Effect of various phosphorus levels on growth and yield of chilli (*Capsicum annuum*) in Deukhuri, Dang of Nepal

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**Abstract**

Phosphorus affects the growth, development, maturity, earliness in flowering, fruiting and yield of chilli. The level and availability of phosphorus for chilli depend on the phosphorus already present in soil and climatic conditions. However, sufficient information is not available about the effect of various phosphorus levels on chilli production for the soil with a medium phosphorus level of the inner terai region of Nepal. Thus, the study was carried out to investigate the effect of various phosphorus levels on chilli on the soil having medium phosphorus at the Gadawa-4 Gangaparaspur of Deukhuri valley of the Dang district in 2018. The experiment consisted of six levels of phosphorus viz 0, 30, 60, 90, 120 and 150 kg P ha$^{-1}$. The single factor experiment was laid in a Randomized Complete Block Design with four replications. The highest plant height (60.22 cm), number of primary branches (9.60), yield per plant (123.20 g) and per hectare (9.15 t ha$^{-1}$), and early 50% flowering (44.00 days) were recorded in 90 kg P ha$^{-1}$. 60 kg P ha$^{-1}$ showed the highest number of fruits per plant (60.22). The maximum fruit length (6.80 cm) was recorded at 120 kg P ha$^{-1}$. The study concluded that a 90 kg P ha$^{-1}$ showed superiority in terms of growth parameters and phenological parameter, yield per plant and per hectare. Therefore, a 90 kg P ha$^{-1}$ could be used to get the highest yield of chilli for the soil with a medium phosphorus level of inner terai place like Deukhuri, Dang of Nepal.

**Keywords:** Chilli, growth, phosphorus level, yield

1 Introduction

Chilli (*Capsicum annuum*) is one of the important spice crops which belongs to the family Solanaceae. The *Capsicum* genus consists of 35 species (García et al., 2016). Chilli may be annual or short-lived perennial plants. Chilli has a hot pungent taste due to the presence of a chemical called capsaicin. Proteins, lipids, carbohydrates, fibers, mineral salts (Ca, P, Fe) and vitamins A, D3, E, C, K, B2 and B12 are also found in chilli (El-Ghorab et al., 2012). It is used for vegetables, spices, condiments, sauces and pickles. Different spice crops are grown in Nepal, among them chilli is one of the important spice crops which is widely cultivated from terai to mid-hills of Nepal. In Nepal, chilli was cultivated in an area of 10,692 ha in the period 2018/19 with the production of 67,167 tonnes (MoALD, 2020). In Dang, chilli was cultivated in 503 ha of land in the period 2018/19 with the production of 6,165 tonnes (MoALD, 2020).

Phosphorus is one of the essential macronutrients. Phosphorus is the primary nutrient for crop growth and development (Hinsinger, 2001). Phosphorus is necessary to promote lateral root morphology and root branching (Lopez-Bucio et al., 2003). Phosphorus is also necessary for chilli/pepper production. Phosphorus requirements for pepper varied with soil conditions and a balanced phosphorus level is required to enhance the production of pepper (Hunde, 2020). The vegetative growth, yield components like the...
2 Materials and Methods

2.1 Site and climate

The study was carried out during the period from July 2018 to December 2018 at a farmer’s field in Deukhuri valley of Dang district of Nepal. The site is situated 12 km south-east from Lamahi. Geographically the location of the site is 27.80 N latitude and 82.53 E longitudes. The elevation of the site is 567 meters above sea level. The annual average maximum temperature, minimum temperature, rainfall and relative humidity of the site in that year were 29.31 °C, 18.72 °C, 1587.75 mm and 53.74%, respectively.

