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Effect of potassium fertilization on the growth, yield and root quality of carrot

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ABSTRACT

Optimum dose of potassium is essential for successful carrot production in different soil structures of Bangladesh. In this experiment, carrot was cultivated in silt clay loam soils at Regional Agricultural Research Station under Jamalpur district of Bangladesh during winter season of 2013-2014 and 2014-2015. The objective was to find out an appropriate rate of potassium for higher yield and quality of carrot. There were seven fertilizer combinations comprising T_1: Recommended dose (100-30-12-2.5 kg N-P-S-Zn ha^{-1} with 1.5 ton cowdung ha^{-1}) + 0 kg K ha^{-1}, T_2: RD + 30 kg K ha^{-1}, T_3: RD + 50 kg K ha^{-1}, T_4: RD + 70 kg K ha^{-1}, T_5: RD + 90 kg K ha^{-1}, T_6: RD + 110 kg K ha^{-1} and T_7: Farmer's practice (60-90-70 kg N-P-K ha^{-1} with 1.0 ton CD ha^{-1}). The favorable effects of K on the growth, total yield and root parameters were obtained when carrot plants fertilized with 70 kg K ha^{-1} plus recommended dose of other fertilizers. Carrot yield and quality was increased gradually with K fertilization and highest yield was recorded from 70 kg K ha^{-1}, however statistically similar yield was obtained from 50, 90 and 110 kg K ha^{-1} in addition to recommended dose of other fertilizers. The estimated optimum and economic rate of K from the simple polynomial regression equation were 92 kg K ha^{-1} and 91 kg K ha^{-1}, respectively.

Introduction

Carrot (*Daucus carota* L.) is a dicotyledonous, herbaceous, biennial vegetable of Apiaceae (Umbeliferae) family originated from middle Asia (Pierce, 1987; Salunke & Desai, 1984) grown in cool season. Carrot is an important vegetable in our diet and is used as raw or cooked in a various ways such as baked, boiled, steamed, fried, diced, roasted, sauteed and pickled (Nonnecke, 1989). It contains a health constituent beta-carotene that effect against human cancer (Peto et al., 1981) furthermore, carrots are rich in Vit. A, C, K and B_8, pantothenic acid, folate, potassium, iron, copper and manganese. The popularity of carrot is increasing day by day especially in urban areas of Bangladesh because of its nutritive value and diversified use in making palatable foods. But large scale production of carrot is yet to be started to meet up its demand when the production is much higher in developed countries as Israel, United Kingdom, Sweden, USA and Canada.

Increasing production of carrot in Bangladesh is influenced by several factors including judicial application of fertilizer particularly the mobile nutrients N and K are important. There have been several studies on N fertilization of carrot grown in Bangladesh (Moniruzzaman et al., 2013; Ali et al., 2003) and elsewhere in the world (Hartz et al., 2005; Sanderson & Ivany, 1997). However, there are a few reports on K fertilization of carrot while K is one of the major plant nutrient element plays a vital role in metabolism for crop production and quality determination. Moreover, large amount of potassium increased both yield and quality of agricultural product, and enhances the ability of plants to resist diseases, insect's attacks, cold and drought stresses and other adverse conditions. For carrot production large amount of potassium are involved (Kadar, 2008) even in sandy soil, higher yield is achieved by application of higher level of potassium (Hochmuth et al., 2006; El-Tohamy et al., 2011). Potassium acted on many physiological processes is thus impact on photosynthesis and translocation carbohydrates from leaves to roots that can have direct consequence on carrot production and quality of roots (Ivanov, 2001; Bartaseviciene & Pekarskas, 2007; Anjaiah & Padmaja, 2006; Sharangi & Paria, 1995; Balooch et al., 1993; Lyngdoh, 2001; Sharangi & Paria, 1997).

