Asian Journal of Agricultural and Horticultural Research

Volume 10, Issue 4, Page 364-373, 2023; Article no.AJAHR.103647
ISSN: 2581-4478

Effects of Different Levels of Potassium and Their Split Applications on Growth and Yield of Chilli (*Capsicum annuum* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJAHR/2023/v10i4278

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/103647

Original Research Article

Received: 04/06/2023
Accepted: 08/08/2023
Published: 21/08/2023

ABSTRACT

This research aimed to investigate the effects of split applications of potassium (K) fertilizer on the growth and yield characteristics of chilli (*Capsicum annuum L.*), as previous studies have primarily focused on single basal applications of K, leaving the effectiveness of split applications uncertain. The field experiment was conducted on Loamy sand soil with medium K status, evaluating six levels of K (0, 40, 80, 100, 120, and 150 kg ha^{-1}) applied as full K basal dose, 2 splits, and 3 splits. The experiment followed a two-factorial randomized complete block design with three replications and eighteen treatments. Results showed that the three split applications, with 50% at basal dose, 25% at 25 days after transplanting (DAT), and 25% at 45 DAT, resulted in superior plant height, number of fruits per plant, fruit yield, root length, root fresh weight, and root dry weight.

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Consequently, it is recommended to employ split applications of K in two or three splits, depending on the initial soil K status and soil type, to enhance growth and maximize yield per unit of nutrient applied.

Keywords: Chilli; growth; potassium; split application.

1. INTRODUCTION

Capsicum annuum L, a vegetable, and spice of economic importance in Nepal, belongs to the Solanaceae family [1]. It is the third most significant crop in the Solanaceae family, following tomato and potato [2]. Potassium (K) is an essential macronutrient, playing a crucial role in various physiological processes such as photosynthesis, enzyme activation, translocation, and fruit development [3-7]. However, the bioavailability of soil K is often low, particularly in acidic soils, and is mainly limited to the topsoil as a substantial portion of soil K is incorporated into minerals, posing a common problem that affects agricultural production [8]. Approximately 18% of Nepal's soils are estimated to have low potassium levels [9]. Reports of K deficiency in soils from different regions of Nepal suggest that insufficient K fertilizer input may be a contributing factor [10].

Furthermore, most of the farmers are unaware of the effective dose of K needed to be applied in the field and the application of K to chilli has received the least attention. In traditional farming, the full dose of K required by the crop is applied at the time of sowing, which may not be available to crops during critical growth stages due to leaching losses, competition between microorganisms and plants, and K fixation in clay minerals, which further restricts K availability [11]. The introduction of high-yielding varieties under intensive cropping systems has caused the K status of the soil to decrease from high to medium to low [12]. Another issue that has been noticed is the possibility that excessive amounts of fertilizer may be applied because the amount of K in the soil is underestimated [13]. Although K is abundant in many soils, the majority of soil K may not be accessible to plants because the pool of plant-available K (solution K) is less than other forms of existing K [14]. The competition between microorganisms and plants lowers the K availability of crop plants as well as leaching losses and luxury consumption further lower the K availability [15].

A field experiment showed that split application of K fertilizer improved wheat yield and K uptake [12]. The split application of K on growth and yield-attributing characteristics of rice in calcareous soil was found more beneficial [16]. Splitting the application of K also helps to minimize losses through leaching and provide nutrition at appropriate times as plants matured. So, splitting potash applications are crucial to increase available K in the soil and the mobility of K to plant from the soil over single applications [17]. However, the effects of split application of K have been studied mainly in cereal crops viz, rice, and wheat. Such experiments have not been undertaken in chilli and other vegetable crops. Due to restrictions in the availability of mineral nutrients such as K fertilizer, the yield potential of various vegetables has not been met. Thus, it can be hypothesized that there may be a significant difference in the effect of the split application of K levels in different growth and yield characteristics in chilli. So, this nutrient management trial was conducted to access the growth and yield response of chilli to the soil application of K.