2.2 Soil sampling

The soil sampling of the field was done with an auger. The soil samples were taken randomly in a zigzag fashion at the depth of 0-20 cm. Twelve soil samples were taken from the whole experimental field and mixed in a clean bucket to form a composite soil sample. All the gravels, pebbles, debris were removed. The soil was air dried, ground and sieved through a 2 mm sieve. Then the soil was poured on the piece of clean paper, spread evenly and divided into four quarters. The two opposite quarters were rejected while the rest were mixed again. The same process was repeated until half kilogram of soil was left. After that soil was collected in a clean bag and subjected to soil test to find out pH, organic matter, nitrogen, phosphorus and potassium content of the field. Soil samples were analyzed in the soil lab of Prithu Technical College, Lamahi, Dang Deukhuri. The total nitrogen was determined by the Kjeldahl method (Kirk, 1950), available phosphorus by spectrophotometer (Olsen et al., 1954) and available potassium by the Ammonium acetate method (Simrad, 1993). Organic matter was determined by the Walkley-Black method (Walkley and Black, 1934), pH by 1:2 soil water suspensions method (Jackson, 1973). The soil was rated according to the rating chart of soil (NARC, 2013). The soil fertility status of the field is given in (Table 1).

2.3 Seedling raising in nursery

The variety of chilli used in the study was NS 1701. In Nepal, NS 1701 was registered in 2010 (Krishi Diary, 2018). Seedlings were grown in the nursery by making a fine seedbed of area 2 m × 1 m on 17 July, 2018 with the line sowing method. The first irrigation was applied immediately after the sowing of seed and the rest of the irrigations were applied at seven days of interval.

2.4 Experimental approaches

The study was carried out in single-factor Randomized Complete Block Design (RCBD) with 4 replications having 6 treatments (i.e six levels of phosphorus) per replication. With a total area of 162.5 m², the individual plot measured 3.375 m² (2.25 m × 1.5 m). The spacing between each replication was 1 m and each treatment was 0.5 m. Healthy seedlings were transplanted on 20 August, 2018 in the prepared field. The spacing of 45 cm × 30 cm (row × plant) was maintained during transplanting. There were 25 plants in each plot (5 × 5). First irrigation was applied immediately after transplanting and the rest of the irrigations were given at the interval of seven days. FYM was applied at the rate of 20 t ha⁻¹ during field preparation (Singh and Bhandari, 2015). The phosphorus provided by FYM was not considered in our study. The nitrogen (N), phosphorus (P) and potassium (K)
were fully matured and before they changed from green to red. The same level of N and K was 100 kg ha\(^{-1}\) and 100 kg ha\(^{-1}\), respectively (Singh and Bhandari, 2015). The same level of N and K was applied in all the treatments. The six levels of phosphorus (0, 30, 60, 90, 120 and 150 kg P ha\(^{-1}\)) were applied. Urea was applied at three splits (i.e. 1/3rd as basal dose, 1/3rd after 30 days and remaining 1/3rd after 50 days of transplanting). The full dose of single superphosphate and muriate of potash were applied as a basal dose. FYM, urea, single superphosphate and muriate of potash were applied by the broadcasting method. Manual weeding was done at 30 and 60 days after transplanting. Manual harvesting was done six times at an interval of six days when fruits were fully matured and before they changed from green to red.

### Table 1. Soil analysis report of the field before planting of chilli

<table>
<thead>
<tr>
<th>Properties</th>
<th>Value</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>6.64</td>
<td>Slightly acidic</td>
</tr>
<tr>
<td>Total Nitrogen (%)</td>
<td>0.20</td>
<td>Medium</td>
</tr>
<tr>
<td>Available P(_2)O(_5) (kg ha(^{-1}))</td>
<td>47 (20.44 kg P ha(^{-1}))</td>
<td>Medium</td>
</tr>
<tr>
<td>Available K(_2)O (kg ha(^{-1}))</td>
<td>215 (179.17 kg K ha(^{-1}))</td>
<td>Medium</td>
</tr>
<tr>
<td>Organic matter (%)</td>
<td>4.10</td>
<td>Medium</td>
</tr>
</tbody>
</table>