Researchers typically have focused on vegetable yield responses to fertilization, seldom emphasized on quality of products when aesthetic value and appearance are important in fresh market vegetables and carrots as well (Howarth et al., 1990). Diameter, length, shape, and external appearance are the quality grading attributes of carrots (Anon, 1980; Benjamin & Sutherland, 1989). Color, crispness, firmness and succulence are some of the features that consumers use as a measures freshness and indicators of shelf life (Ben–Yehoshua, 1987). Unfortunately, moisture loss affects these physical features (Phan et al., 1973) hence it is a critical factor in storage life of carrots. Shelf life of carrots can be defined as the time period carrot can stay on the shelf life while maintain acceptability to the consumer (Dennis, 1981). Potassium fertilization was associated with increase in carotene concentration in the carrot root (Ali et al., 2003; Evers, 1989). However, excessive or under dose of K can effects the growth and yield of the crop. Only an optimum dose of K is necessary to produce maximum yield and a good quality of carrot. Therefore, the present study was undertaken to find the response of potassium fertilizer for sustainable yield, quality and shelf life of carrot.

Materials and methods

Experimental site, soil and weather condition

The experiment was conducted at the field of Regional Agricultural Research Station (RARS) under Jamalpur district in Bangladesh during the period from 2013-2014 and 2014-2015. Before initiation the experiment, the soil samples were collected from a depth of 0-20 cm for each replication and analyzed. The chemical properties of soils in the experimental site was silt clay loam in texture belonging to Sonalata series under Agro-Ecological Zone-8/9 (AEZ-8/9), 24˚56´11´´N latitude and 89˚55´54´´E longitude and an altitude of 16.46m. The temperature during 1st and 2nd study period was 19.62 °C and 15.83 °C, respectively and rainfall was 37.25 mm and 22.50 mm, respectively. The soil was neutral (pH 7.1) and low in organic matter (1.58%), whereas very low in N content (0.09%). The soil P, S, B, and Zn content were above the critical level (Critical levels of P, S, B, and Zn were 42.0, 18.0, 0.42 and 1.7 μg g^{-1}, respectively) and the K content was 0.14 meq $100g^{-1}$ soil.

Planting materials

The seeds of carrot cv. New Kuroda (a Japanese variety) collected from a local market of Jamalpur were used in the experiment. It is a popular heat tolerant variety, which is deep orange in color, smooth and uniform in shape having 18 cm length and 6 cm diameter.

Cultivation procedure

Seven fertilizer applications were designed to evaluate the response of different levels of potassium on carrot comprising T_1: Recommended dose (100-30-12-2.5 kg of N-P-S-Zn ha^{-1} with 1.5 ton cow dung ha^{-1}) + 0 kg K ha^{-1}, T_2: RD + 30 kg K ha^{-1}, T_3: RD + 50 kg K ha^{-1}, T_4: RD + 70 kg K ha^{-1}, T_5: RD + 90 kg K ha^{-1}, T_6: RD + 110 kg K ha^{-1} and T_7: Farmer's practice (60-90-70 kg of N-P-K ha^{-1} with 1.0 t CD ha^{-1}. The experiment was laid out in randomized complete block design (RCBD) replicated in thrice. The unit plot size was 2 m × 2 m. Urea, triple super phosphate (TSP), muriate of potash (MoP) and gypsum were used as sources of N, P, K and S, respectively. Di-ammonium phosphate (DAP) was used instead of MoP in case of farmers practice. A blanket dose of 100-30-12-2.5 kg of N-P-S-Zn ha^{-1} along with 1.5 t CD ha^{-1} were applied to all the fertilizer applications except farmers' practice. One third of N and entire amount of CD, P, K, and S were applied as per treatment at the time of final land preparation. The remaining two third N was applied in two equal installments at 3rd and 5th weeks of planting.

The seeds were sown on 20 November, 2013 and 15 November, 2014, respectively maintaining the spacing 20 cm × 20 cm. Seedlings were thinned out in two times leaving one plants in each hill at thirty days after sowing (DAS) and thirty five DAS. Weeding was done three times to keep the crop field free from weeds, for better aeration and to achieve good quality of carrot roots. The field was irrigated three times during the whole period of crop growth. Just after sowing watering was done at twenty five DAS, the second and third irrigation were done at 50 and 60 DAS, respectively. The crop was harvested on 15 February, 2014 and 9 February 2015, respectively.

