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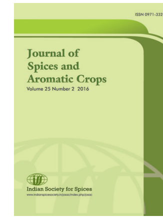

Response of transplanted fennel (*Foeniculum vulgare* Mill.) to potassium fertilization

R L Bhardwaj

Krishi Vigyan Kendra, Agricultural University, Sirohi-307 001, Rajasthan.
**E-mail: rajubhardwaj3@gmail.com*

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Abstract

This study presents the results of farmer's field experiment on the effects of potassium (K) fertilization on transplanted fennel (*Foeniculum vulgare* Mill.) production. Four treatments (K_1 = 20 kg K ha^{-1}, K_2 = 40 kg K ha^{-1}, K_3 = 60 kg K ha^{-1}, K_4 = 80 kg K ha^{-1}) were compared using four replications under Completely Randomized Design. Application of potassium @ 60 kg ha^{-1} recorded highest value of plant height primary branches plant^{-1}, secondary branches plant^{-1}, number of leaves, number of roots plant^{-1}, tap root length, fresh weight of shoot, fresh weight of root and minimum root: shoot ratio. The maximum value of number of umbels plant^{-1}, umbellate umbel^{-1}, number of seeds umbel^{-1}, test weight, seed yield, straw yield and harvest index was also observed in same treatment. All the quality parameters like, volatile and total oil content, soluble sugar, total carbohydrate, crude protein, potash content of seed and soil and overall quality of seeds were higher with application of 80 kg K ha^{-1}, whereas disease incidence was significantly reduced with application of higher dose of K. The maximum gross return, net return and highest benefit: cost ratio was also recorded with application of 60 kg K ha^{-1}.

Keywords: potassium, transplanted fennel, bio-chemical properties, umbels

Introduction

Fennel (*Foeniculum vulgare* Mill.) is an herbaceous plant belonging to Apiaceae family which is in beneficial for stomach, flatulence, spasm, cough and inflammation. It is widely cultivated seed spices throughout the temperate and sub tropical regions of the world. Its seeds are widely used in the preparation of various dishes like soups, sauces, pastries, confectioneries, pickles and meat dishes etc. Major production centers of fennel in India are Rajasthan, Gujarat, Andhra Pradesh, Punjab, Madhya Pradesh, Uttar Pradesh, Karnataka and Haryana. It is mainly grown in the *Rabi* season but in some parts of Southwest Rajasthan like Sirohi, Jalore, Jodhpur and Pali is grown in *Kharif-Rabi* season by seedling transplanting method from month of July to March. The total area under fennel cultivation in Rajasthan is 58474 ha and 85189 t production with 14.5 q ha^{-1} productivity. The maximum area of transplanted fennel is in district Sirohi *i.e.* 4091 ha and 4236 t production with 10.35 q ha^{-1} productivity (Anonymous 2014). Because the fennel growers go behind the package of practices of *Rabi* season (Direct seed sowing) crop which is short duration (4 to 5 months) with low yield whereas the transplanted fennel is long duration (7-8 months), high yielding crop (maximum potential around 20-28 q ha^{-1}). The transplanted fennel production potential is 2 to 3 times more than direct seeded one (Bhardwaj 2014) and the production technology and management practices are also different. The nutritional utilization of transplanted fennel differs from *Rabi* fennel crop because of tremendous yield potential due to precocious bearing and indeterminate flowering habit with simultaneous vegetative growth, flowering and fruiting.

Potassium is necessary in young growing tissues for cell elongation and possibly for cell division. It also, helps in several physiological processes and uptake of other nutrients. Potassium is known to play a vital role in photosynthesis and carbohydrate formation in fennel (Sadanandan *et al*. 2002). It has also been shown that K plays a key role in the activation of more than 60 enzymes in plants. It has also, a role in stomata opening and closing for respiration and photosynthetic transfer. Even though potassium is abundant in many soils, the bulk of soil K may be unavailable to plants, because the pool of plant available K is much smaller compared to the other forms of K. 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 fennel yield and increase disease (gamosis) incidence (Bhardwaj 2014). Indeed, high rates of N application have become a habitual practice among farmers so that K has become the yield limiting nutrient in fennel growing area of Rajasthan (Bhardwaj & Meena 2015). 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).