2. MATERIALS AND METHODS

2.1 Location and Site of Experiment

The field experiment was conducted at the Institute of Agriculture and Animal Science (IAAS) from March to June 2022 to study the effect of level and doses of potassium on the growth and yield parameters of chilli in Sundarbazar, Lamjung which lies in Gandaki Province of Nepal. It is located at 28° N latitude and 84° E longitude. It lies in the sub-tropical climate belt of Nepal. The site has a sub-tropical climate with cold winters, and hot summer, with average annual precipitation low.

2.2 Design of Experiment

The field experiment was conducted in two factorial Randomized Complete Block Design (RCBD) with 3 replications and 18 treatments in each replication. The first factor consisted of six doses of potassium (0, 40, 80, 100, 120, and 150kg ha^{-1}). The second factor included three frequencies of potassium application (100% basal dose, 50% basal +50% 25 DAT, 50%basal+25% (25 DAT) +25% (45 DAT).

2.3 Nursery Bed Preparation

The nursery bed was prepared on 16th February 2022. The field was ploughed and pulverized with the help of a spade to make it loose and friable. All unwanted things like weeds, stone, and plant debris were removed with the help of a rake to make it free from a host of insect pests, viruses, and other diseases. The FYM was mixed uniformly and raised bed was prepared. Seeds of the NS-1701 variety were sown at a depth of 4-5cm with the line sowing method. After sowing, water was sprinkled thoroughly with a fine rose can, ensuring the soil was moist but not overwatered till the seedling emerged. After the seedling emerges, irrigation was done lightly with a rose can at certain intervals as per the requirement of soil conditions.

2.4 Field Preparation

The soil was thoroughly ploughed to make the soil well pulverized for seedling transplantation; weeds and trash were removed. 54 plots were prepared according to the experimental design using pegs, measuring tapes, and ropes.

2.5 Manures and Fertilizer Application

The recommended dose of FYM is 20 tons/ha and inorganic fertilizers 100 kg/ha N, 100 kg/ha P and 100 kg/ha K for chilli [18]. For the experiment, we applied the recommended dose of NPK. A full dose of FYM and Phosphorous in the form of SSP (Single Super Phosphate) was applied at basal dose. The dose of nitrogen in the form of Urea was applied in three splits (1/3rd as basal dose, 1/3rd in 25 days, and 1/3rd in 45 days after transplanting). The dose of Potassium was applied in the form of MOP (Muriate of Potash) in basal dose, two splits, and three splits that vary according to the treatments. The fertilizer requirement per plot was calculated according to the requirement of chilli in that plot size (1.2m*1.8m).

2.6 Transplanting

Uniform-sized thirty days old healthy, vigorous seedlings with 3-4 leaves were chosen and transplanted in the experimental plots (1.8 m x 1.2 m) on the 16th of March, 2022 at 60cm*30cm plant geometry. After transplanting, light irrigation was given with a rose cane to prevent wilting.

2.7 Cultural Operations Followed after Transplanting

The first and light irrigation was given at the time of transplanting and the subsequent irrigations were given in the interval of 4-5 days or once a week depending on the weather and soil conditions. For crop protection, Roger was applied at 2 ml/liter of water through spraying to control aphids and other sucking insects. The granular insecticides were also incorporated into the soil during field preparation to protect from cutworms in the field. The first weeding and earthing up was done in 20 days after transplanting and the second weeding was done in 40 days after transplanting to avoid invasion of weed species.

2.8 Detail of the Observations

2.8.1 Plant height (m)

The height of each sample plant was measured from ground level to the base of the last pair of leaves at 60 days after transplanting. Height was measured using a wooden scale in centimeters and later converted into meters. Then, the average height of the plant was found.

2.8.2 Number of fruits

The total number of fruits plucked from two sample plants of each treatment was recorded and the sum total of all fruits of the sample plant was divided by 2 to get the number of fruits per plant.