Data recording

Data on yield and different yield attributes were recorded from ten randomly selected plants from each plot and total yield was calculated from whole plot and converted it to per hectare.

Shelf life determination

For the study of shelf life and quality, each lot of carrot was stored up to 60 days at 18 °C temperature and 30 days at room temperature. A temperature of 18 °C is a controlled temperature that was created for using as cold storage. Each root was weighed individually at harvest and at 15-days interval during storage. Weight loss was determined as [(initial root wt.–wt. after every 15 days in storage/initial root wt.) × 100]. The data on different parameters such as color, per cent of total soluble solid (TSS), per cent loss of moisture and the external appearance was recorded in this context.

Statistical analysis

All data were computed and analyzed statistically using statistical software MSTAT-C (Gomez & Gomez, 1984) and means were separated by Duncan's Multiple Range Test (DMRT) at 5% level of significance. Economic analysis was done on the basis of prevailing market price of input and output during the study period. The optimum dose of K for maximum yield and economic yield was calculated from simple polynomial regression equation i.e. $Y = \alpha + \beta_1 X + \beta_2 X^2$ (Zaman et al., 1982). Here X is the independent variable (K rate) and Y is the dependent variable (yield). The optimum dose of K rate for maximum yield was $X = -\beta_1/2\beta_2$ and economic yield was $X_e = -1/2\beta_2 (\beta_1 - P_x/P_y)$ where, P_x is the price of input (K rate) and P_y is the price of the products. Price of K and carrot were considered as Tk. 17 kg^{-1} and Tk. 30 kg^{-1}, respectively.

Results and discussion

Effect of potassium fertilization on vegetative growth parameters of carrot

The application of different levels of potassium had significant effect on growth parameters, i.e., shoot height, number of leaves per plant and shoot fresh weight (Table 1). The highest shoot height (64.88 cm) was found in T_4 (RD + 70 kg K ha^{-1}), which was identical to rest of all treatments except farmer's practice and control. The lowest plant height (56.76 cm) was recorded in control where no potassium was used. Treatment T_4 produced the maximum number of leaves (11.45) and it was followed by T_3 (11.32) and the minimum (10.68) was obtained from T_1 treatment. The highest shoot weight per plant was obtained from T_3 treated plot (88.67 kg) although, it was similar to T_1, T_2, T_4 and T_5 and lowest one was recorded from T_7 treatment (66.33 kg). These results may be due to the role of potassium element in metabolism and many processes needed to promote plant vegetative growth and development. The obtained results are good accordance with those recorded by Ali et al. (2003) and Hossain et al. (2009) who found that increasing potassium fertilization increased shoot height, number of leaves per plant and shoot fresh weight.

Effect of potassium fertilization on root yield and yield components of carrot

The carrot yield and its components like root length, root diameter and root weight were significantly increased by increasing K fertilizer (Table 1). Treatment T_4 demonstrated the highest root length (14.01 cm) which was identical to T_5 and T_6. Like root length, the root circumference varied due to different treatment. The maximum root circumference (4.48 cm) was recorded with RD + 70 kg K ha^{-1}, which was statistically similar with T_2, T_3 and T_6, but different from rest of the treatment. The minimum root circumference was observed in the FP. The T_4 treatment also showed the highest individual fresh weight (0.130 kg), followed by T_5, T_6, T_3 and T_2. The lowest root weight per plant was obtained from T_1 (0.115 kg). The root yield showed significant variation due to application of different fertilizers.