Therefore, the proposed investigation was planned to find out the effect of K on growth, yield and qualitative attributes of transplanted fennel under agro-climatic conditions of Southwest Rajasthan.

Materials and methods

The field experiment was conducted on two adjoining sites at Kacholi village in district Sirohi (Rajasthan) during two consecutive seasons (*Kharif-Rabi*) from June 2013 to March 2014 and June 2014 to March 2015. The soil of experimental field was uniform in fertility, sandy loam in texture, low in organic carbon (0.65% and 0.62%), medium in available P (28.5 kg and 26.5 kg ha^{-1}) and medium in K (190.0 kg and 185.0 kg ha^{-1}) with EC of 2.0 dS m^{-1} and slightly alkaline reaction (pH 8.1) during both years of experimentation. The climatic parameter *viz.*, average minimum and maximum temperatures were 25.0°C+ 5.0ºC and 36.0°C+ 5.0ºC, average relative humidity of 52.0 + 10.0% and 515.0 mm rainfall per annum were recorded during the experimentation.

The investigation comprised of four treatments *i.e.* K_1 (20 kg K ha^{-1}), K_2 (40 kg K ha^{-1}), K_3 (60 kg K ha^{-1}), K_4 (80 kg K ha^{-1}) and it was laid out in Completely Randomized Design with four replications. The net plot size was 2.5 m × 3.3 m. Full dose of organic matter (200 q ha^{-1}) was applied at the time field preparation and half dose of P (30 kg ha^{-1}) and K *i.e.* K_1 (10 kg ha^{-1}), K_2 (20 kg ha^{-1}), K_3 (30 kg ha^{-1}), K_4 (40 kg ha^{-1}) with one fourth dose of N (30.0 kg ha^{-1}) was applied at the time of seedling transplanting as basal dose. Second half dose of P and K with one fourth dose of N was applied at 30 days after transplanting by side dressing method and pursues a light irrigation. Remaining dose of N was applied at 60 and 90 days after transplanting by top dressing method after light irrigation. The intercultural operations (weeding, irrigation, mulching, etc.) and plant protection measures were followed uniformly for the all plots during the entire period of experimentation of both years. In a well prepared field, 45 days old seedlings of fennel local cultivar '*Abu saunf*' were transplanted by pair row planting at 210 cm/120 cm × 25 cm (24271 plants ha^{-1}) during last week of June. Light irrigation was applied immediately after transplanting.

Randomly selected five plants were used for observations on plant growth, yield attributes and yield from each plot. Plant height (at 90 DAT and at harvesting) was measured from soil surface to the highest shoot tip. Stem girth was measured from one cm above the base of the stem using vernier calliper. Observations on number of branches, number of nodes on main shoots at harvest, number of leaves, first flower initiation, last flower initiation, duration of flowering (days), number of umbel plant^{-1}, number of umbellate umbel^{-1}, number of seeds umbel^{-1} were recorded by standard counting method. Number of roots and root length was measured by destructive sampling method (uproot the randomly selected other 5 plants from each treatment). Stem and root were weighed to record the fresh weight. Length and width of seed was calculated by using vernier caliper and expressed in millimeter. Test weight was measured by weighing 1000 seeds and expressed in gram. The total seed yield, straw yield and biological yield was calculated by weighing total seed, straw produced and is presented on hectare basis. The Harvest Index was calculated using the following formula:

Harvest Index (%) = Economic yield / Biological yield × 100

In order to determine the volatile oil per cent and total oil content (%), a sample of 100 g of fennel seeds from the each plot were crushed in electric grinder and were mixed with 500 ml distilled water and then subjected to hydro-distillation for 3 h using a Clevenger-type apparatus (Kapoor *et al*. 2004; Darzi *et al*. 2012). For fixed oil extraction from fennel seeds the 50 g of seed were crushed to coarse powered and extracted with petroleum ether (40^{o}C – 60^{o}C) in a Soxhlet extraction method (AOAC 1970). Soluble sugars concentrations in seeds (collected at the end of the first and second years of each treatment) were determined according to Ciha & Brun (1978) with some modifications. For measurement of total carbohydrates a phenol-sulfuric acid assay was used (Dubois *et al.* 1956). A volume of 0.5 mL of 5% (v/v) phenol solution and 2.5 mL of concentrated sulfuric acid were added to 0.5 mL aliquots. The mixture was shaken, heated in a boiling water-bath for 20 min and cooled to room temperature. The absorption was then determined by spectrophotometry at 490 nm in blue colour. Protein content in seed of each treatment was determined by using the micro kjeldhal methods described by Black (1965). Whole plant samples of above ground level were collected, dried to constant weight (70°C), powdered to pass through a 0.2 mm sieve, digested and analyzed for K by flame photometer (Jackson 1958), K content in soil is also determine by same method. Furthermore, the net return was calculated by subtracting cost of each treatment from gross return. The gross return was calculated from yield multiplied by average market rate during the period of investigation. The benefit cost ratio was calculated by dividing net return to total cost. Disease incidences in plants were recorded after appearance of disease symptoms, which were counted at 150 DAT and data presented in per cent basis. The overall quality (taste, brightness, seed colour, size and shape) and consumer preference of seed was done by a panel of five semi-trained judges by scoring based visual inspection (Bhardwaj *et al*. 2014). After carrying out Bartlett's test for homogeneity of variance, the two years data were pooled. The significance of variance in the pooled data of two years was done by the standard procedure described by (Steel *et al*. 1997). Data were subjected to analysis of variance and estimation of the significance of difference between treatments means was done at $P<0.05$.

Results and discussion

Vegetative growth parameters

There was a significant variation in plant height among the different potassium levels (Table 1). At the 90 DAT and at time of last harvest the highest plant height was recorded with the application of 60 kg K ha^{-1}, which was closely followed by the 80 kg K ha^{-1} that was statistically at par. The lowest plant height at 90 DAT and at last harvest was recorded from the plots which received 20 kg K ha^{-1}. Similar results were also observed by Ali *et al*. (2007) on onion, Singh (2014) on patchouli and Abou-Dahab *et al*. (2014) in safflower.

Table 1. Effect of varying levels of potash on the vegetative growth of fennel

Treatments	Plant height at 90 DAT (cm)	Plant height at harvest (cm)	Number of primary branches $plant^{-1}$	Number of secondary branches $plant^{-1}$	Number of nodes on main shoot at harvest
K_1 (20 kg K ha^{-1})	52.19	109.65	5.44	12.89	10.62
K_2 (40 kg K ha^{-1})	60.66	121.40	8.21	16.83	13.23
K_3 (60 kg K ha^{-1})	68.41	132.45	10.18	21.63	15.33
K_4 (80 kg K ha^{-1})	66.28	129.30	9.71	19.88	17.19
S Em. ±	0.907	2.390	0.134	0.590	0.272
$P < 0.05$	3.561	9.381	0.528	2.317	1.068
Treatments	Number of leaves $plant^{-1}$	Stem girth (cm)	Number of roots $plant^{-1}$	Root length (cm)	Fresh weight of shoot (g)
K_1 (20 kg K ha^{-1})	16.52	10.19	16.5	16.13	655.17
K_2 (40 kg K ha^{-1})	22.71	11.29	20.19	20.09	710.28
K_3 (60 kg K ha^{-1})	30.40	12.19	23.79	23.79	774.85
K_4 (80 kg K ha^{-1})	28.25	12.81	25.64	25.14	750.22
S Em. ±	0.769	0.194	0.272	0.530	7.361
$P < 0.05$	3.020	NS	1.068	2.082	28.896
Treatments	Fresh weight of root(g)	Root/shoot ratio	Flower initiation (DAT)	Flower continued (DAT)	Duration of flowering (days)
K_1 (20 kg K ha^{-1})	130.49	0.197	86.43	209.83	123.15
K_2 (40 kg K ha^{-1})	141.93	0.202	82.45	202.81	119.96
K_3 (60 kg K ha^{-1})	154.03	0.183	80.35	198.05	117.30
K_4 (80 kg K ha^{-1})	150.20	0.202	79.7	194.11	114.01
S Em. ±	1.559	0.003	1.368	2.012	2.012
$P < 0.05$	NS	0.011	5.371	NS	NS

There was a significant effect of K dose on number of primary and secondary branches $plant^{-1}$ (Table 1). The maximum number of branches and secondary branches was obtained from 60 kg K ha^{-1}, which was followed by 80 kg K ha^{-1} and 40 kg K ha^{-1} respectively. The lesser number of primary branches and secondary branches $plant^{-1}$ was observed from application of 20 kg K ha^{-1}. Similar result was also observed by El-Magd *et al*. (2010) and Bhardwaj (2014) in fennel. From the Table 1 it was also found that K at a level of 80 kg K ha^{-1} produced maximum number of nodes on main shoot at the time of last harvest, while the lowest nodes was found from 20 kg K ha^{-1}.

