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Assessing the Effect of Potassium nutrition on the Chilies (*Capsicum annuum* L.) Nursery Growth and Production

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Abstract

Healthy seedlings production plays pivotal role for better growth and quality production of chili. Optimum use of nutrients especially potassium (K) plays a key role for strong and vigorous seedlings, hence assessed in chili. The present study explored the response of chili seedlings to K nutrition. The trial was run by employing randomized complete block design with three replications and four K rates. The K nutrition doses included 0, 30, 60 and 90 Kg ha^{-1} with 0 Kg was used as control. The two widely grown varieties of area (Ghotki and Longi) were used in the study. There was a substantial variation to most of the parameters with regards to K application. The chili varieties also responded differently to K nutrition for most of the studied traits. Relatively, the maximum (18.65 cm) and minimum seedling height (14.25 cm) was noted by nourishing seeds with increasing K rates (90 Kg ha^{-1}) and control (0 Kg ha^{-1}). Positive effect of K application was also observed on leaf growth and development and more leaves (12.91) were observed at higher K rates. Shoot and root growth traits also responded significantly, and highest fresh seedling shoot weight (5.28 g), and root weight (0.92 g) were recorded when plants were nursed under the influence of highest K nutrition. In case of varieties, Ghotki showed superior performance over Longi for all the traits studied. It is concluded that nursery of chili crop may be raised by applying K @90 kg ha^{-1} for healthy and vigorous seedling production.

Keywords: Potassium, chili, growth, nursery, seedlings, ghotki, longi

Introduction

Chili, commonly known as red pepper (*Capsicum annuum* L.) is one of the extensively grown and consumed vegetable crops of family Solanaceae. Chiliis very popular among farming community due to its more income returns to the famers Ahmed *et al*., 2018). Chili contains appreciable amounts of various health beneficial compounds including fatty acids, vitamins, minerals, carotenoids, fiber, mineral elements and protein (Qi *et al*., 2019). Chili is also well known for his health beneficial properties and recommended for patients suffering from fever, constipation, indigestions and cold. Different value-added products including pickles, spices and dried powder are also prepared from chili (Qamar *et al*., 2020). Chili is important commercial vegetable crop of Pakistan with major planting area in Sindh Province. Pakistan is one of the principal producers of chilies (GoP, 2018). The red chili grown in Pakistan is very famous in middle east and European union countries. It is reported that Pakistan is fourth largest producer of red chili (FAO, 2017).

Healthy seedlings play key role for successful, profitable, and quality chili production. Seed germination is critical stage in any crop because most of other plant stages directly reliant on proper and uniform germination of the seed. Judicious use of nutrient elements plays a key role for healthy seedling production (Roy *et al*., 2006). Among plant nutrients, potassium is vital for healthy growth and quality production of chili. It improves the root growth and development and enhances the tolerance of seedlings against drought, cold, heat and different biotic and abiotic stresses (Gong *et al.* 2020). It avoids energy losses and lessen respiration. It regulates the turgor in plants and prevent water loss and wilting in plants. It helps in food formation and play an essential role in photosynthesis process, (Sharma and Kumar, 2017). It enhances the chlorophyll content in plants and plays a significant role in water and nutrient transport. It enhances the enzymatic activity in plants and is involved in different photosynthesis and biochemical processes including protein synthesis, stomatal activity (Byun *et al*., 2020). It is well reported that potassium is an activator of over 60 enzyme systems in crop plants. It is well documented that most of the crop species are nourished with overuse of nitrogenous fertilizers that resulted in the susceptibility of plants to various insect pests and disease infestation (Prasad *et al*., 2009). Since potassium plays a vital role in enhancing the tolerance of plants against biotic and abiotic stresses, hence the optimum use of potassium could counter the attack of insects and diseases in plants (Olatunji & Afolayan, 2018).