2.8.3 Total yield (kg ha^{-1})

All horticulturally matured fruits were harvested from sample plants and weighed with the help of digital weighing balance in grams. Plot values were calculated and converted to yield/ hectare.

2.8.4 Root length(cm)

The root length of the individual plant was measured with the help of a ruler in cm from the last portion of the stem from where the root arises to the end of the tap root.

2.8.5 Root fresh weight (g)

Sample chilli plants were uprooted and cut at 2 cm above the point of root initiation. Roots were washed in tap water and were kept in the soil lab to let all moisture dry. After the root was dry, the root fresh weight was taken with the digital weighing balance in grams.

Table 1. Treatment details

Treatment	Details of treatment
T1	NP + K (40 kg/ha) (100% as basal)
T2	NP + K (40 kg/ha) (50% as basal + 50% at 25 DAT)
T3	NP + K (40 kg/ha) (50% as basal + 25% at 25 DAT + 25 % at 45 DAT)
T4	NP + K (80 kg/ha) (100% as basal)
T5	NP + K (80 kg/ha) (50% as basal + 50 % at 25 DAT)
T6	NP + K (80 kg/ha) (50% as basal + 25% at 25 DAT + 25% at 45 DAT)
T7	NP + K (100 kg/ha) (100% as basal)
T8	NP + K (100 kg/ha) (50% as basal + 50% at 25 DAT)
T9	NP + K (100kg/ha) (50% as basal + 25% at 25 DAT + 25% at 45 DAT)
T10	NP + K (120 kg/ha) (100% as basal)
T11	NP + K (120 kg/ha) (50% as basal + 50% at 25 DAT)
T12	NP + K (120kg/ha) (50% as basal + 25% at 25 DAT + 25% at 45 DAT)
T13	NP + K (150 kg/ha) (100% as basal)
T14	NP + K (150 kg/ha) (50% as basal + 50% at 25 DAT)
T15	NP + K (150kg/ha) (50% as basal + 25% at 25 DAT + 25% at 45 DAT)
T16	NP (-K)
T17	NP(-K)
T18	NP(-K)

N- Nitrogen, P- Phosphorous, K- Potassium, DAT- Days After Transplanting

2.8.6 Root dry weight (g)

Chilli roots were oven dried at 72 degrees Celsius for 24 hours. Root dry weight was weighed with a digital weighing balance in grams.

Table 2. Soil analysis report

Test	Results	Remarks
PH	6	Slightly Acidic
Organic matter (%)	1.3	Medium
Nitrogen (%)	0.07	Low
Phosphorous(kg/ha)	6.9	Medium
Potassium(kg/ha)	226.80	Medium

2.9 Statistical Analysis

The recorded data were entered in MS-Excel 2016 according to the replications and treatments and R-package was used for data analysis. The mean for all the treatments was calculated and analysis of variance for all the characters was performed by F- Difference between treatment means was determined by LSD method according to Gomez and Gomez, (1984) at a 5% level of significance.

3. RESULTS

3.1 Effect of Different Levels and Split Application of Potassium in Growth Parameters of Chilli

Analysis of variance showed that the effect of the split application of potassium was significant for the different growth parameters of chilli (Fig. 1,4,5,6). The highest plant height of chilli was obtained in the treatment applied to 40 kg K ha^{-1}(0.60 m) and the lowest plant height (0.52 m) was obtained in the control. Although insignificant higher plant height (0.67 m) was recorded by the application of K at the rate of 40 kg ha^{-1} in three splits. A significant effect was observed in root length by the application of potassium in three splits. Maximum root length (10.6 cm) was observed with 40 kg ha^{-1} in three splits application. The effect of the split application of K levels was also statistically significant on root fresh weight. The maximum root fresh weight (54.06 gm) was obtained by three split applications of K at the rate of 40 kg ha^{-1}. While minimum root fresh weight (27.4 gm) has been obtained by three split applications of K at the rate of 150 kg ha^{-1}. Root dry weight was increased significantly by the split application of potassium. The maximum root dry weight has been observed with two splits application of K at the rate of 40 kg ha^{-1} (16.30 gm) which is similar with three splits application of K at the rate of 40 kg ha^{-1}. While minimum root dry weight has been observed with three splits application of K at the rate of 150 kg ha^{-1}.