The number of leaves per plant was significantly influenced by the K dose (Table 1). At the time of last harvest the total number of leaves was highest, when K was applied 60 kg K ha^{-1} followed by 80 kg K ha^{-1}, while the lowest number of leaves $plant^{-1}$ was obtained from 20 kg K ha^{-1}. These results were in agreement with those obtained by El-Magd *et al*. (2010) in fennel, El- Bassiony (2006) in onion and Akhter *et al*. (2013) in ginger.

The K treatment had an insignificant effect on stem girth of fennel during the time of experiment, after that the highest stem girth was reported when K was applied at 80 kg K ha^{-1} followed by 60 kg K ha^{-1}. The number of roots $plant^{-1}$ and root length was significantly influenced by the K dose. The maximum number of roots and highest length of root was reported, when K applied 80 kg K ha^{-1} followed by 60 kg K ha^{-1}, while the minimum number of roots and root length $plant^{-1}$ was obtained from 20 kg K ha^{-1}. This is also in accordance with experiments conducted by Ali *et al*. (2007) in onion, Akhter *et al*. (2013) in ginger and Bhardwaj (2014) in fennel.

The positive response of fennel to increased K fertilization expressed itself by way of enhanced fresh weight of shoot and root coupled with minimum root/shoot ratio of up to 60 kg K ha^{-1} application (Table 1). Fresh weight of shoot increase significantly but fresh weight of root increased non-significantly up to 80 kg K ha^{-1}. From the table 1 it was found that K at level of 60 kg K ha^{-1} produce maximum fresh weight of shoot and root with minimum root/shoot ratio, while the lowest fresh weight of shoot and root was found from 20 kg K ha^{-1}. Bidari & Hebsur (2011) also reported similar results in different vegetables and Bhardwaj *et al*. (2014) in fennel.

The enhancement in vegetative parameters as a result of application of K might be because K is often described as a quality element for crop production as it indirectly improves utilization of N and protein configuration as well as being beneficial to growth and development of the plant. On the other hand, K helps in the root development and increased the efficiency of leaf in the manufacture of sugar and starch and also plays a significant role for translocation of sugars. Higher dose of K reduced growth parameter because excess K reduces nitrates in soil and plants. K exerts a balancing role on the effects of both N and P consequently it is especially important in a nutrient fertilizer application (Brady 1995). Singh *et al*. (1998) reported that, plant height of okra was significantly increased with increasing levels of K upto 75 kg K_2O ha^{-1}. These facts are in close agreement with the observation of Ali *et al*. (2007) in onion, Bidari & Hebsur (2011) in different vegetables, Akhter *et al*. (2013) in ginger, Bhardwaj *et al*. (2014) in fennel and Singh (2014) in patchouli.

During blossoming or anthesis, particularly in seed spices, short acceleration of mineral uptake and synthesis of organic compounds takes place resulting in gradual increase in K uptake. In the study, the effect of K dose had a significant effect in relation to flower initiation and non-significant in relation to flower continued and duration of flowering. The longer time (86.43 days) was obtained from 20 kg K ha^{-1} and the shortest time (79.70 days) was observed from 80 kg K ha^{-1}, which was similar to 40 kg K ha^{-1} and 60 kg K ha^{-1} respectively. The duration of the crop was found to be short with increase levels of K because plants tend to bloom earlier with higher C: N ratio and potassium play significant role in balancing of C: N ratio in plants. Ali *et al*. (2007) also reported similar results in onion, Akhter *et al*. (2013) in ginger and Bhardwaj (2014) in fennel.

Yield and yield attributes

Data present in Table 2 reveal that yield attributes *viz*., number of umbels $plant^{-1}$, number of umbellates $umbel^{-1}$, number of seeds $umbellate^{-1}$ and test weight of fennel seed was enhanced by increasing K fertilizer levels up to 60 kg K ha^{-1}, which were not differ remarkably with 80 kg K ha^{-1}.