Red chili has the widest area in Sindh province that accounts 85-90- %. Nevertheless, this huge area has not been accompanied by high yield and quality production of this commercial crop of the region. The yield and quality production of chili can be enhanced through raising of healthy and vigorous chili seedlings. The strong and vigorous seedlings are essential start of any crop specie that may fetch more income to the growers (Ahmad *et al*., 2019). The judicious use of the potassium nutrition could be one of the strategies to produce healthy seedlings of chili. Most of the farmers of the region produce chili by applying conventional techniques and do not apply proper nutrition especially K fertilizers to the to the chili seedlings that resulted in poor and weak seedlings that eventually led to less yield and quality production (Anatalia *et al*., 2018). So far, most of the studies focused on the effect of potassium nutrition on the growth and yield of chili. However, the effect of potassium nutrition for raising healthy and vigorous seedlings has not been documented (Foyer., 2018.)

Since the chili is an important crop of Sindh Province of Pakistan and offers more income returns to the farming community of the region (GOP, 2018). However, it has been observed with great concern that yield that growers are getting from this important value-added crop is far less than the other countries. In this context there is an acute need to enhance the quality production of chili. For enhancing the yield and quality production of any crop, healthy and vigorous seedlings play a crucial role and are considered as first and essential start. The optimum use of K nutrition is vital for producing healthy and strong seedlings (Chadwick *et al*. 2015).

In the light of above discussed facts, the present study has been attempted to explore the potential of K nutrition for producing healthy and vigorous seedlings of chili.

Materials and Methods

Study area: The study was executed at the research area of Department of Horticulture, Sindh Agriculture University Tandojam from February to March 2023. The study area is located at Latitude: 25° 25' 21.40" N and Longitude: 68° 32' 13.38" E. The soil used in the study was flat, having a texture clay loam and bulk density 1.54 (g/cc), porosity (37.97) and their field capacity was (23.97%). The average recorded temperature ranged from 28 to 31^{0}C respectively during the period of study.

Plant Material: The seeds of two commercial varieties were acquired from local agrarian shop.

Experimental Design and Preparation of Land and Flat Beds: The study was executed following randomized complete block design with three replications and four K rates. The land was thoroughly prepared by applying ploughing and land leveling. The land was then pulverized and flat beds measuring size of 2x1 m in length and width were prepared, respectively. A total of 30 beds were prepared and experimental area comprised of 60 m^2.

Application of K nutrition: After preparation of soil and flat beds, the sowing of seeds was done. K rates were considered as treatment while beds which were not nourished with K nutrition were considered as control. The study comprises of four K rates i-e Control (0 kg K ha^{-1}), 30 kg K ha^{-1}, 60 kg K ha^{-1}, and 90 kg K Ha^{-1}. After the emergence of the seedlings, full dose of K nutrition was applied according to the plan of study to each bed. The source of K nutrition was sulphate of potash (SOP) 50 % K. To avoid the disease infestation and insect pest attack, seedlings were strictly monitored. Standardized cultural practices including weeding and irrigation were applied to all the bed properly. Data was taken after 45 days of sowing of seeds.

Data Collection: Ten seedlings from each bed were randomly selected for collection and recording of Data. The observations considered for recording and analysis of the data included germination time, leaves in individual seedlings, seedlings height (cm), chlorophyll content (SPAD), fresh shoot biomass (g), dry shoot biomass (g), fresh root weight (g) and stem girth (mm).

Observations Recording Methodology

Germination time: Germination time was recorded based on days that first seed takes for germination after seed sowing.

Seedling height (cm): Seedlings height was measured at the end of experiment from seedlings base to the terminal growth point with the help of ruler and average was worked out.

Leaves plant^{-1}: This parameter was recorded by counting the leaves of each sampled seedling by adding the values of all sampled seedlings and then mean values were recorded.

Stem girth (mm): Stem girth was recorded with the help of vernier caliper. The stem girth was recorded at three portions terminal, central and base portions of the seedlings and then mean of these portions were calculated.