3.2 Effect of Different Levels and Split Application of Potassium in yield parameters of Chilli

The yield parameters were significant for the different levels and split applications in chilli. The number of fruits per plant significantly affected the split application of potassium. The maximum number of fruits per plant (22) was recorded from 3 splits application of 40 kg K ha^{-1}, whereas the minimum number of fruits per plant (10) was recorded from basal dose application of 120 kg K ha^{-1}. The application of different K levels and their split applications showed a significant effect on the yield of chilli. The application of K at the rate of 40 kg ha^{-1} in three splits (NP + K (40 kg ha^{-1}) (50% as basal + 25% at 25 DAT + 25 % at 45 DAT)) gave the highest yield (0.91 kg ha^{-1}) and it was lowest with application of K at the rate of 120 kg K ha^{-1}(NP + K (120 kg ha^{-1}) (100% as basal)) (0.25 kg ha^{-1}).

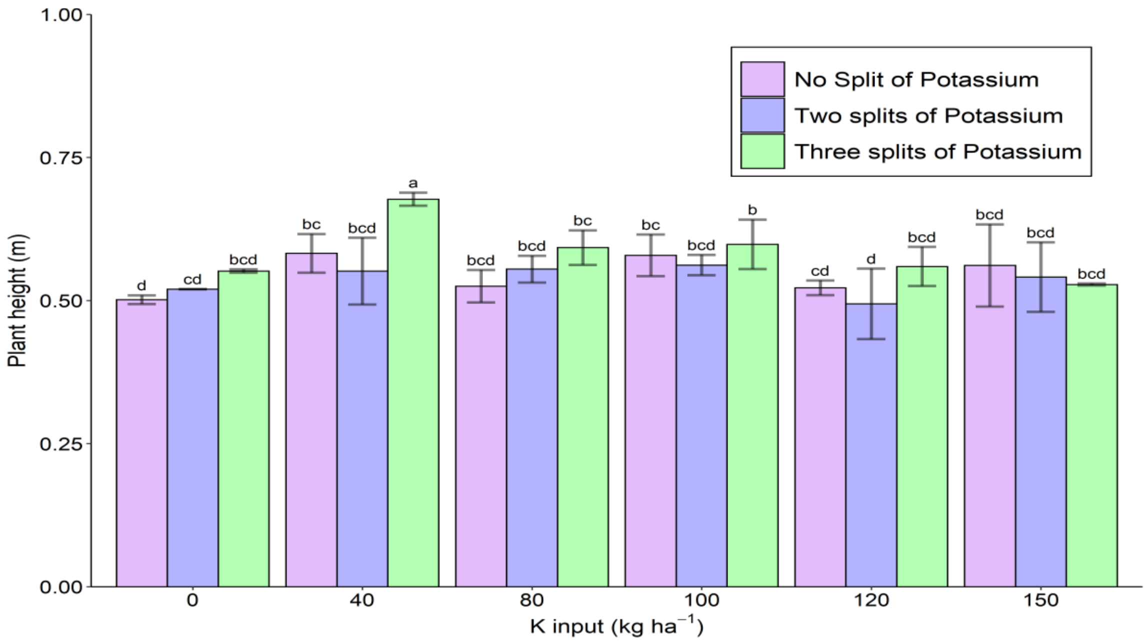

Fig. 1. Effect of different levels of K and its split application on plant height of chilli