Conversion factor: P\(_2\)O\(_5\) = P \times 2.30; K\(_2\)O = K \times 1.20

were supplied through urea, single superphosphate and muriate of potash respectively. The level of N and K was 100 kg ha\(^{-1}\) and 100 kg ha\(^{-1}\), respectively (Singh and Bhandari, 2015). The same level of N and K was applied in all the treatments. The six levels of phosphorus (0, 30, 60, 90, 120 and 150 kg P ha\(^{-1}\)) were applied. Urea was applied at three splits (i.e. 1/3rd as basal dose, 1/3rd after 30 days and remaining 1/3rd after 50 days of transplanting). The full dose of single superphosphate and muriate of potash were applied as a basal dose. FYM, urea, single superphosphate and muriate of potash were applied by the broadcasting method. Manual weeding was done at 30 and 60 days after transplanting. Manual harvesting was done six times at an interval of six days when fruits were fully matured and before they changed from green to red.

### 2.5 Data collection

Randomly five representative plants from the inner rows of each plot of each replication were labeled and tagged for recording data. Plants were tagged only from inner rows to avoid border effects. The parameters like growth (plant height and number of primary branches), phenological (days to 50% flowering), yield and yield contributing traits (number of fruits per plant, fruit length, yield per plant and per hectare) were recorded. The height of each tagged plant was measured from the soil surface to the tip of the plant at physiological maturity with measuring tape. The average plant height was calculated and expressed as plant height in centimeter (cm). The fruit yield of sampled plants was measured by the digital weighing balance. Then the average yield per plant was calculated and expressed as a yield per plant in gram (g). Finally, the average fruit yield of each treatment was calculated, based on that average yield of each treatment, the average yield per ha of each treatment was calculated and expressed in tonnes per hectare (t ha\(^{-1}\)).

### 2.6 Statistical analysis

The collected data were analyzed using R studio (Version 1.1.463). The Analysis of Variance (ANOVA) in Randomized Complete Block Design (RCBD) was used to determine the level of significance. The treatment means were compared by the Least Significant Difference (LSD) test at 1 and 5% levels of probability (Gomez and Gomez, 1984).

### 3 Results

#### 3.1 Growth parameters

The different phosphorus levels affect plant growth parameters i.e. plant height and number of primary branches (Table 2). The plant height was ranged from 52.15 cm to 60.22 cm. The highest plant height (60.22 cm) was recorded in 90 kg P ha\(^{-1}\) followed by 56.77 cm in 60 kg P ha\(^{-1}\) while 150 kg P ha\(^{-1}\) recorded the lowest plant height (52.15 cm). The plant height in 90 kg P ha\(^{-1}\) was about 1.16 times the plant height of 150 kg P ha\(^{-1}\). Further, the plant height in 90 kg P ha\(^{-1}\) was about 1.15 times the plant height of 0 kg P ha\(^{-1}\). Among six treatments, 90 kg P ha\(^{-1}\) showed the maximum number of primary branches (9.60) followed by 8.65 in 60 kg P ha\(^{-1}\). The minimum number of primary branches (7.65) was recorded in 0 kg P ha\(^{-1}\). The number of primary branches in 90 kg P ha\(^{-1}\) was about 1.26 times the number of primary branches of 0 kg P ha\(^{-1}\).
3.2 Phenological parameter

A significant effect of various phosphorus levels was observed for phenological parameter i.e. days to 50% flowering (Table 2). Among six treatments, 90 kg P ha$^{-1}$ required the lowest days (44.00) for 50% flowering followed by 46.25 days in 30 kg P ha$^{-1}$ while 0 kg P ha$^{-1}$ required the highest days (51.50) for 50% flowering. 30, 60, 90, 120 and 150 kg P ha$^{-1}$ behaved equally without any significant differences among each other. The difference in days to 50% flowering between 0 kg P ha$^{-1}$ and 90 kg P ha$^{-1}$ was 7.5 days.