Among the treatment, the marketable yield was increased up to T_4 (70 kg ha^{-1}) treatment and then it declined with subsequent higher doses, 90 kg ha^{-1}. Although, the highest root yield 30.50 t ha^{-1} obtained from T_4 treatment which was statistically at par with T_5 and T_6 treatment. The lowest yield (23.22 t ha^{-1}) was recorded from control treatment so far. It was clearly observed that yield increased with increase in level of K fertilizer. The increases in these traits may be due to superiority in vegetative parameter, which could be attributed stimulatory effect of K on rate of photosynthesis, as well as transport of photosynthetic product from the leaves to storage root. Alt (1987) and Hossain et al. (2009) also reported that the root yield was higher in increased rate of K fertilizer. One factor quadratic response function fitted to yield data and the polynomial regression equation was $Y = 0.000663 K^2 + 0.1223K + 23.248$ which indicated that maximum and economic root yield could be estimated by the optimum levels of 92.23 and 91.81 kg K ha^{-1}, respectively.

Table 1. Yield contributing characters and yield of carrot as influenced by potassium application (Pooled data)

Potassium application	Shoot height (cm)	Leaves plant^{-1} (No)	Shoot wt plant^{-1} (kg)	Root length (cm)	Root circumference (cm)	Individual root wt. (kg)
T_1	56.76b	10.68	73.67ab	12.07b	4.20cd	0.115b
T_2	60.92ab	10.96	83.33ab	12.44b	4.45a	0.121ab
T_3	61.22ab	11.32	88.67a	12.70b	4.38ab	0.123ab
T_4	64.88a	11.45	80.00ab	14.01a	4.48a	0.130a
T_5	61.98ab	11.21	79.33ab	13.28ab	4.29bc	0.128ab
T_6	59.60ab	11.21	68.67b	13.13ab	4.41ab	0.123ab
T_7	56.89b	10.97	66.33b	12.36b	4.14d	0.116b
CV (%)	6.24	3.59	4.87	5.09	1.80	5.26

Values in a column having same letter(s) do not differ significantly at 5% level by LSD
T_1 = Recommended dose (100-30-12-2.5 kg N-P-S-Zn ha^{-1} with 1.5 ton cow dung ha^{-1}) + 0 kg K ha^{-1}, T_2 = RD + 30 kg K ha^{-1}, T_3 = RD + 50 kg K ha^{-1}, T_4= RD + 70 kg K ha^{-1}, T_5 = RD + 90 kg K ha^{-1}, T_6 = RD + 110 kg K ha^{-1} and T_7 = Farmer's practice (60-90-70 kg N-P-K ha^{-1} with 1.0 t CD ha^{-1}).

