Research Findings

Field day at the Spice Research Center, Shibganj, Bogra, Bangladesh. Photo by B. Tirugnanasotkhi.

Effect of Potassium Fertilization on the Yield and Quality of Ginger *(Zingiber officinale)* grown on a K Deficient Terrace Soil of Level Barind Tract (AEZ 25) in Northern Bangladesh

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Abstract

This study presents the results of a field experiment on the effects of potassium (K) fertilization of ginger (*Zingiber officinale*) on a light textured K deficient soil (Terrace Soil of the Level Barind Tract (AEZ 25) at Shibganj, Bogra) at the Bangladesh Agricultural Research Institute's (BARI) Spices Research Center (SRC). The work was carried out over two growing seasons (2010-2011 and 2011-2012) to establish the optimum application rate of K to maximize yield and nutrient uptake (var. BARI Ada-1) under conditions in which an adequate supply of all other nutrients was supplied, and to draw up a K balance sheet for K utilization by the crop. Five treatments were compared including a control without K application $T_1=K_0$ control, $T_2=K_{40}$, $T_3=K_{80}$, $T_4=K_{120}$ and $T_5=K_{160}$ kg ha^{-1}. The plots

Note: In this paper, K and not K_2O units are used to describe fertilizer application.

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were laid out in a randomized complete block design (RCBD), each treatment with three replications. A blanket dose of $N_{133}P_{23}S_{12}Zn_2$ kg ha^{-1} was given on all plots. Increasing yield and yield attributes of ginger from the K deficient control were obtained up to 120 kg K ha^{-1} after which they declined. Likewise the highest rhizome yield by far was obtained with 120 kg K ha^{-1} application (17.6 and 16 mt ha^{-1} in 2010-2011 and 2011-2012, respectively). K application produced 13-67 percent yield increases in ginger. The response of rhizome yield to K fertilization rates was found to be quadratic (R^2=0.80). The amount of K taken up increased in response to raised levels of K application up to 120 kg K ha^{-1} ranging from 80 to 153 kg K ha^{-1}. An apparent K balance was estimated on the basis of K added through fertilizer and K uptake by the ginger. This K balance was found to be negative except at the highest rate of application of 160 kg K ha^{-1} when a slight positive K balance was recorded. The optimum dose from the graph of the response curve appeared to be 122 kg K ha^{-1} for maximizing ginger production in the location being studied. An economic analysis showed the K application resulting in the highest Marginal Benefit Cost Ratio (MBCR) for ginger to be 120 kg K ha^{-1}. Considering the economic returns and optimum dose, application of K at 122 kg ha^{-1}, along with a blanket dose of $N_{133}P_{23}S_{12}$ Zn_2 kg ha^{-1}, appears to be the best-suited dose which may be recommended for maximizing the yield of ginger in this K deficient Terrace Soil in the Level Barind Tract (AEZ 25). These results also reveal the importance of K fertilization in improving yields and sustaining ginger production in the study area. The observed negative K balance, even when other nutrient supply is balanced, highlights the importance of K management in achieving sustainable yields and maintaining soil health.