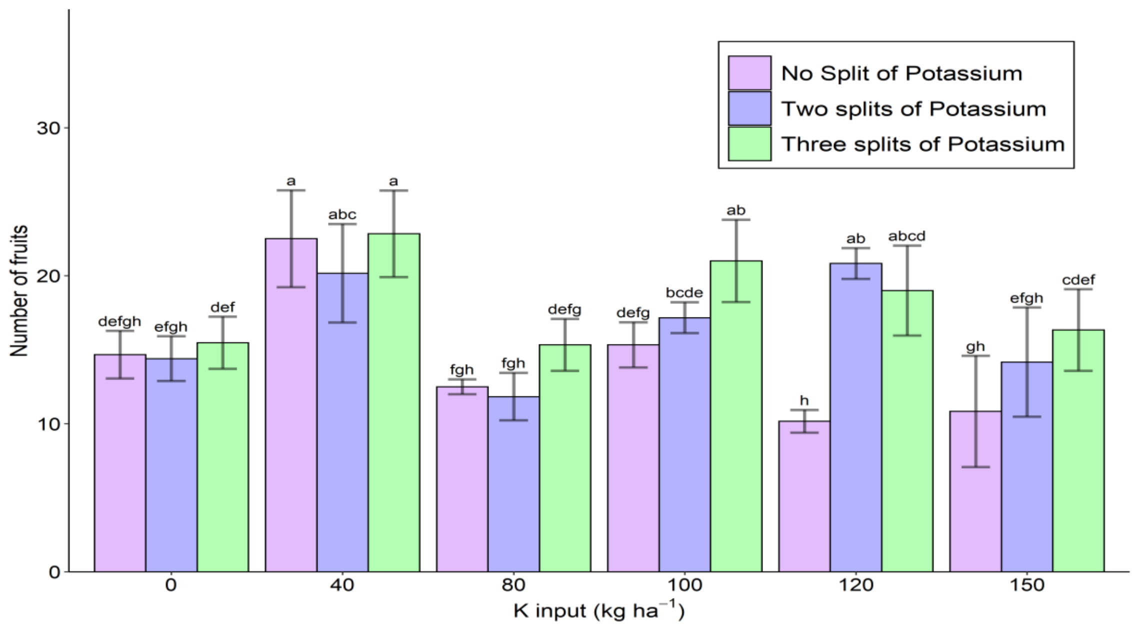

Fig. 2. Effect of different levels of K and its split application on number of fruits of chilli