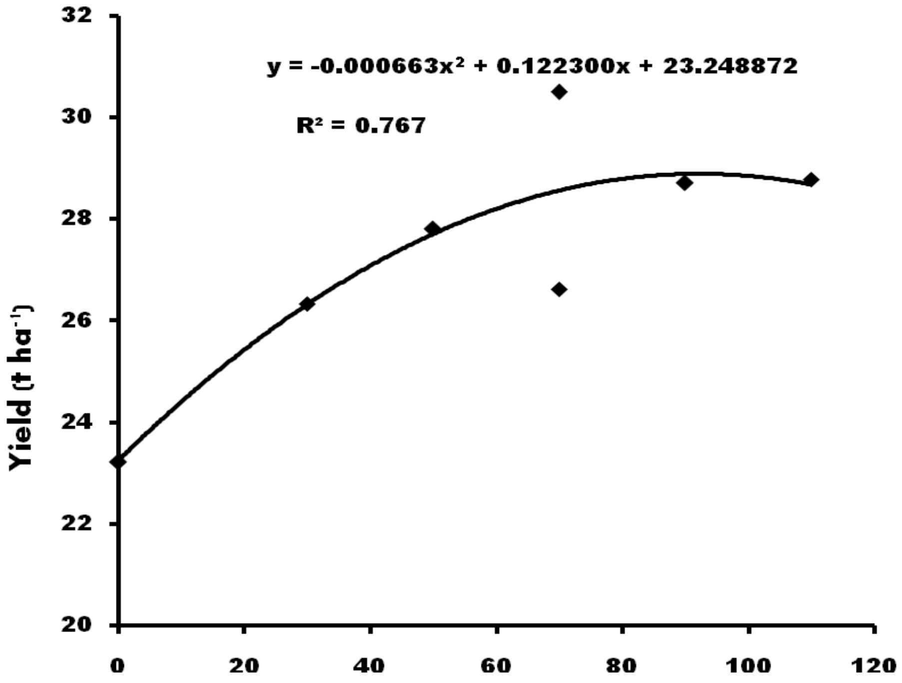

Fig. 1. Response of carrot to K fertilization

Effect of potassium fertilization on weight loss and TSS of carrot

The effects of K fertilizers on weight loss of carrot varied among the treatments (Table 2). Storage at room temperature up to 30 days showed linear weight loss at different rate of K fertilization. After 15 or so far as 30 days of storage at room temperature the loss of weight decreased gradually up to highest rate of K and maximum weight loss was occurred both in farmers' practice as well as in control treatment. At higher rate from 70 kg K ha^{-1} up to 110 kg K ha^{-1}, the minimum weight loss of carrot were occurred, while control and FP showed the maximum weight loss during room temperature. During storage at 18 °C, the similar scenario was also observed in different rates of K application (Table 3). After 60 days of storage at 18 °C, the minimum weight loss was observed in T_4 treatment and the maximum weight was lost at T_1 treatment where no K was applied. Temperature had a noticeable effect on physiological effect on carrots (Table 2 and 3). In visual appearance, the deterioration of freshness and crispness was much more at 18 °C than at room temperature. At the former level it was light orange to orange in color and their condition was fresh and crispy in nature, while at increasing temperature after 15 days carrot roots became orange to deep orange in room temperature whereas orange in 18 °C. Up to the mark of 30 days of storage both at room and 18 °C temperature, the roots became shriveled and rotten although the color was not too much changed at higher rate of potassium.

Shelf life of vegetables is determined by post harvest weight (moisture) loss (Ben-Yehoshua et al., 1987; Laurie et al., 1986). At room temperature, up to 18% weight loss was attained around the 15th day of storage and at that time the carrot roots retained their consume capacity without rotting. Less than 15 days can therefore be the average shelf life of carrots stored at room temperature. This results are in agreement with the result of Biegon (1995) who showed the shelf life of carrot attained around 12th day of storage at 13 °C.

During storage at room temperature the total soluble solids in roots were increased up to 30 days by application of different rate of K fertilizer comparing with control (Table 2). The highest TSS content (12%) was observed in T_4 and T_5 treatments after 30 days of storage at room temperature. Although, the similar sequence of increases was observed in T_4 treatment both in initial and 15 days after storage at room temperature. Such results are in agreement with the result of Ali et al. (2003) who found that TSS increased with increasing levels of potassium. El-Tohamy et al. (2011) also gave similar statement that foliar application of K significantly improved the TSS in carrot roots. Thus, improvement of TSS in roots could be attributed to the mode of action of macro nutrients in enhancing the photosynthetic activity and enzymes of carbohydrates transformation.