Introduction

In Bangladesh total agricultural production has increased significantly but in recent years a decline or stagnation of major crop yields has been recorded. This has resulted from the cumulative effects of many soil-related constraints, the important ones being nutrient mining, depletion of soil organic matter, imbalanced use of fertilizers, scanty use of bio and organic fertilizers and poor management practices. Additionally, despite the steady increase in use of chemical fertilizers containing nitrogen (N), phosphorus (P), K and sulfur (S) nutrients, these nutrients have not been applied in balanced amounts. A nutrient use ratio analysis shows that potassium (K) use is especially low in relation to N and P and it is for this reason that K deficiency is widespread across the country. Efforts to boost crop production have been made largely by the application of N and P fertilizers, while comparatively little attention has been paid to the application of K fertilizers. The continuous use of N fertilizer without K has created an imbalance in K:N ratio within the plant system, likely to be limiting to crop yield. Indeed, high rates of N application have become a habitual practice among farmers so that K has become the yield limiting nutrient in Bangladesh. Consequently, in the most intensively cropped areas of Bangladesh, there is evidence of high rates of K mining from the soil (130-165 kg K ha^{-1} $year^{-1}$), which makes up about 80 percent of total nutrient mining (175-215 kg of N + P_2O_5 + K_2O ha^{-1} $year^{-1}$). After N and P, K is the third major plant nutrient identified as deficient in most soils in Bangladesh (Noor *et al.*, 1998). The previously held common view that adequate amounts of K were present in Bangladesh soils might possibly have been true for local crop varieties with low yield potentials. In recent years, however, crop intensification, involving high yielding and hybrid/super hybrid varieties has highlighted widespread deficiency of K in Bangladesh soils for a number of crops including potato, sweet potato and other root crops, sugarcane, fruit, onion, garlic, fiber crops and high-yielding variety (HYV) cereals (Islam *et al.*, 1985; Kundu *et al.*, 1998; Noor *et al.*, 1993; Miah *et al.*, 2008). With adequate K supply, yields are enhanced and disease resistance is increased in roots and tubers (Nwaogu and Ukpabi, 2010). Other beneficial effects of K as a plant nutrient also include improved plant-water relations, raised photosynthetic activity, as well as more efficient translocation of photosynthetic products to fruits and roots, and increased resistance to both biotic and abiotic crop stresses (Marschner, 1995).

Ginger (*Zingiber officinale* Roscoe) is one of the major spice root crops grown in Bangladesh. It is a traditional foodstuff, highly valued for its significant seasoning and is used regularly in daily life. It also possesses medicinal properties. The crop is marketed in different forms such as raw ginger, dry ginger, bleached dry ginger, ginger powder, ginger oil, ginger candy, ginger flakes etc. Agronomically, ginger takes up large amounts of nutrients. Lujio *et al.* (2004) reported that one crop can remove as much as 400 kg N ha^{-1}, 145 kg P_2O_5 ha^{-1} (32 kg P ha^{-1}), and 950 kg K_2O ha^{-1} (394 kg K ha^{-1}) from the soil, an almost equal amount of N and K. The particularly high K requirement makes ginger sensitive to low soil K supply. In the plant, K indirectly improves utilization of N and protein formation, as well as raising yields, size of fingers and oleoresin content (Lujio *et al.*, 2004). In Bangladesh, the recovery and diversification of spice exports to international markets is a real possibility but this may be restricted by a lack of K supply. Spices like ginger and turmeric are well adapted to northern Bangladesh, but the region's sandy soils are highly leached and the consequent lack of K can become a constraint to production. These spice crops are highly sensitive to this lack and require a large amount of available soil K. In the case of ginger in particular, there is a growing understanding by farmers of the importance of using K, balanced by the use of N and P fertilizers to improve rhizome yields. This has contributed greatly to the economic viability of the crop and led to increase in demand for K fertilizers. There is now therefore a need for a quantitative investigation as to how much K is required by the ginger crop and how efficiently this nutrient is utilized.

The experiment cultivated a ginger crop (var. BARI Ada-1) over two seasons (2010-2011 and 2011-2012) on light textured K deficient terrace soil (Level Barind Tract (AEZ 25) at Shibhangi, Bogra) at the Bangladesh Agricultural Research Institute's (BARI) Spices Research Center (SRC). The aim was to: (i) establish, the optimum application rates of K for the maximum yield and yield components for plants adequately supplied with all other nutrients; (ii) determine the uptake of K by the crop; and (iii) draw up a K balance sheet of K uptake and loss in this particular soil.

Photo 1. Ginger rhizome (BARI Ada-1) is a popular spice in Bangladesh. IPI-BFA-BARI, SRC, Bogra, 2011-2012.