Fresh and dry shoot weight (g): Harvested samples were brought to the laboratory for fresh and dry shoot and root weight. Fresh shoot weight was measured with the help of electronic digital weight balance by separating the root portion of the plant and vegetative growth of the plant at ground level is considered. Dry shoot biomass was measured from oven dried samples at the temperature of 70^{0}C to a consistent weight.

Fresh root weight (g): Fresh root biomass was recorded by separating vegetative growth and root growth of sampled plants. The separated roots were washed with tap water and extra moisture was removed with tissue paper and then root biomass of sampled seedlings were recorded with the help of digital electronic balance.

Chlorophyl content (SPAD): The device Soil Plant Analysis Development (SPAD 502) was used to measure the chlorophyll content in the leaves. The three portions of leaves (upper, middle and lower) were analyzed, and average was taken out.

Data Analysis: Statistical analysis of the observed data of all the parameters was conducted using Statistix version 8.1 computer software. For assessment of significance of variances among treatment means, the Least Significant Difference test (LSD) was applied.

Results

Effect of K nutrition on germination time: The germination time showed a non-significant difference with respect to different K rates. However, varieties showed a significant difference for germination time. Ghotki took less time for germination (5.00 days) in comparison with counterpart variety longi (7.41 days).

Table 1: Germination time of chili varieties as influenced by various potassium treatments.

Potassium Rates	**Chili varieties**		**Mean**
	Longi	**Ghotki**	
0 Kg ha^{-1}	7	5	**6A**
30 $Kgha^{-1}$	7.66	5	**6.33A**
60 $Kgha^{-1}$	7.66	5.33	**6.5A**
90 $Kgha^{-1}$	7.33	4.66	**6A**
Mean	**7.41A**	**5B**	

	Potassium rates		**chili varieties**		**Potassium x Chili varieties**
SE±	0.6944		0.4910		0.9820
LSD 0.05	1.4893		1.0531		2.1061
CV%	19.37				

Effect of K nutrition on leaves of Chili seedlings: There were considerable differences among K rates for number of leaves of chili seedlings where increasing K rates (90 kg ha^{-1}) recorded the highest number of leaves (12.91). The beds that were not nourished with K nutrition (control 0 kg ha^{-1}) obtained minimum leaves (7.5). The varietal effect showed that variety Ghotki produced maximum leaves (10.77) in comparison with variety Longi (9.58). It was further observed that K nutrition had positive and substantial effect on leaf growth and development of chili because leaves in individual seedlings increased significantly when K rate was increased.

Table 2: Leaves $plant^{-1}$ of chili varieties as influenced by various potassium treatments.

Potassium Rates	**Chili varieties**		**Mean**
	Longi	**Ghotki**	
0 $Kgha^{-1}$	7	8	**7.5D**
30 $Kgha^{-1}$	8.5	9.66	**9.08C**
60 $Kgha^{-1}$	10.66	11.76	**11.21B**
90 $Kgha^{-1}$	12.16	13.66	**12.91A**
Mean	**9.58B**	**10.77A**	

	Potassium rates		**chili varieties**		**Potassium x Chili varieties**
SE±	0.5174		0.3658		0.7317
LSD 0.05	1.1097		0.7846		1.5693
CV%	8.80				

Effect of different K rates on seedlings height of chili (cm): Significant differences were recorded among K rates for seedlings height of chili. The K rate of 90 Kg ha^{-1} recorded the tallest chili seedlings (18.65 cm) where those grown under 0 Kg K ha^{-1} produced shortest plants (14.25 cm). Plants that received 60 kg K ha^{-1} and 30 Kg ha^{-1} recorded height of the seedlings (16.86 cm and 15.53 cm) respectively. It is important to note that significant difference was observed among all K rates. The varietal effect revealed that tallest plants having height (17.04) were recorded in variety Ghotki, while Longi showed seedling height (15.60). The K rates and varieties interaction demonstrated that seedlings height was substantially higher (19.20cm) in variety Ghotki at elevated K rate (90 kg ha^{-1}).

Table 3: Plant height (cm) of chili varieties as influenced by various potassium treatments.

