Science, Technology and Development 35 (4): 185-191, 2016
ISSN 0254-6418 / DOI: 10.3923/std.2016.185.191

Effect of Potassium and Phosphorus on the Physical and Biochemical Characteristics of Local Garlic under the Agro-climatic Conditions of Rawalakot, Azad Jammu and Kashmir

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Abstract: The effect of potassium (K) and phosphorus (P) on morphological and biochemical characteristics of garlic (*Allium sativum* L.) was studied at Rawalakot, Azad Jammu and Kashmir (AJK), during the year 2011-12. Three levels of potassium (140, 175 and 210 kg K ha^{-1}) and two levels of phosphorus (105 and 140 kg P ha^{-1}) were applied alone and in different combination (140 kg K ha^{-1} + 105 kg P ha^{-1}, 140 kg K ha^{-1} + 140 kg P ha^{-1}, 175 kg K ha^{-1} + 105 kg P ha^{-1}, 175 kg K ha^{-1} + 140 kg P ha^{-1}, 210 kg K ha^{-1} + 105 kg P ha^{-1}, 210 kg K ha^{-1} + 140 kg P ha^{-1}). The experiment was laid out under RCBD (randomized complete block design) with twelve treatments and three replications. The data was collected on days to sprouting, germination percentages, plant height, number of leaves per plant, weight of bulb per plant, number of cloves per bulb, diameter of the bulb, leaf area, leaf fresh weight, leaf dry weight, pH, chlorophyll content of leaves, acidity, vitamin C, total phenolic content and total anti-oxidant potential. The data obtained were statistically analyzed for analysis of variance and means were compared, using LSD. Potassium @ 210 kg ha^{-1} and Phosphorus @140 kg ha^{-1} gave best results for days to sprouting, plant height, number of leaves per plant, dry weight of leaves and ascorbic acid. Therefore, the potassium application @ 210 kg ha^{-1} along with phosphorus @140 kg ha^{-1} is considered as suitable dose for the best production of garlic under Rawalakot conditions.

Key words: Morphological and biochemical characteristics, Amount of potassium and phosphorus, Rawalakot environmental conditions.

INTRODUCTION

Garlic (*Allium sativum* L.) belongs to the family *Alliaceae* (Tidal, 1986). It is an erect herb with the height of 75-90 cm, grown annually and vegetatively. It is grown best in dry and mild winter (Brewster, 1994). In addition to vitamins, garlic is rich in sugar, protein, fat, potassium, calcium, sulfur, phosphorus, fiber and iodine. Due to its pungent flavour, it is used as a spice, flavoring and seasoning for foodstuff. A 100 g edible portion of garlic contains 59% moisture, 6.4 g protein, 149 k/Cal energy, 0.5 g fats, 33.1 g carbohydrates, 1.5 g fiber, 181 mg Ca, 153 mg P, 1.7 mg Fe, 17 mg Na, 401 mg K, 0.08 mg riboflavin, 0.25 mg thiamine, 0.06 mg nicotinamide and 10.8 mg ascorbic acid (Lorenz and Maynard, 1988).

Garlic has distinct odor, which is produced by an organic sulphur compound, known as “Allicin” and is well known to be a natural antiseptic. Modern research regarding garlic reveals that it kills TB germs (Hussain *et al.*, 2005). It is beneficial for treatment of lingering stomach disease, earache and sore ear (Saleem *et al.*, 2002).

The presence of phosphorus in the soil enhanced plant growth as a major building block of DND molecules. Inorganic phosphorus is readily absorbed and used by plant, if it is not fixed (Hinsinger, 2001). Phosphorus is making up about 0.2% of a plant’s dry weight and it is essential for root development. It is a vital component of nucleic acids (DNA and RNA), energy molecules (AMP, ADP and ATP) and phospholipids. Limited phosphorus in bulbous crops reduced root growth, leaf growth, bulb size, yield and delayed maturation (Stone *et al*., 2001).

Potassium is very important in overall metabolism of plant enzymes activity. Potassium plays an important role in photosynthesis by increasing growth and has advantageous effect on water consumption (Mansour, 2006). Soil, rich in potassium, results in high yield, high oil content and increased bulb size of garlic (Jahangir *et al.*, 2005). Potassium nutrition is one of the major factors that affect growth, yield and quality of garlic. There is a close relationship between the applied K levels and garlic productivity (Black, 1960; Bidwell, 1979).