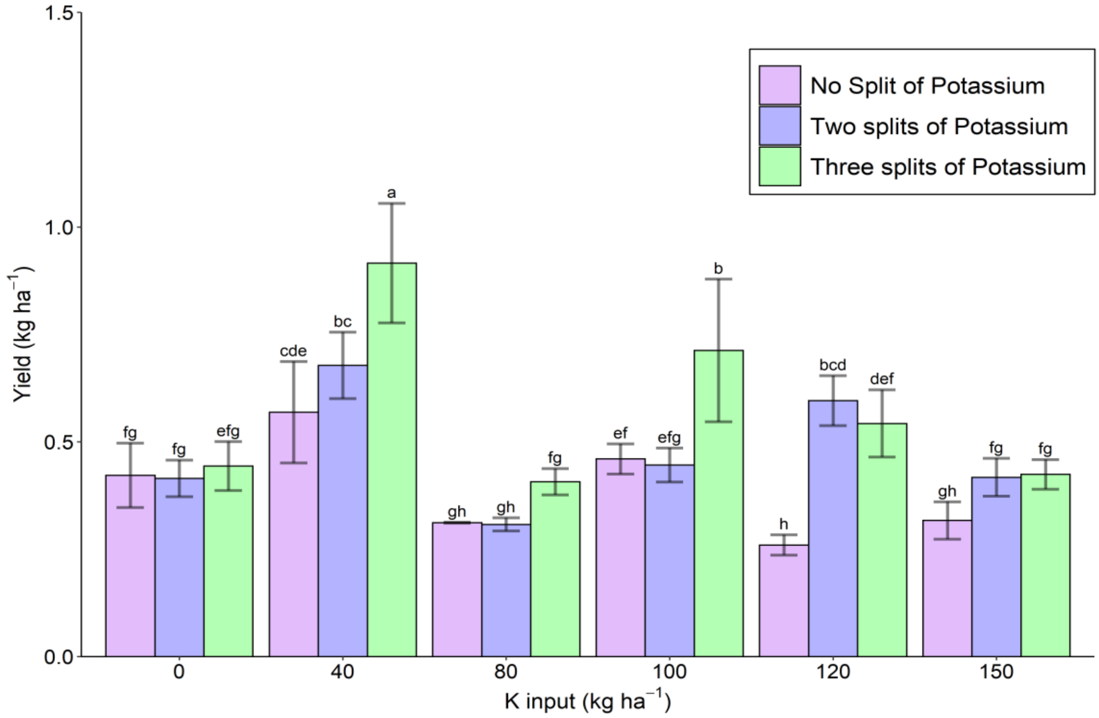

Fig. 3. Effect of different levels of K and its split application on Total yield of chilli

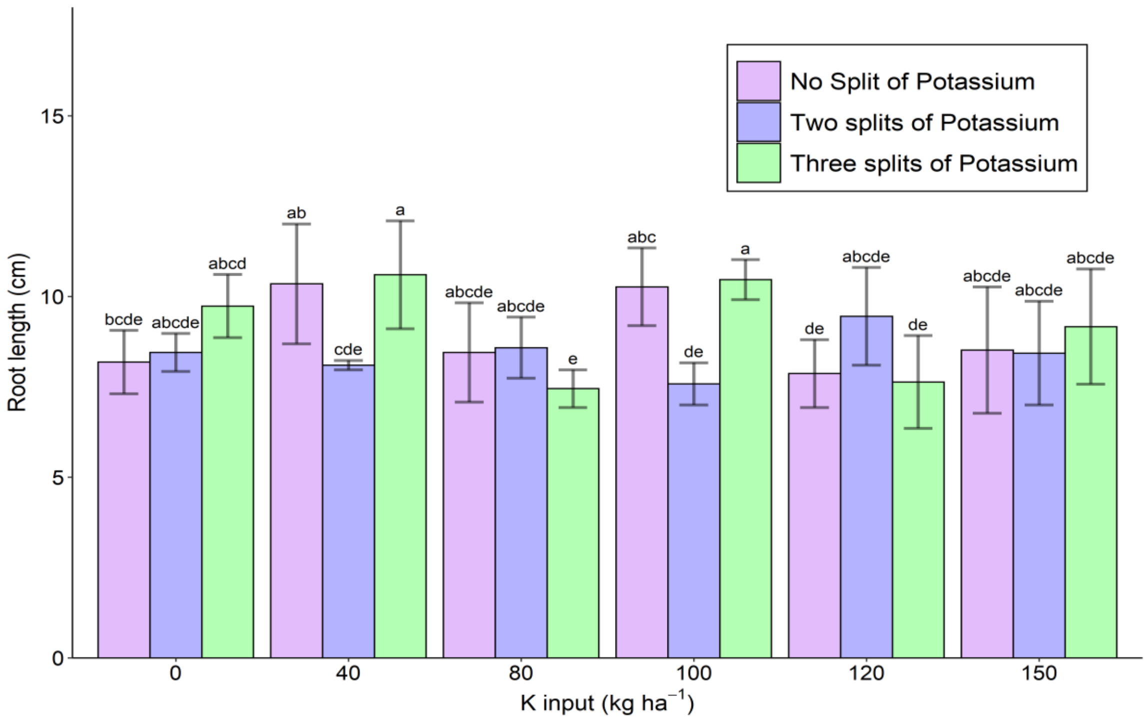

Fig. 4. Effect of different levels of K and its split application on root length of chilli