Potassium Rates	Chili varieties		Mean
	Longi	**Ghotki**	
0 $Kgha^{-1}$	13.40	15.10	**14.25D**
30 $Kgha^{-1}$	14.76	16.30	**15.53C**
60 $Kgha^{-1}$	16.16	17.56	**16.86B**
90 $Kgha^{-1}$	18.10	19.20	**18.65A**
Mean	**15.60B**	**17.04A**	

	Potassium rates		chili varieties		Potassium x Chili varieties
SE±	0.387		0.2739		0.5477
LSD 0.05	0.8307		0.5874		NS
CV%	4.11				

Effect of K rates on fresh shoot weight and dry shoot weight (g) of Chili Seedlings: The K nutrition showed considerable effect on fresh and dry shoot weight of chili seedlings Significant difference was also noted in varieties. Varieties sown in beds that were applied K@ 90 Kg ha^{-1} produced maximum fresh and dry shoot weight (5.28 g and 4.79 g) and (0.83 g and 0.65 g), respectively. However, non-significant difference was noted between these two K rates and significant difference was recorded among other K rates. The chili seedlings that were not nourished with K nutrition showed minimum fresh and dry shoot weight (1.18 g and 1.96g and0.35 g and 0.50 g), respectively. In varieties Ghotki had a maximum fresh and dry shoot weight (5.76 g and 0.83g), respectively. Longi showed minimum fresh and dry shoot weight (4.79 g and 0.65 g), respectively.

Table 4: Fresh shoot weight (g) of chili varieties as influenced by various potassium treatments.

Potassium Rates	Chili varieties		Mean
	Longi	**Ghotki**	
0 $Kgha^{-1}$	1.18	1.96	**1.57D**
30 $Kgha^{-1}$	2.35	3.25	**2.80C**
60 $Kgha^{-1}$	3.57	4.46	**4.08B**
90 $Kgha^{-1}$	4.79	5.76	**5.28A**
Mean	**2.97B**	**3.86A**	

	Potassium rates		chili varieties		Potassium x Chili varieties
SE±	0.3915		0.2768		0.5536
LSD 0.05	0.8397		0.5937		1.1874
CV%	19.83				

Table 5: Dry shoot weight (g) of chili varieties as influenced by various potassium treatments.

Potassium Rates	Chili varieties		Mean
	Longi	**Ghotki**	
0 $Kgha^{-1}$	0.35	0.50	**0.42C**
30 $Kgha^{-1}$	0.39	0.56	**0.47C**
60 $Kgha^{-1}$	0.51	0.66	**0.59B**
90 $Kgha^{-1}$	0.65	0.83	**0.74A**
Mean	**0.47B**	**0.63A**	

	Potassium rates		chili varieties		Potassium x Chili varieties
SE±	0.0339		0.0240		0.0480
LSD 0.05	0.0728		0.0515		0.1030
CV%	10.53				

Effect of K rates on fresh root weight (g) of Chili Seedlings: The K nutrition had a considerable effect on fresh root weight of chili seedlings. There were significant differences among different K rates where chili seedlings had the highest fresh root weight (0.92 g) at K rate (90 kg ha^{-1}). However, there was no significant difference between control and 30 kg K ha^{-1}). The control (0 kg K ha^{-1}) obtained lowest fresh root weight (0.83g). Chili varieties responded positively to K nutrition and significant difference was noted between varieties. Ghotki had a maximum fresh root weight (0.96 g) while longi showed fresh root weight (0.88 g). The treatment interaction showed that Ghotki had higher root biomass (0.88 g) at elevated K rate of 90 kg ha^{-1}.

Table 6: Fresh roots weight (g) of chili varieties as influenced by various potassium treatments.

