision of the recommended fertilization practices would benefit the farmers.

Nevertheless, before any further research is executed, farmers may consult the economic consequences of the different K application practices tested in the present study (Table 3). Considering the current market price of each crop species, even small improvements in yield may be significant for the farmers' net return.

Conclusions

1. Potassium application is essential if seeking to exploit the potential of vegetable crops.
2. For most crop species tested, the recommended K dose should be revisited, as well as the whole fertilization practice, to maintain a balanced nutrition status.
3. The positive response to split K dose may indicate that it is beneficial to distribute K application along the cropping season.

References

Balasubramanian, R., K. Balakrishnan, and S. Manoharan. 1991. Effect of Potassium on Chili. Spice India 4:5-6.

Bidari, B.I., M.D. Martur, and K.K. Math. 2004. Influence of Soil Properties on Yield and Quality of Chilies (*Capsicum annuum* L.) and Partitioning of Nutrients in Fruit Components. Paper presented at "Nation. Symp. on Input Use Efficiency in Agric. - Issues and Strategies", 25-27 Nov. 2004, Kerala, India. Agric. Univ., Thrissur, Kerala.

Deka, N.C., and T.C. Dutta. 2000. Effect of Potassium on Yield and Economics of Potato Cultivation in an Acidic Soil of Asssam. Journal of Potassium Research 16:77-79.

Engels, C., E.A. Kirkby, and P. White. 2012 Mineral Nutrition, Yield and Source-Sink Relationships. *In:* Marschner, P. (ed.). Marschner's Mineral Nutrition of Higher Plants, 3rd edition. Elsevier Ltd. p. 85-133.

Geraldson, C.M. 1985. Potassium Nutrition of Vegetable Crops. *In:* Munson, R.D. (ed.). Potassium in Agriculture. ASA-CSSA-SSSA, Madison, WI, USA. p. 915-927.

Imas, P., and S.K. Bansal. 1999. Potassium and Integrated Nutrient Management in Potato. International Potash Institute, Switzerland. http://www.ipipotash.org/presentn/kinmp.php#application.

Hari, G.S., P.V. Rao. Y.N. Reddy, and M.S. Reddy. 2007. Effect of Nitrogen and Potassium Levels on Yield and Nutrient Uptake in Paprika (*Capsicum annuum* L.) under Irrigated Conditions of Northern Telangana Zone of Andhra Pradesh. The Asian J. Hort. 2:193-196.

Hassan, S., Z.A. Ramlan, and S. Inon. 1994. Influence of Potassium Fertilizers and Mulching on Growth and Yield of Chili (*Capscium annuum*). Act Hort. 369:311-317.

Hawkesford, M., W. Horst, T. Kichey, H. Lambers, J. Schjoerring, I. Skrumsager-Møller, and P. White. 2012. Functions of Macronutrients. *In:* Marschner, P. (ed.). Marschner's Mineral Nutrition of Higher Plants, 3rd edition. Elsevier Ltd. p. 135-189.

Hochmuth, G.J., R.C. Hochmuth, and M.E. Donley. 1993. Eggplant Yield in Response to Potassium Fertilization on Sandy Soil. Hort. Sci. 28:1002-1005.

Lin, D., H. Danfeng, and W. Shiping. 2004. Effects of Potassium Levels on Fruit Quality of Muskmelon in Soilless Medium Culture. Scientia Horticulturae 102:53-60.

Marcelis, L.F.M., E. Heuvelink, L.R. Baan Hofman-Eijer, J. Den Bakker, and L.B. Xue. 2004. Flower and Fruit Abortion in Sweet Pepper in Relation to Source and Sink Strength. Journal of Experimental Botany 55(406):2261-2268.

Mengel, K., and E.A. Kirkby. 1987. Principles of Plant Nutrition. International Potash Institute, Switzerland.

Patil, S.R., U.T. Desai, B.G. Pawar, and B.T. Patil. 1996. Effect of NPK Doses on Growth and Yield of Bottle Gourd cv. Samrat. J. Maharashtra Agri. University 21:65-67.

Swiader, J.M., S.K. Sipp, and R.E. Brown. 1994. Pumpkin Growth, Flowering, and Fruiting Response to Nitrogen and Potassium Sprinkler Fertigation in Sandy Soil. J. Amer. Soc. Hort. Sci. 119:414-419.

Thakre, C.M., W.P. Badole, T.K. Tiwari, and P.B. Sarode. 2005. Effect of Different Levels of Sulphur, Phosphorus and Potassium on Yield and Quality of Brinjal. J. Maharashtra Agric. Univ. 30:352-353.

Umamaheshwarappa, P., K.S. Krishnappa, M.P. Muthu, V.N. Gowda, and P.V. Murthy. 2003. Effect of Varying Level of NPK on Growth and Yield of Bottle Gourd in Southern Dry Region of Karnataka. Mysore J. Agric, Sci. 37:56-64.

Usherwood, N.R. 1985. The Role of Potassium in Crop Quality. *In:* Munson, R.D. (ed.). Potassium in Agriculture. ASA-CSSA-SSSA, Madison, WI, USA. 489-513.

Wuzhong, N. 2002. Yield and Quality of Fruits of Solanaceaous Crops as Affected by Potassium Fertilization. Better Crops International. 16:6-8.

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