3.3 Yield and yield contributing traits

Different phosphorus concentrations have an effect on yield and yield contributing traits i.e. number of fruits per plant, fruit length, yield per plant and per hectare (Table 3). Among six treatments, 60 kg P ha$^{-1}$ secured the highest position with 60.22 number of fruits per plant while 90 kg P ha$^{-1}$ produced 59.30 number of fruits. The least number of fruit per plant (53.62) was recorded in 150 kg P ha$^{-1}$. The number of fruits per plant in 60 kg P ha$^{-1}$ was about 1.13 times the number of fruits per plant of 150 kg P ha$^{-1}$. The number of fruits per plant in 60 kg ha$^{-1}$ was about 1.12 times the number of fruits per plant of 0 kg P ha$^{-1}$. Further, the results showed that 120 kg P ha$^{-1}$ attained the highest fruit length (6.80 cm) followed by 6.67 cm in 90 kg P ha$^{-1}$ while 30 kg P ha$^{-1}$ attained the lowest fruit length (5.62 cm). The fruit length in 120 kg P ha$^{-1}$ was about 1.21 times the fruit length of 30 kg P ha$^{-1}$. The fruit length in 120 kg P ha$^{-1}$ was about 1.19 times the fruit length of 0 kg P ha$^{-1}$. The yield per plant varied from 99.90 g to 123.20 g while yield per hectare varied from 7.40 t ha$^{-1}$ to 9.15 t ha$^{-1}$. Among six treatments, 90 kg P ha$^{-1}$ recorded the highest yield per plant (123.20 g) and per hectare (9.15 t ha$^{-1}$). The lowest yield per plant (99.90 g) and per hectare (7.40 t ha$^{-1}$) was obtained in 0 kg P ha$^{-1}$. Both the yield per plant and per hectare in 90 kg P ha$^{-1}$ was about 1.24 times the yield per plant and per hectare of 0 kg P ha$^{-1}$.

4 Discussion

In the present study, various phosphorus levels showed significant effect on all the parameters observed. The maximum plant height attained was 60.22 cm in 90 kg P ha$^{-1}$ after that plant height was drastically reduced with the lowest plant height (52.15 cm) in 150 kg P ha$^{-1}$. It is because phosphorus enhances plant growth but high levels of phosphorus cause stunted growth (Dawling, 2017). These results are in harmony with the findings of Akram et al. (2017) who obtained an increase in plant height up to certain phosphorus levels and decreased in plant height after certain levels of phosphorus and the stunted height at high levels of phosphorus.

Further, the highest number of primary branches (9.60) was found in 90 kg P ha$^{-1}$ while the lowest (7.65) was recorded in 0 kg P ha$^{-1}$. Phosphorus has a significant role in the number of branches and phosphorus enhances the number of branches (Islam et al., 2018). The current result is in harmony with the findings of Lodhi et al. (2017) on bell pepper. 50% flowering was obtained in 90 kg P ha$^{-1}$ at the lowest days (44.00) while 0 kg P ha$^{-1}$ required the highest days (51.50) for 50% flowering. It might be due to the vital role of phosphorus in early flowering (Singh, 2003). Naeem et al. (2002) obtained an early flowering on chilli with the application of phosphorus. Alabi (2006) also obtained an early 50% flowering on pepper with the application of phosphorus.

The highest number of fruits (60.22) was recorded in 60 kg P ha$^{-1}$. It is because phosphorus is one of the major influential nutrients for the number of fruits per plant (Khan et al., 2010). The lowest number of fruits per plant (53.62) was recorded in 150 kg P ha$^{-1}$. Epstein and Bloom (2005) stated that zinc is necessary for the fruiting process and Alloway (2008) stated that high phosphorus level causes zinc deficiency stress on crops. Thus, 150 kg P ha$^{-1}$ might have recorded the lowest number of fruits per plant. Except for 150 kg P ha$^{-1}$, other treatments recorded more number of fruits per plant than 0 kg P ha$^{-1}$.