The highest number of umbels $plant^{-1}$, number of umbellates $umbel^{-1}$ and number of seeds $umbel^{-1}$ was obtained from 60 kg K ha^{-1}, which was *at par* with 80 kg K ha^{-1}. Whereas the lowest number of umbels $plant^{-1}$, number of umbellates $umbel^{-1}$ and number of seeds $umbellate^{-1}$ was noted from 20 kg K ha^{-1}. These results were in agreement with those obtained by Alt *et al*. (1999), El-Magd *et al*. (2010) and Bhardwaj *et al*. (2014) on fennel, El-Bassiony (2006) and Ali *et al*. (2007) on onion. The effect of K on length of seed, width of seed and test weight were obtained from 60 kg K ha^{-1}, which was higher than 80 kg K ha^{-1}, whereas the lowest length of seed, width of seed and test weight was found from 20 kg K ha^{-1} (Table 2). Fertilization with K not only resulted in a higher uptake of K but also increased the availability of other nutrients in the soil, leading to optimum vegetative growth, enhanced uptake of nutrients, with the promotion of photo-assimilation and translocation of assimilates from source to sink, the result of which was reflected by increased seed size and weight. Although K is not a constituent of any organic molecule or plant

Table 2. Effect of varying levels of potash on the yield and yield attributes of fennel

Treatments	Number of umbels plant^{-1}	Number of umbellate umbel^{-1}	Number of seeds umbel^{-1}	Length of seed(mm)	Width of seed(mm)
K_1 (20 kg K ha^{-1})	15.83	14.14	378.86	4.54	1.27
K_2 (40 kg K ha^{-1})	17.53	17.14	399.21	5.29	1.45
K_3 (60 kg K ha^{-1})	19.52	20.13	417.06	6.10	1.70
K_4 (80 kg K ha^{-1})	19.01	19.79	414.28	5.84	1.62
S Em. ±	0.284	0.344	2.834	0.089	0.029
P < 0.05	1.115	1.349	11.126	0.349	0.113
Treatments	Test weight (g)	Seed yield (q ha^{-1})	Straw yield (q ha^{-1})	Biological yield(q ha^{-1})	Harvesting Index (%)
K_1 (20 kg K ha^{-1})	10.98	15.97	72.45	88.44	18.08
K_2 (40 kg K ha^{-1})	11.94	20.27	78.55	98.84	20.53
K_3 (60 kg K ha^{-1})	12.30	24.29	84.55	108.86	22.33
K_4 (80 kg K ha^{-1})	12.29	23.48	82.11	105.61	22.25
S Em. ±	0.071	0.460	0.898	1.422	0.543
P < 0.05	0.279	1.804	3.527	5.583	2.150

structure, it is involved in numerous biochemical and physiological processes and plays a vital role in plant growth, yield and quality. Similar results were also observed by Ali *et al*. (2007) on onion, Bhardwaj (2014) and Bhardwaj & Meena (2015) on fennel.

There were significant ($p<0.05$) differences between the seed yield, straw yield, biological yield and harvesting index of fennel in the both experimental years (Table 2) due to increasing the level of K. The highest value of seed yield, straw yield, biological yield and harvesting index was reported with 60 kg K ha^{-1} which was significantly superior to all other level of K but *at par* with 80 kg K ha^{-1} and remarkably higher than 40 kg K ha^{-1}. The respective percentage increase in seed yield, straw yield, biological yield and harvesting index under application of K @60 kg ha^{-1} was 52.03%, 16.70%, 23.08% and 23.50% over that of with 20 kg K ha^{-1} respectively. Relative consistency in seed yield, straw yield, biological yield and harvesting index with increase in K dose from 20 to 60 kg K ha^{-1} indicated that the application of K greater than 60 kg ha^{-1} may not be beneficial for harvesting economical yield of fennel. An adequate supply of K is associated with high photosynthetic activity leading to reproductive growth (yield attributes) associated with keeping the balance between plant source and sink which can produce more dry matter (fully filled seeds) and physiologically more stout and healthy plants with deep root system, where as the excess dose of K reduced the availability of nitrate, which is responsible for vigour vegetative growth and development. Majumdar *et al*. (2000) reported that, increased levels of K had significant influence on the fruit yield of tomato with highest yield under 90 kg K_2O ha^{-1}. Similarly Singh (2014) reported that application of 41.5 kg K ha^{-1} produced significantly higher herbage yield over control in patchouli. These finding also agreement with Ali *et al*. (2007) in onion, Akhter *et al*. (2013) in ginger and Bhardwaj (2014) in fennel.