Material and methods

The unit plot size was 2 m × 1.5 m, with row to row spacing of 50 cm and plant to plant spacing of 25 cm. The ginger variety Bari Ada-1 was used as a test crop. There were five treatments comprising, viz. T_1=K_0, T_2=K_{40}, T_3=K_{80}, T_4=K_{120} and T_5=K_{160} kg ha^{-1} with three replications. The experiment was laid out in a Randomized Complete Block Design (RCBD). All treatments received a blanket dose application of $N_{133}P_{23}S_{12}Zn_2$ kg ha^{-1}. Urea, triple superphosphate, muriate of potash, gypsum and zinc sulphate were used as the sources of N, P, K, S and Zn, respectively. Half of the K was applied as a basal application at the time of final land preparation and half of the N was applied at 50 days after planting. The remaining N and K were top dressed in two equal splits at 80 and 110 days after planting. Two rhizomes of ginger were sown in May in both years in each pit and on emergence the plants were thinned to one plant per hill. All necessary intercultural operations were carried out as and when necessary. The crops were harvested when all the plants started drying in February 2011 and 2012. Data on various parameters including yield and K concentration of 10 randomly selected plants from each treatment were recorded. Collected data were analyzed statistically with the help of a statistical package, MSTAT-C, and Duncan's Multiple Range Test (DMRT) was used to determine the significant differences between treatments (Steel and Torrie, 1960). Plant samples were also collected from each plot for chemical analysis.

Photo 2. The ginger plant is sensitive to and needs a large amount of K. IPI-BFA-BARI, SRC, Bogra, 2011-2012.

Soil chemical analyses

Initial soil samples collected from 0-15 cm depth prior to fertilizer application, were analyzed for all important soil parameters using standard procedures (Table 1). The soil was found to be slightly acidic, intensively leached, and deficient in soil available K, as well as S and boron (B).

Standard methods were used in these determinations. Soil pH was measured by a combined glass calomel electrode (Jackson, 1958). Organic carbon was determined by the wet oxidation method (Walkley and Black). Total N was determined by a modified Kjeldahl method and calcium (Ca) and magnesium (Mg) by soil extraction with KCl. Available K, manganese (Mn) and zinc (Zn) were determined by AAS following $NaHCO_3$ extraction of the soil. B was determined by the $CaCl_2$ extraction method. Available P was measured by the Bray and Kurtz method and S was estimated using the turbidimetric method with $BaCl_2$.

Table 1. Fertility status of soil at SRC.

Soil parameters	pH	OM	Ca	Mg	K	Total N	P	S	B	Mn	Zn
		%	----*meq 100 g*$^{-1}$----			%	------------------*µg g*$^{-1}$------------------				
2010-2011	5.6	0.94	3.8	0.8	0.10	0.07	12	8	0.18	8.0	1.2
2011-2012	6.2	1.1	4.7	1.9	0.11	0.09	19	21	0.26	9.4	0.63
Critical level	-	-	2.0	0.5	0.12	-	7.0	10	0.20	1.0	0.6

Plant chemical analyses

The collected plant samples from each plot were dried at 65°C in an electric oven for 72 h then ground to pass through a 20 mesh sieve and analyzed following standard procedures. Plant samples were digested with HNO_3-$HClO_4$ (3:1) for K determination. Nutrient uptake was calculated by multiplying the concentration of K in the plant samples with the corresponding plant dry weights. Potassium balance was calculated by subtracting outputs (K removed or taken up by ginger rhizome and straw) from the inputs (K added as fertilizer) (Panaullah *et al.*, 2000).

Table 2. Yield contributing characters of ginger as influenced by different rates of K application (average of 10 plants).