The highest fruit length (6.80 cm) was recorded in 120 kg P ha$^{-1}$ because phosphorus helps in cell division and cell elongation (Singh, 2003). Similarly, phosphorus is also a major nutrient that plays significant role in maintaining good quality and length of fruits (Dubey et al., 2017). The lowest fruit length (5.62 cm) was recorded in 30 kg P ha$^{-1}$, not in 0 kg P ha$^{-1}$. The reason behind it might be plants of 0 kg P ha$^{-1}$ may have adapted some root modification because in the case of phosphorus deficiency plants modify their root morphology to get phosphorous (Vance et al., 2003; Raghothama and Karthikeyan, 2005). The difference of phosphorus level in 0 kg P ha$^{-1}$ and 30 kg P ha$^{-1}$ was not that much so this adaptation might have helped 0 kg P ha$^{-1}$ but 0 kg P ha$^{-1}$ was unable to overcome the results of other treatments on fruit length.

The highest yield per plant (123.20 g) and yield per hectare (9.15 t ha$^{-1}$) was recorded in 90 kg P ha$^{-1}$ while the lowest yield per plant (99.90 g) and per hectare (7.40 t ha$^{-1}$) was recorded in 0 kg P ha$^{-1}$. It is because phosphorus is involved in different cellular activities such as energy transfer, photosynthesis, transformation of sugar, and also enhances root proliferation that helps in improving soil nutrient exploration (Lodhi et al., 2017, 2019). Phosphorus enhances the yield of pepper (Hunde, 2020). Our result is in harmony with the findings of Chaudhary et al. (2007) on capsicum and El-Ezz (2018) on sweet pepper.
Table 2. Effect of different phosphorus levels on growth and phenological parameters of chilli

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Plant height (cm)</th>
<th>Number of primary branches</th>
<th>Days to 50% flowering</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 kg P ha⁻¹</td>
<td>52.45c</td>
<td>7.65b</td>
<td>51.50a</td>
</tr>
<tr>
<td>30 kg P ha⁻¹</td>
<td>55.90abc</td>
<td>8.40b</td>
<td>46.25b</td>
</tr>
<tr>
<td>60 kg P ha⁻¹</td>
<td>56.77ab</td>
<td>8.65ab</td>
<td>47.25b</td>
</tr>
<tr>
<td>90 kg P ha⁻¹</td>
<td>60.22a</td>
<td>9.60a</td>
<td>44.00b</td>
</tr>
<tr>
<td>120 kg P ha⁻¹</td>
<td>53.80bc</td>
<td>8.55ab</td>
<td>46.75b</td>
</tr>
<tr>
<td>150 kg P ha⁻¹</td>
<td>52.15c</td>
<td>7.85b</td>
<td>47.25b</td>
</tr>
</tbody>
</table>

LSD (0.05) 4.33 1.13 3.77
F test ** ***
CV% 5.20 8.93 5.307
Grand mean 55.21 8.45 47.16

Treatments means followed by the common letter or letters within the column are not significantly different among each other at a 5% level of significance. LSD = Least significant difference, CV = Coefficient of variation, *= Significant at P ≤ 0.05 and **= Significant at P ≤ 0.01

Table 3. Effect of different level of phosphorus on yield and yield parameters of chilli