Potassium Rates	Chili varieties		Mean
	Longi	Ghotki	
0 $Kgha^{-1}$	0.79	0.83	**0.81C**
30 $Kgha^{-1}$	0.80	0.86	**0.83C**
60 $Kgha^{-1}$	0.84	0.90	**0.87B**
90 $Kgha^{-1}$	0.88	0.96	**0.92A**
Mean	**0.82B**	**0.88A**	

	Potassium rates		chili varieties		Potassium x Chili varieties
SE±	0.0109		7.683		0.0154
LSD 0.05	0.0233		0.0165		NS
CV%	2.19				

Effect of K rates on stem girth (mm) of Chili Seedlings: The data with regards to stem girth of chili seedlings showed significant difference among various K rates. There was also a significant difference between varieties. The maximum stem girth (3.88 mm) was recorded when K was applied to plants @ (90 kg ha^{-1}). Plants nourished with 30 kg ha^{-1} and 60 K ha^{-1} showed stem girth (2.02 mm 3.21 mm). The lowest value (1.76 mm) for stem girth was observed in plants which were not nourished with K nutrition. Chili varieties showed significant difference to K fertilization. The variety Ghotki had got maximum stem girth (4.21mm) while Longi variety recorded minimum stem girth (3.50).

Table 7: Stem girth (mm) of chili varieties as influenced by various potassium treatments.

Potassium Rates	Chili varieties		Mean
	Longi	Ghotki	
0 $Kgha^{-1}$	1.43	2.10	**1.76D**
30 $Kgha^{-1}$	1.90	2.66	**2.02C**
60 $Kgha^{-1}$	2.86	3.56	**3.21B**
90 $Kgha^{-1}$	3.50	4.21	**3.88A**
Mean	**2.42B**	**3.15A**	

	Potassium rates		chili varieties		Potassium x Chili varieties
SE±	0.1112		0.0786		0.1573
LSD 0.05	0.2385		0.1687		NS
CV%	6.91				

Effect of K rates on chlorophyll content (SPAD)of Chili Seedlings: There was a significant difference for chlorophyll content of leaves among different K rates. A highly significant difference was also noted between varieties. The highest chlorophyll content (61.70 SPAD) was noted when plants received K nutrition @ (90 kg ha^{-1}). There was a linear decrease in chlorophyll content when plants were nourished with decreased K rates. The K rates when applied to the plants @60 and 30 kg ha^{-1} showed chlorophyll content in the leaves (51.78 and 36.08 SPAD). The lowest chlorophyll content in the leaves (34.25 SPAD) was recorded in the pants that were not fertilized with K nutrition. Chili varieties showed significant difference for chlorophyll content in leaves. The variety Ghotki had a maximum chlorophyll content (61.70 SPAD) over variety Longi (41.15 SPAD). The interaction results (K X Varieties) showed that maximum chlorophyll content (64.96 SPAD) was found in variety Ghotki.

Table 8: Chlorophyl content (SPAD) of chili varieties as influenced by various potassium treatments.

Potassium Rates	Chili varieties		Mean
	Longi	Ghotki	
0 $Kgha^{-1}$	30.16	38.33	**34.25C**
30 $Kgha^{-1}$	32.10	40.06	**36.08C**
60 $Kgha^{-1}$	47.90	55.66	**51.78B**
90 $Kgha^{-1}$	58.42	64.96	**61.70A**
Mean	**42.15B**	**49.75A**	

	Potassium rates		chili varieties		Potassium x Chili varieties
SE±	1.6398		1.1595		2.3190
LSD0.05	3.5170		2.4869		4.9738
CV%	6.18				