Treatment	Plant height (cm)		No. of tillers/plant		No. of leaves/plant	
	2010-2011	2011-2012	2010-2011	2011-2012	2010-2011	2011-2012
T_1 (K_0)	65.00	56.9 b	13.4 c	10.0 d	161.9 b	90.2 d
T_2 (K_{40})	68.83	59.3 b	14.7 ab	11.4 cd	177.8 ab	114.9 c
T_3 (K_{80})	76.20	62.8 b	15.5 a	12.6 bc	205.8 a	132.2 b
T_4 (K_{120})	73.53	68.9 a	15.5 a	16.5 a	211.5 a	164.5 a
T_5 (K_{160})	71.53	66.7 a	14.3 bc	13.9 b	201.3 ab	145.4 b
CV (%)	NS	4.0	3.8	7.6	11.2	6.2

Note: Figures in a column having same letter(s) do not differ significantly at 5% level by DMRT.

Table 3. Yield and yield contributing characters of ginger as influenced by different rates of K application (average of 10 plants).

Treatment	Rhizome weight/plant		Fresh rhizome yield		Yield increase over control	
	2010-2011	2011-2012	2010-2011	2011-2012	2010-2011	2011-2012
	--------------*g*--------------		-----------*mt ha^{-1}*-----------		-------------*%*-------------	
T_1 (K_0)	245.0 d	183.3 c	12.8 c	9.6 d	-	-
T_2 (K_{40})	290.0 c	203.0 bc	15.2 b	11.3 cd	19	18
T_3 (K_{80})	350.0 ab	217.0 bc	16.1 ab	12.4 bc	26	29
T_4 (K_{120})	380.0 a	273.3 a	17.6 a	16.0 a	38	67
T_5 (K_{160})	330.0 b	232.0 b	14.5 bc	13.7 b	13	43
CV (%)	5.3	8.1	7.4	9.1	-	-

Note: Figures in a column having same letter(s) do not differ significantly at 5% level by DMRT.

Results and discussion

The positive response of ginger to increased K fertilization expressed itself by way of enhanced tillering coupled with increased yields of up to 120 kg K ha^{-1} application (T_4 treatment), (Tables 2 and 3). Both leaf and tiller number per plant increased significantly up to this treatment (120 kg K ha^{-1}), the average for the number of tillers being 15.5 and 16.5 for the two growing seasons respectively. Above this level of K application, these yield contributing characters declined. The lowest values were found in the T_1 treatment, the control (K_0). At the highest level of K application (160 kg K ha^{-1}) tiller numbers decreased to 14.3 and 13.9 for the two growing seasons respectively. Leaf numbers followed the same trend. Similarly, rhizome weight per plant progressively and significantly increased up to the T_4 treatment (380 and 273 g), which was significantly higher than all other treatments (Table 3). As for the other parameters, rhizome weight per plant showed a decrease at the highest level of K application (330 and 232 g). Application of K increased fresh rhizome yield of ginger progressively and significantly up to 120 kg K ha^{-1} in both the years (Table 3). The highest fresh rhizome yield (17.6 and 16.0 mt ha^{-1}) was obtained following the application of 120 kg K ha^{-1}, which was significantly higher than any of the other treatments. The highest dose of K (160 kg ha^{-1}) produced the second highest fresh rhizome yield (14.5 and 13.7 mt ha^{-1}).

In the 2011-2012 season, K fertilizer application of 120 kg K ha^{-1} increased rhizome yields by 67% over the control (K_0). These findings are in a similar range to those reported by Lujui *et al.* (2004) of 26 to 47% (34% average) in Yangji, China. K is often described as a quality element for crop production as it indirectly improves utilization of N and protein formation as well as being beneficial to size, weight, oil content, and color. This is also in accordance with experiments conducted by the Indian Institute of Spices Research (IISR) which showed that application of K to ginger and turmeric increased yield and size of fingers. K also increases the oleoresin concentration in ginger (Sadanandan *et al.*, 2002).