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Number of fruits plant⁻¹</th>
<th>Fruit length (cm)</th>
<th>Yield plant⁻¹ (g)</th>
<th>Yield (t ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 kg P ha⁻¹</td>
<td>54.05c</td>
<td>5.72c</td>
<td>99.90c</td>
<td>7.40c</td>
</tr>
<tr>
<td>30 kg P ha⁻¹</td>
<td>55.72bc</td>
<td>5.62c</td>
<td>105.40c</td>
<td>7.80c</td>
</tr>
<tr>
<td>60 kg P ha⁻¹</td>
<td>60.22a</td>
<td>6.32abc</td>
<td>109.90bc</td>
<td>8.15bc</td>
</tr>
<tr>
<td>90 kg P ha⁻¹</td>
<td>59.30ab</td>
<td>6.67ab</td>
<td>123.20a</td>
<td>9.15a</td>
</tr>
<tr>
<td>120 kg P ha⁻¹</td>
<td>56.27bc</td>
<td>6.80a</td>
<td>117.50ab</td>
<td>8.70ab</td>
</tr>
<tr>
<td>150 kg P ha⁻¹</td>
<td>53.62c</td>
<td>5.95bc</td>
<td>100.85c</td>
<td>7.47c</td>
</tr>
</tbody>
</table>

LSD (0.05) 3.62 0.75 11.08 0.82
F test ** * ** **
CV% 4.25 8.08 6.71 6.75
Grand mean 56.53 6.18 109.45 8.11

Treatments means followed by the common letter or letters within the column are not significantly different among each other at a 5% level of significance. LSD = Least significant difference, CV = Coefficient of variation, *= Significant at P ≤ 0.05 and **= Significant at P ≤ 0.01
Although 150 kg P ha$^{-1}$ was the highest phosphorus level in our study, 150 kg P ha$^{-1}$ was unable to secure the top position in any of the observed parameters. Further, 120 kg P ha$^{-1}$ secured top position in only one parameter i.e. fruit length. One reason behind this is that high levels of phosphorus decrease the availability of phosphorus solubilizing microbes which help to hydrolyze organic and inorganic insoluble phosphorus compounds to soluble phosphorus that can easily be taken by plants (Zheng et al., 2017). But in the reduction of such microbes, applied phosphorus can’t be utilized appropriately by plants. Another reason is that high levels of phosphorus restricts the absorption of nitrogen and also cause deficiency of zinc, iron, cobalt, and calcium because high phosphorus locks these nutrients (Dawling, 2017). The next reason is high levels of phosphorus also restrict the growth of mycorrhizae due to which plants become unable to absorb nutrients and water properly (Dawling, 2017). Due to these reasons, chilli might have shown poor performance at high levels of phosphorus. Other researchers also noted a decrease in the performance of crops due to high levels of phosphorus. Alabi (2006) obtained an increase in plant height of pepper with phosphorus application but no significant effect on the height with a high level of phosphorus. Chaudhary et al. (2007) reported an increase in yield and yield attributes of capsicum up to certain phosphorus levels and a decrease with high phosphorus levels. Similarly, Bahuguna et al. (2015) also noted a decrease in yield per hectare of capsicum with high phosphorus levels. El-Ezz (2018) on sweet pepper noted an increase in the number of fruits per plant, yield per plant and yield per hectare with the application of phosphorus but a decrease in the average number of fruits per plant, yield per plant and per hectare with the application of high percentage of phosphorus.

However, it should be noted that the study was conducted in an open farmer’s field of inner terai Deukhuri, Dang. The soil of the field was slightly acidic with medium nitrogen, phosphorus, potassium and organic matter. Thus, the environmental factors, pH, soil nutrient content including the organic matter of the field might have influenced the results to some extent. The effectiveness and availability of phosphorus to crops depend on various factors such as the climate, pH, soil nutrient content including organic matter (USAD-NARS, 2014).

5 Conclusion

Based on the result obtained from the study, 90 kg P ha$^{-1}$ level of phosphorus showed superiority in terms of growth parameters (plant height and number of primary branches), phenological parameter (days to 50% flowering), yield per plant and per hectare than other phosphorus levels. Our study also concluded that neither low nor high phosphorus levels enhance the growth and yield of chilli. So for the soil with a medium phosphorus level of inner terai place like Deukhuri, Dang it is suggested to use a 90 kg P ha$^{-1}$ to obtain a higher yield.

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Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

References