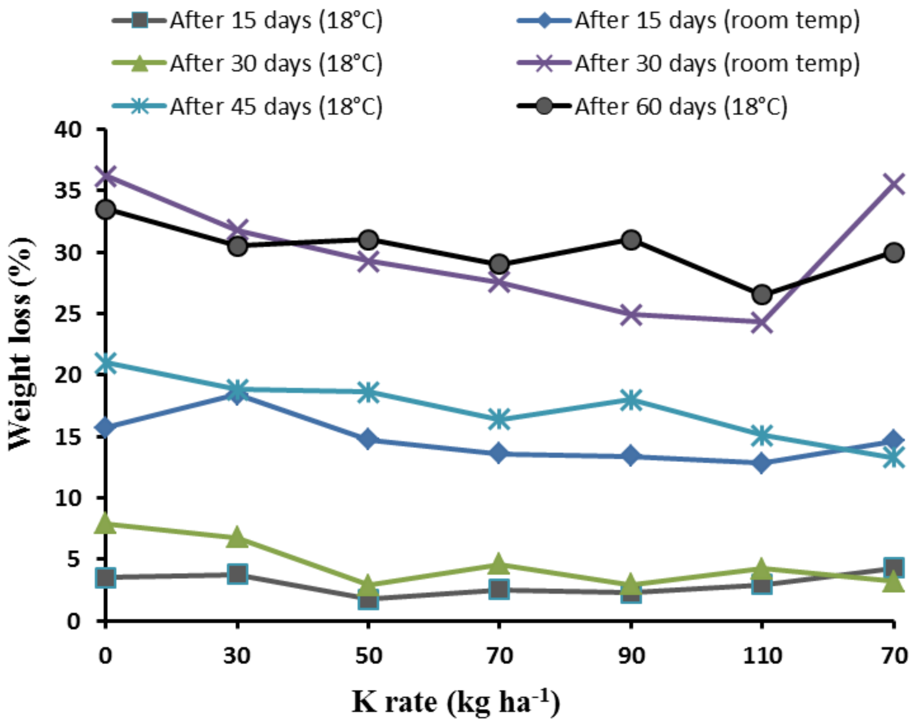

Fig. 2. Per cent weight loss of carrot root at 18°C and room temperature as influenced by K fertilizers

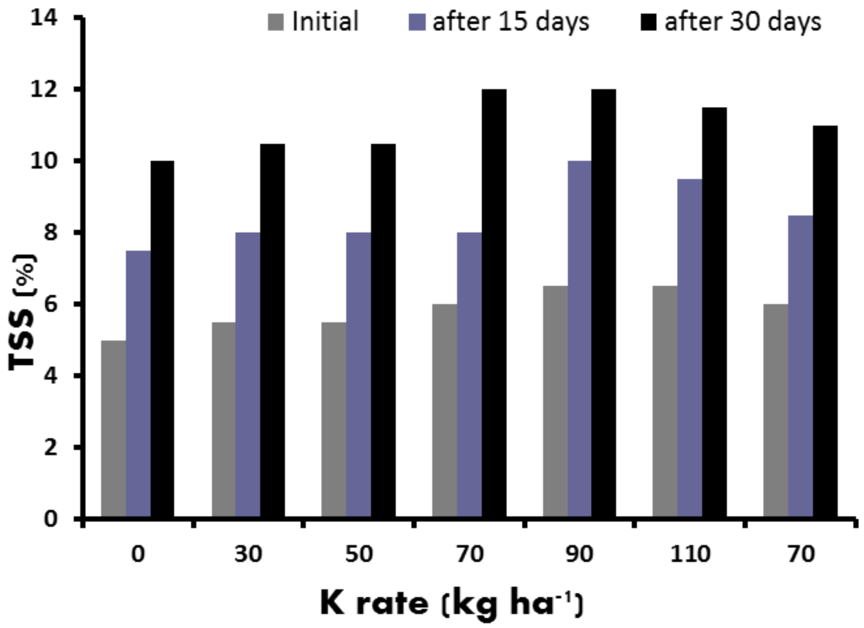

Fig. 3. Per cent total soluble solids as influenced by K fertilization

Conclusion

Application of potassium fertilizer in combination with recommended dose of other fertilizer had significant effect on yield parameters and yield of carrot. The yield of carrot increased with the increase of K fertilizer and the highest yield was recorded at 70 kg K ha^{-1} along with recommended doses of other fertilizer. However, identical yield was obtained from higher doses as 50, 90 and 110 kg K ha^{-1} fertilizer compared to control. The higher rate of potassium fertilizer also enhanced root quality and shelf life of carrot. Although, the estimated optimum and economic rate of K from the simple polynomial regression equation were 92 kg K ha^{-1} and 91 kg K ha^{-1}, respectively.

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