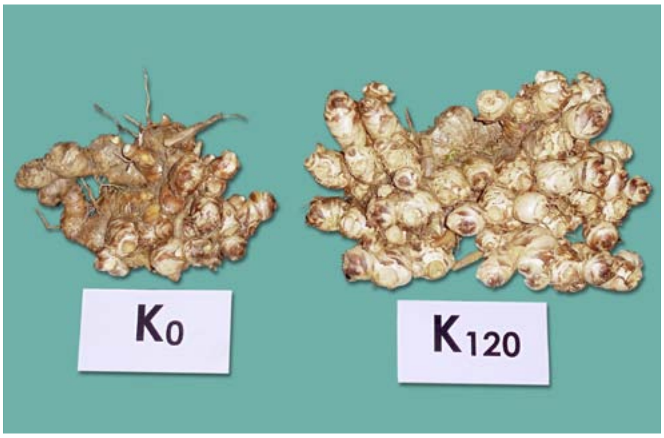

Photo 3. Effect of K on ginger rhizome. IPI-BFA-BARI, SRC, Bogra, 2010-2011.

Response function

Regression analysis showed a positive and quadratic relationship between rhizome yield of ginger and applied K (Fig. 1). From the

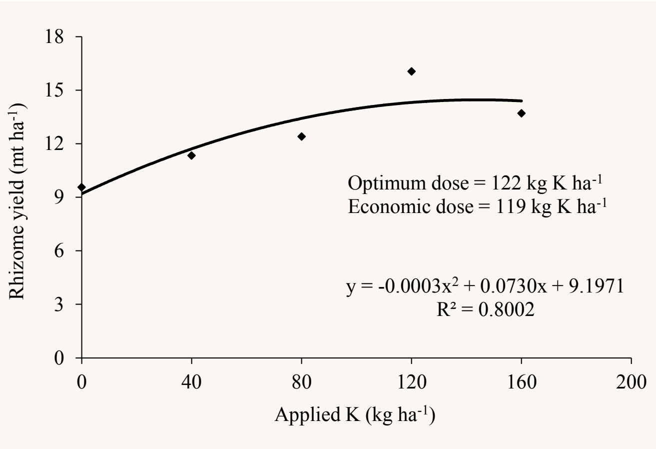

Fig. 1. Response of ginger to K fertilization, 2011-2012.

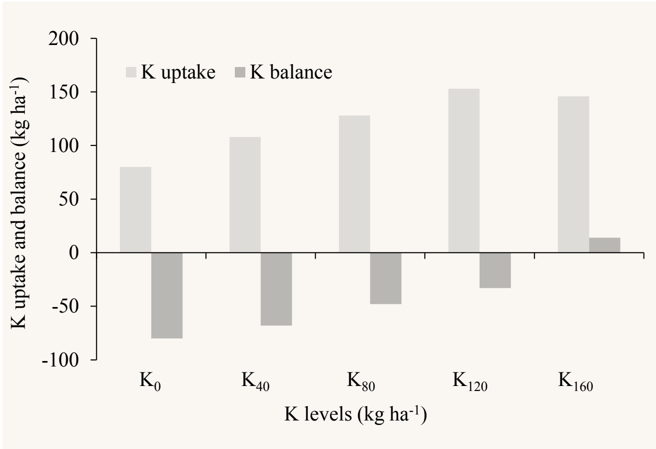

Fig. 2. Apparent K balance for ginger.

regression equation, the optimum dose of K appeared as 122 kg K ha^{-1} for maximizing rhizome yield while that for economic dose was 119 kg K ha^{-1} (Table 4 and Fig. 1).

K uptake and balance

The uptake of K by ginger ranged between 80 to 153 kg K ha^{-1} for the varied rates of K application (Fig. 2). This finding is in agreement with the observation of Sadanandan *et al.* (2002) who reported a rate of 111 kg K ha^{-1} year^{-1} for ginger. In our findings the highest rate of K uptake occurred at a rate of application of 120 kg K ha^{-1}. It has been observed that spice crops remove more K than any other nutrient element. Among the spices, turmeric removes the most K, followed by ginger. The K requirements of spices vary for different spice varieties and locations in which they are grown (Sadanandan *et al.*, 2002). Studies have shown that K requirement of spices depends on the K status and dynamics of K in the soil, as well as the rooting pattern of different spices and varieties, and their productivity. There is thus an essential need for K to be supplied and maintained at optimum rates to augment production and improve quality (Sadanandan *et al.*, 2002; Sadanandan, 2000).