Bio-chemical parameters

Total carbohydrate and soluble sugar content: Table 3 shows that total contents of carbohydrates and soluble sugars in fennel seeds increased significantly with increasing K rates. The highest contents of total carbohydrates and soluble sugars were recorded when plants were treated with 80 kg K ha^{-1} which was significantly superior to all other level of K but *at par* with 60

Table 3. Effect of varying levels of potash on the bio-chemical traits of fennel seed

Treatments	Soluble sugars (%)	Total carbo-hydrate (%)	Crude protein content (%)	Potash content (%)	Volatile oil content (%)	Total oil content (%)
K_1 (20 kg K ha^{-1})	3.23	10.68	12.96	2.59	0.521	3.98
K_2 (40 kg K ha^{-1})	3.68	12.15	16.77	2.75	0.581	5.17
K_3 (60 kg K ha^{-1})	3.90	13.45	18.65	2.89	0.611	5.73
K_4 (80 kg K ha^{-1})	3.98	13.65	19.41	2.93	0.621	5.78
S Em. ±	0.117	0.224	0.555	0.117	0.005	0.230
P < 0.05	0.459	0.877	2.180	0.459	0.020	0.903

kg K ha^{-1}. Total carbohydrates were 27.80% and soluble sugars were 23.21% higher than the application of 20 kg K ha^{-1} in fennel. This is because the K enhanced root development and efficiency of leaf in the manufacture of sugar and starch. It is also essential for the translocation of sugar from source to sink. These results were in accordance with those reported by Alt *et al*. (1999), Sadanandan *et al*. (2002) on fennel and El-Bassiony (2006) on onion. Furthermore, K plays a direct or indirect role in plant metabolism on fennel. Similar response to K in fennel was also reported by El-Magd *et al*. (2010) & Bhardwaj *et al*. (2014).

Potash and protein content in seed: Application of 80 kg K ha^{-1} resulted in the highest K and protein content in fennel seeds, which was significantly superior to the other lower levels of K but *at par* with 60 kg K ha^{-1} (Table 3). These results may be due to the influence of K on the ribosome structure and the biosynthesis of some hormones (gibberellines, auxins, cytokinins) involved in protein synthesis (El-Wahab & Mohamed 2007). Increase in protein content ascribed to increase in N uptake at higher levels of K and also as N is a part of amino acid, which constitutes building blocks of protein and that might have resulted in higher protein content. El-Magd *et al.* (2010) studied four rates of K sulphate and showed higher content K in tissues of sweet fennel leaves and bulbs were obtained with plants treated with 75 kg K_2O fed^{-1} (0.4ha). Similar increasing trend in protein content with K application was also reported by El-Magd *et al*. (2010) in fennel crops, Singh (2014) in patcholi and Bhardwaj (2014) in fennel.

Volatile oil and total oil content in seed: Generally, all levels of K progressively increased the volatile oil and total oil content of fennel seed (Table 3). The application 80 kg K ha^{-1} seemed to be optimal for obtaining a higher concentration of volatile oil (0.621%) and total oil content (5.78%) which was significantly superior to other lower doses of K, but *at par* with 60 kg K ha^{-1}. The effect of different K treatments on volatile oil and total oil content may be due to its effect on enzyme activity and metabolism of oil production in fennel. These results were in accordance with those obtained by Bhardwaj *et al*. 2014 in fennel. Singh (2014) reported that K has a positive effect on the quantity of essential oil extracted from patcholi plants. The application of K not only increased seed yield but also improved oil contents in fennel (Bhardwaj 2014).