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Potassium and phosphorus are major elements, required by the plant in larger amount and are supplied by fertilizers. Keeping in view the importance of potassium and phosphorus for the plant, this research project was carried out with the objective to sort out most suitable levels of potassium and phosphorus for better growth and quality of garlic at Rawalakot, Azad Jammu and Kashmir.

Study area: The study area (Rawalakot) is mainly hilly and mountainous. It is characterized by a temperature that is sub-humid climate with annual average rainfall ranging from about 500-2000 mm. The mean annual temperature ranges from a minimum of 0°C to a maximum of 30°C, accompanied by severe cold and snow in winter (Abbasi and Khan, 2004).

MATERIALS AND METHODS

This research work was carried out at research farm of Faculty of Agriculture, University of Azad Jammu and Kashmir, to evaluate the suitable doses of potassium and phosphorus for local garlic of Rawalakot. Variable doses of potassium (sulphate of potash) and phosphorus (SSP) in different combinations were used as shown in Table 1.

Table 1: Variable doses of potassium (sulphate of potash) and phosphorus (SSP).

T_1	K0P0 as control
T_2	K1P0 (140 kg K ha^{-1} + 0 kg P ha^{-1})
T_3	K2P0(175 kg K ha^{-1} + 0 kg P ha^{-1})
T_4	K3P0 (210 kg K ha^{-1} + 0 kg P ha^{-1})
T_5	K0P1 (0 kg K ha^{-1} + 105 kg P ha^{-1})
T_6	K0P2 (0 kg K ha^{-1} + 140 kg P ha^{-1})
T_7	K1P1 (140 kg K ha^{-1} + 105 kg P ha^{-1})
T_8	K1P2 (140 kg K ha^{-1} + 140 kg P ha^{-1})
T_9	K2P1 (175 kg K ha^{-1} +105 kg P ha^{-1})
T_{10}	K2P2 (175 kg K ha^{-1} + 140 kg P ha^{-1})
T_{11}	K3P1 (210 kg K ha^{-1} + 105 kg P ha^{-1})
T_{12}	K3P2 (210 kg K ha^{-1} + 140 kg P ha^{-1})

1. Pre-soil analysis: Soil pH was measured by 1:2 soil water ratios. Soil (10 g) was taken in 50 ml beaker and 20 ml water was added and its pH was determined with pH meter (McLean, 1982). Phosphorus from soil samples was determined, using AB-DTPA method (Soltanpour and Workman, 1979). In order to determine concentration of P in the samples, standard curve method was used. Calculations: P (mg L^{-1}) = P (dilution factor × mg L^{-1} in extract). To extract K, 5 g soil was shaken with 100 ml 1N ammonium acetate solution ($NH_4C_2H_3O_2$). The mixture was filtered by Whatman filter paper No. 40. The extractable K in the extract was measured directly by Flame Photometer (Cambardella *et al.,* 2003). Nitrogen was determined by Kjeldahl method (1883). Nitrogen was determined by titrating the sample against 0.01 N HCl (Bremner and Mulvaney, 1982).

2. Data collection: Days to sprouting were counted from date of sowing in each plot and the average was determined. The germination of cloves for five selected plants per plot from each treatment was counted and germination percentage was determined by the following formula.

Germination percentage = Germinated cloves / Total no. of planted cloves × 100. The plant height was measured with the help of measuring tape from the soil surface to the top of plant and then average was calculated. Number of leaves of the individual plants was counted separately in each bed and then the average was determined. With the help of top loading balance, weight of bulb of each plant was taken. The diameter of the bulb was measured with the help of Vernier's callipers. Fresh weight of leaves of six selected plants from each treatment was measured, using electrical balance. The leaves of six selected plants from each treatment were taken and oven dried at 65°C for 48 hours and then weighed on electric balance. Five plants were randomly selected from each treatment and with the help of leaf area meter, their leaf area was measured and data was collected. pH was measured with the help of digital pH meter. Chlorophyll content readings were made with a handheld dual-wavelength meter (SPAD 502, Chlorophyll meter, Minolta Camera Co., Ltd., Japan. The titratable acidity was evaluated by the following method, given in AOAC. (1990). Acidity was determined by the following formula:

$$\text{Acidity\%} = \frac{0.1 \times \text{equivalent wt. of acid} \times \text{normality of NaOH} \times \text{ml of NaOH used}}{\text{Wt. of sample}} \times 100$$