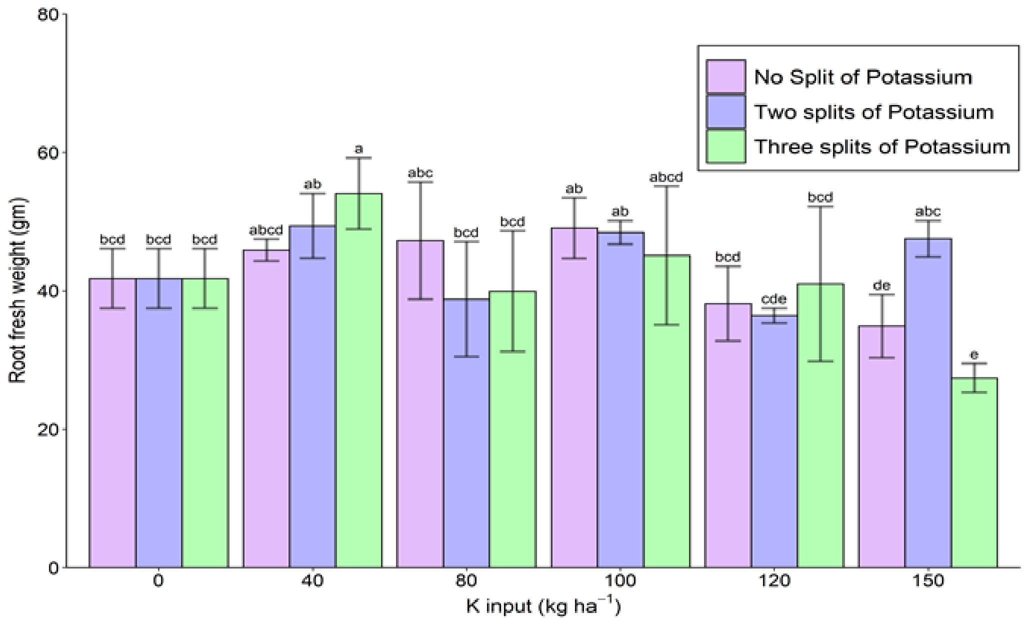

Fig. 5. Effect of different levels of K and its split application on root fresh weight of chilli

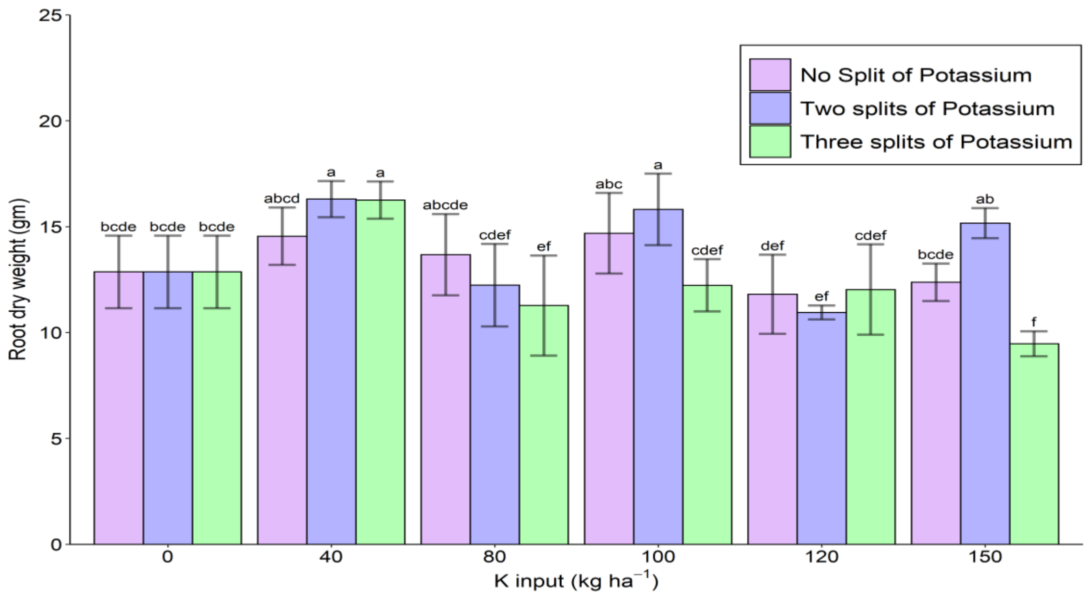

Fig. 6. Effect of different levels of K and its split application on root dry weight of chilli