Economics and quality parameters

Economics: The economic performance of different levels of K is presented in Table 4. Application of 60 kg K ha^{-1} showed maximum gross return, net return and highest benefit cost ratio. The minimum gross return, net return and lowest benefit cost ratio was recorded from those plots where 20 kg K ha^{-1} was applied. Hence, 60 kg K ha^{-1} was found to be the most profitable treatment. Application of K fertilizer resulted in a substantial increase in plant growth, yield and quality of seeds. Significant increase in marketable quantity of quality seed and farmers fetching higher market price of produce and also increases net return, benefit: cost ratio. Similarly Lester *et al*. (2007) showed that foliar application of K markedly improved

Table 4. Effect of varying levels of potash on the economics, disease incidence, quality seed and nitrogen content in soil

Treatments	Gross return (Rs)	Net return (Rs)	B: C ratio	Disease incidence (%)	Quality score of seed*	Potash content in soil (kg ha^{-1})
K_1 (20 kg K ha^{-1})	145139.6	105669.0	2.69	9.97	3.36	172.3
K_2 (40 kg K ha^{-1})	198984.4	158658.8	3.95	7.74	3.63	179.3
K_3 (60 kg K ha^{-1})	251399.8	210435.8	5.14	6.24	3.83	187.3
K_4 (80 kg K ha^{-1})	249351.2	207567.2	4.97	5.81	3.95	198.3
S Em. ±	1073.47	1072.01	0.027	0.191	0.032	1.534
P< 0.05	4213.64	4207.91	0.106	0.750	0.125	6.020

*Marking on the basis of quality of seed (1=very poor quality; 2=poor quality; 3=average quality; 4=good quality; 5=excellent quality)

marketable quality by increasing firmness, sugar content and fruit human health quality by increasing ascorbic acid, beta-carotene, and finally increase market value of the produce and net return. Bhardwaj *et al*. (2014) reported that the net income and B:C ratio increased up to Rs. 2.50 lakh and 3.5, respectively with increased K level up to 60 kg ha^{-1} and then it started to decrease. Similar results were reported by Akhter *et al*. (2013) on ginger.

Disease incidence in crop: The increase in potassium levels caused a significant decrease in disease incidence (gamosis or *sugari* disease) at the time of flowering. Maximum disease incidence (9.97%) of plants was reported by applying 20 kg K ha^{-1} while the minimum (5.81%) was observed in case of 80 kg K ha^{-1}. The decrease in disease incidence with increasing dose of K may be due increased disease resistance. Deficiency of K is one of the factors that predispose the plant to the attack of pests and disease (Sadanandan *et al*. 2002). They found that application of 140 kg K ha^{-1} significantly reduce the incidence of phytophthora foot root of black pepper. With adequate K supply, yields are enhanced disease resistance is increased in roots and tubers (Nwaogu & Ukpabi 2010). Lester *et al.* (2007) also had reported the positive effects of K fertilization on disease control.

Overall quality of seed: The overall quality of seed increased with increased level K (Table 4). The maximum quality score (3.95) was also observed when application of K at 80 kg ha^{-1}. This is because the application of optimum dose of K significantly increases length and width of seed, test weight, sugar, carbohydrate and total oil content in seed, all these factors improved quality score of the seed. K application has influenced the physiological processes such as photosynthesis that ultimately resulted in fully filled quality seed of fennel (Bhardwaj 2014).

Seed germination: There was a marked influence on the percentage of seed germination by K (Fig. 1). The per cent seed germination was found to be the highest (69.34%) in 60 kg K ha^{-1}, which was similar with 80 kg K ha^{-1} and the lowest (61.74%) was observed in 20 kg K ha^{-1}. The percentage of germination of seed gradually increased with increase in the level of K up to 60 kg ha^{-1}, further increase in the level of K had

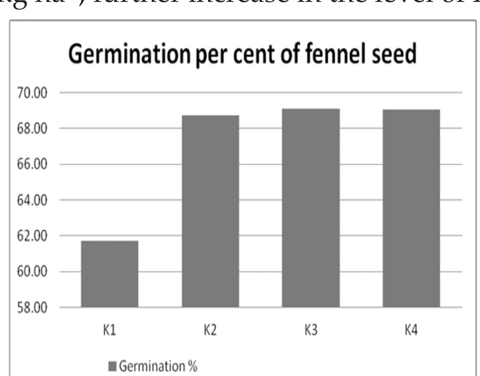

Fig. 1. Effect of varying levels of potash on the germination per cent of fennel seeds

no effect. Similar results were also observed by Ali *et al*. (2007) in onion & Bhardwaj (2014) in fennel.

It may be concluded that the transplanted fennel should be fertilized with a dose of potassium 60 kg ha^{-1} for significant increase in economically acceptable yield, quality and profitability.

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