Vitamin C evaluation was carried out, using the method developed by Ruck (1963). The total phenolic content as garlic acid equivalent (GAE) was evaluated by the method of Singleton *et al*. (1999). The total antioxidant potential of the extracts was estimated in the laboratory, using the phosphomolybdenum reduction assay according to Prieto *et al*. (1999).

3. Statistical analysis: The calculated data was statistically analyzed for analysis of variance (ANOVA) and means were compared, using LSD (least significant difference) test (Steel *et al.,* 1997).

RESULTS AND DISCUSSION

1. Effect of potassium and phosphorus on sprouting and plant height: The data concerning to days to sprouting and plant height of garlic was significantly influenced by the application of potassium and phosphorus as described in Table 2. Minimum (12.10) days to sprouting of garlic was found when potassium @ 175 kg ha^{-1} (K_2) was applied while the maximum (16.78) days to sprouting were recorded with potassium @ 0 kg ha^{-1} (K_0). These results agree with those of Derbala and El-Kader (2009). The data pertaining to days to sprouting of garlic was significantly influenced by the application of phosphorus. Minimum (13.20) days to sprouting of garlic were found when phosphorus @ 140 kg ha^{-1} (P_2) was given while the maximum (15.45) days to sprouting were recorded when potassium @ 0 kg ha^{-1} (P_0) was given. The presence of major nutrients enhanced the biochemical processes within the seeds or cloves that resulted in shorter time needed for seed germination. These results resemble those reported by Hilman and Noordiyati (1988).

Table 2: Effect of potassium and phosphorus on sprouting and plant height.

Treatment	Mean
Means for effect of potassium on days to sprouting	
LSD value = 0.85763, Means sharing same letters do not differ significantly	
K_0 (K @ 0 kg ha^{-1})	16.78 c
K_1 (K @ 140kg ha^{-1})	14.46 b
K_2 (K @ 175 kg ha^{-1})	12.10 a
K_3 (K @ 210 kg ha^{-1})	13.00 a
Means for effect of phosphorus on days to sprouting	
LSD value = 0.7425, Means sharing same letters do not differ significantly	
P_0 (P @ 0 kg ha^{-1})	15.45 c
P_1 (P @ 105kg ha^{-1})	13.60 b
P_2 (P @ 140 kg ha^{-1})	13.20 a
Means of potassium on plant height (cm)	
LSD value = 0.8684, Means sharing same letters do not differ significantly	
K_0 (K @ 0 kg ha^{-1})	50.14 c
K_1 (K @ 140kg ha^{-1})	60.26 b
K_2 (K @ 175 kg ha^{-1})	60.19 b
K_3 (K @ 210 kg ha^{-1})	65.59 a
Means for effect of phosphorus on plant height (cm)	
LSD value = 0.752, Means sharing same letters do not differ significantly	
P_0 (P @ 0 kg ha^{-1})	55.17 c
P_1 (P @ 105kg ha^{-1})	59.79 b
P_2 (P @ 140 kg ha^{-1})	62.18 a

The results related to plant height of garlic were significantly influenced by the application of potassium. The maximum (65.59 cm) plant height of garlic was observed when potassium @ 210 kg ha^{-1} (K_3) was applied while the potassium @ 0 kg ha^{-1} (K_0) gave minimum (50.14 cm) plant height. Ruiz (1985) also gave similar results when he observed that garlic height increased with increasing level of potassium. Phosphorus significantly enhanced the plant height of garlic. Maximum (62.18 cm) plant height was noted when phosphorus @ 140 kg ha^{-1} (P_2) was applied, while the minimum (55.17 cm) plant height was observed when 0 kg of phosphorus ha^{-1} (P_0) was applied. These results are in agreement with the findings of Majanbu *et al*. (1985) and Abbas *et al*. (2006).