An apparent K balance was estimated on the basis that K was added through fertilizer and removed through K uptake by the ginger plant (Fig. 2). The K balance was found to be negative in all the treatments except T_5 (160 kg K ha^{-1}) in the location under study, even with balanced fertilization with other nutrients.

Economic performance

The economic performance of different levels of K is presented in Table 5. The highest gross return (Tk. 336,444 = USD 4,313 ha^{-1} yr^{-1}) was obtained from 120 kg K ha^{-1} (T_4) but its variable cost (Tk. 13,857 ha^{-1} yr^{-1}) was less. The highest Marginal Benefit Cost Ratio (MBCR) (8.1) was obtained from the T_4 treatment where 120 kg K ha^{-1} was used along with the blanket dose of $N_{133}P_{23}S_{12}Zn_2$. Hence, 120 kg K ha^{-1} was found to be the most profitable economically.

Table 4. Response function of ginger to K.

Regression equation	Co-efficient of determination (R^2)	Optimum dose of K	Economic dose of K	Maximum rhizome yield for optimum dose	Production of ginger rhizome for 1 kg fertilizer K (use efficiency)
		----------------------------------*kg ha^{-1}*----------------------------------			
$y=-0.0003x^2+0.073x+9.1971$	0.8002	122	119	13,711	112

Table 5. Economic performance of different levels of K on ginger (average of two years).

Treatment	Applied K	Yield	Gross return	Variable cost	MBCR[(1)]
	--------------*kg ha^{-1}*--------------		------------*Tk. ha^{-1} yr^{-1}*------------		
T_1	0	11,178	223,556	10,257	-
T_2	40	13,267	265,333	11,457	3.6
T_3	80	14,250	285,000	12,657	4.9
T_4	120	16,822	336,444	13,857	8.1
T_5	160	14,100	282,000	14,090	4.1

Note: [(1)]MBCR = Marginal Benefit Cost Ratio.

Input Price:
1 kg N = Tk. 43.48
1 kg P = Tk. 110
1 kg K = Tk. 30
1 kg S = Tk. 83.33
1 kg Zn = Tk. 472.22
Variable cost includes fertilizer cost only

Output Price:
1 kg ginger = Tk. 20

The lowest gross return (Tk. 223,556 ha^{-1} yr^{-1}) was obtained from the T_1 treatment where no K was applied.

Conclusions

Ginger was found to be highly responsive to K which increased yields in the light textured K deficient Terrace Soil of the Level Barind Tract (AEZ 25) at Shibganj, Bogra. Rhizome yield of ginger increased up to 120 kg K ha^{-1} application in the study area. From the obtained quadratic relationship between rate of K application and rhizome yield, an optimum dose for maximizing ginger production was calculated as 122 kg K ha^{-1}. Uptake of K by ginger varied from 80 to 153 kg K ha^{-1} depending on the level of K application. A negative K balance was observed even with balanced fertilization, implying the importance of K management in achieving sustainable yields and maintaining soil health. Economic analysis also showed the highest MBCR at 120 kg K ha^{-1}. Considering the economic returns and optimum dose, K at 122 kg ha^{-1}, along with a blanket dose of $N_{133}P_{23}S_{12}Zn_2$ kg ha^{-1}, appears to be the best-suited dose for maximizing the yield of ginger in the K deficient Terrace Soil of Level Barind Tract (AEZ 25).

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The paper "Effect of Potassium Fertilization on the Yield and Quality of Ginger *(Zingiber officinale)* grown on a K Deficient Terrace Soil of Level Barind Tract (AEZ 25) in Northern Bangladesh" also appears on the IPI website at:

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