4. DISCUSSION

The increase in plant height might be because K increases N assimilation, which increases the vegetative growth of the plant [19]. It also maintains auxin homeostasis and activates more than 60 enzymes for plant growth regulation [20,21]. The increase in root length might be due to cell expansion in the elongation zone due to turgor pressure building up osmotically through active substances K+ ions [8]. The Split application of K maintained the availability of K in the root zone of growing plants was also reported by Kolar and Grewal [22]. The chances of leaching losses of K may be little. The increase in root fresh weight might be due to the reason that as K+ ions enter into the root cells, cell water potential decreases, resulting in the movement of water in the cell due to osmosis, which ultimately increases the root fresh weight. Moreover, root growth is supported by the crucial role of potassium in the transportation of photosynthetic products [23].

The increase in root dry weight by the split application of K might be due to the increased availability of K to the crops. K+ ions play an important role in protein synthesis and enzyme activation in root cells [24,25]. K+ helps in the translocation of photosynthates like starch from leaves to the root cells, which finally increases the root dry weight of chilli [26]. As K rates increased, it resulted in the reduction of % dry matter of sweet potatoes [27]. So, the total yield decreases when the dose of potassium is increased from 100 kg/ha to 120kg/ha. The highest number of fruits per plant and highest fruit yield might be due to the vigor of the plant and a greater number of leaves per plant with the largest leaf area. Similar results were found by [28] that the yield of chilli was significantly influenced by the levels and sources of K. Similar results were found by Wuzhong [29] that K fertilization significantly increased the fruit yield of eggplant, tomato, sweet pepper, and chilli. The increase in total yield may be due to the reason that the split application of K fertilizer increases the availability of K to the crops. K helps in the efficient absorption of nutrients from the soil. K helps in the translocation of photosynthates from leaves to fruits, which finally increases the yield of chilli [26]. It was reported that the application of 40 kg K_2O ha^{-1} $year^{-1}$ in three splits $year^{-1}$ produced the maximum essential oil yield of lemongrass [30]. The three-split application of K recorded significantly higher yield attributes than applying full K at basal dose. Luxury consumption of potassium can be reduced by making split applications of potash at no more than half the nitrogen rates on soils kept low in available potassium [17]. Splitting the applications of K also minimizes the leaching losses and improves the efficiency of K used in tropical soil with small clay contents [31]. The split application of K also increased the accumulated amount, uptake efficient, and productive efficiency of N and K significantly and had a better effect on crops as compared to the basal application of K [32]. The split application of K also increased the utilization of N, K, Ca, and Mg compared with its basal application [33]. The three-split application of the base rate of fertilizer in which one-third of the base level was applied pre-plant, at first fruit set, and after the midseason harvest increased the total yield in bell pepper [34]. This method likely provides nutrition at appropriate times as the plants matured.

The split application of K showed a similar effect of the increasing trend in all the crop characters with the increase of the split applications from 1 to 3 according to Mahfuza et al. [35]. Similar results were found by Sharma and Singh [11] in rice and by Sharma et al. [36] in soybean. As well similar results were found by Gupta et al. [37] in brassica. Similar results were found by Ravichandran and Sriramachandrasekharan [38] in rice in both kharif and rabi seasons. This is because the time of fertilizer application may considerably influence crop response to fertilizer [38].

5. CONCLUSION

The results of this field experiment showed that soil application of K fertilizers in split doses was beneficial over single basal application. Plant height, number of fruits per plant, root length, root fresh weight, and root dry weight of chilli plant was found higher with the soil application of K at the rate of 40 kg ha^{-1} in three split doses. However, soil K status differs for different geographic regions and different land use systems, which requires more trials to access the K levels needed to be applied for effective nutrient management.

ACKNOWLEDGEMENT

The authors would like to acknowledge the Institute of Agriculture and Animal Science, Lamjung Campus for providing experimental field and other resources to carry out field research.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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