Discussion

The present investigation explored the role of potassium nutrition in nursery growth and development of chili varieties. The Various K rates showed positive and substantial effect on chili varieties. Furthermore, advantages of adequate K nutrition highlighted the importance of K for chili (Anatalia *et al*., 2022). K contributes towards chili growth, development and productivity and considered as one of the most essential plant nutrient elements (Trisha, 2018; Hasanuzzaman *et al.* 2018). The adequate supply of K nutrition is pre-requisite for quality production of chili (Oosterhuis et al., 2014). The chili fruit is easily vulnerable to environmental conditions and disease and insect pest attack and K is considered as one of the key elements to induce tolerance of crop plants against different insect pests and diseases (Hasanuzzaman *et al*., 2018). Healthier and strong seedlings play key role for successful and economical production of chili. The balanced application of the potassium nutrition could be one of the sustainable strategies to produce healthy seedlings of chili (Lester *et al.* 2010). Available reports have highlighted that balanced supply of K had positive effect on shoot and root growth and development. Moreover, application of K at initial stage also caused healthier and strong seedlings (Oosterhuis *et al*., 2014). Nevertheless, most of the growers of the region raise chili nursery/seedlings with no application of K that caused weaker seedlings (Shin 2014). This eventually led to less and poor-quality production. Most of the past research described the potassium nutritional effect on the growth and productivity of chili. Nevertheless, influence of potassium nutrition for raising healthy and vigorous seedlings has not been documented.

In this study K supply significantly contributed to chili seedling growth and development. The adequate K supply produced taller seedlings with maximum shoot and root biomass production. The increasing K rates also caused the maximum leaves in both chili varieties. The inadequate supply of K caused poor growth and weaker seedlings with less shoot and root growth and development. K plays a crucial role in various physiological and metabolic processes, including water and nutrient uptake, photosynthesis, enzyme activation, and protein synthesis (Shafeek *et al.*, 2012). Moreover, its role in opening of stomata and transport of sugar is well documented (Marschner, 2012). The greatest performance of seedlings of chili genotypes at young stage could be attributed to effective role of K in enhancing the various physiological and biochemical activities in plants consequently plants with maximum leaf, shoot and root growth and development were produced (Gong *et al.* 2020). In large red chili cultivation, there has been a notable imbalance in the use of fertilizers, with excessive use of nitrogen (N) and phosphorous (P_2O_5, while the use of potassium (K_2O) fertilizer is lacking. This imbalance can have detrimental effects on the quality of chili plants and overall yield. To ensure the quality production of chilies, it is crucial to implement proper potassium management strategies (Lester *et al*, 2010). One effective strategy for nutrient management in chili production is to ensure a balanced application of K fertilizers. Chili is relatively heavy feeder of K, hence supply of K based fertilizers is inevitable to enhance the yield and get more returns from the produce. The early crop stage of any crop is considered most crucial because most of other plant stages directly reliant on early establishment of crop. Hence judicious use of K also needs to be applied to the chili at seedling stage (Hussain *et al*., 2012). The results of our study also advocated the role of K for better nursery development of chili crop. The adequate K nutrition produced healthier and vigorous seedlings with better shoot and root growth and development. Moreover, in our study, plants raised with adequate K nutrition produced more leaves with increasing chlorophyll content. The benefits of balanced K nutrition on chili crop has also been found by other researches including (Trisha, 2018; Anatalia *et al*., 2018; El-Bassiony *et al*., 2010; Idan, 2014; Khan et al., 2014).

Conclusion

Potassium nutrition significantly affected the growth of chili varieties at seedling stage. The adequate K rate enhanced the growth of chili. Both the varieties responded positively to K nutrition for all traits assessed. Regarding the varieties Ghotki variety exhibited superior performance in comparison with its counterpart variety Longi.

Recommendations

It is recommended chili crop nursery may be raised by applying K@90 kg ha^{-1} for healthy and vigorous seedling production. This study was executed at seedling stage, however further study needs to be executed up to physiological maturity of the crop under large field conditions to optimize and validate the K requirements of chili.

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Conflicts of interests

The authors have declared no conflict of interest.

Authors Contribution

Conceived and planned the study Kaleem Kakar, Executed the study Kaleem Kakar& Muhazzam Anwar, Analyzed the data Niaz Ahmed Wahocho, Noor-Un-Nisa Memon & Ghulam Murtaza Jamro Wrote the draft of manuscript Kaleem Kakar & Niaz Ahmed Wahocho & Naqeebullah, Revised the draft Muhammad Nawaz Kandhro

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