Potassium and phosphorus significantly increased the plant height when given in combination. Maximum (68.47 cm) plant height was found in K_3P_2 and minimum (47.10 cm) plant height was observed in control K_0P_0. All the other treatments showed in-between results.

2. Number of plant's leaves: The results regarding number of plant's leaves were significantly increased by application of potassium (Table 3).

Table 3: Interactive effect of potassium and phosphorus levels on plant height (cm).

Interaction	Mean	Interaction	Mean
K_0P_0	47.10 h	K_1P_1	55.10 e
K_1P_0	50.10 g	K_1P_2	61.83 d
K_2P_0	53.27 f	K_2P_1	63.63 c
K_3P_0	56.11 e	K_2P_2	62.38 cd
K_0P_1	61.32 d	K_3P_1	65.93 b
K_0P_2	63.34 c	K_3P_2	68.47 a

LSD = 1.504, Means sharing same letters do not differs significantly.

Maximum number (8.457) of leaves per plant were noted when potassium @ 210 kg ha^{-1} (K_2) was applied while minimum number (6.478) of leaves per plant were observed at 0 kg potassium ha^{-1} (K_0). Potassium generally increases the growth and development processes of the plant that resulted in an increase in the number of leaves per plant. The leaves are the plant factories that manufacture carbohydrates. The photosynthesis occurs in leaf cells and carbohydrates are formed these. El-Bassiony (2006) observed similar results where potassium showed positive response for number of leaves of garlic plants. Phosphorus also significantly increased the number of leaves per plant of garlic and the results are presented in Table 4. Maximum number of leaves per plant (8.03) was shown by the application of phosphorus @ 140 kg ha^{-1} (P_2) while minimum leaves per plant (7.10) were noted at 0 kg phosphorus ha^{-1} (P_0). Phosphorus increased the number of leaves per plant of garlic as phosphorus involves in the many plant growth developmental processes and increased in number of leaves per plant. Islam *et al*. (2007) found that number of leaves per plant of garlic was significantly increased by application of phosphorus.

Table 4: Effect of potassium and phosphorus on leaves per plant.

Treatment	Mean
Means of potassium on number of leaves per plant	
LSD value = 0.1348, Means sharing same letters do not differ significantly.	
K_0 (K @ 0 kg ha^{-1})	6.478 c
K_1 (K @ 140kg ha^{-1})	7.780 b
K_2 (K @ 175 kg ha^{-1})	7.789 b
K_3 (K @ 210 kg ha^{-1})	8.457 a
Means for effect of phosphorus on number of leaves per plant	
LSD value = 0.1167,Means sharing same letters do not differ significantly	
P_0 (P @ 0 kg ha^{-1})	7.101 c
P_1 (P @ 105kg ha^{-1})	7.742 b
P_2 (P @ 140 kg ha^{-1})	8.035 a

Potassium and phosphorus in combination significantly increased the number of leaves per plant (Table 5). Maximum number (8.88) of leaves per plant observed in K_2P_2. K_0P_0 gave the minimum number (6.27) of leaves per plant. Reddy *et al*. (2000) found that number of leaves per plant of garlic was significantly increased by application of potassium and phosphorus.

Table 5: Interactive effect of potassium and phosphorus levels on number of leaves per plant.

Interaction	Mean	Interaction	Mean
K_0P_0	6.13 f	K_1P_1	7.33 d
K_1P_0	6.36 f	K_1P_2	7.96 c
K_2P_0	6.93 e	K_2P_1	8.06 c
K_3P_0	6.90 e	K_2P_2	8.88 a
K_0P_1	8.06 c	K_3P_1	8.56 b
K_0P_2	8.37 b	K_3P_2	8.76 ab

LSD = 0.2334, Means sharing same letters do not differs significantly.

3. Fresh weight of leaves (g): The examination of fresh weight of leaves of garlic showed that potassium @ 175 kg ha^{-1} (K_2) showed superiority (15.00 g) over all other levels of potassium, while the minimum (10.91 g) fresh weight of leaves was noted when potassium @ 0 kg ha^{-1} (K_0) was applied as described in Table 6.

Table 6: Effect of potassium and phosphorus on leaves' fresh weight.

Treatment	Mean
Means for effect of potassium on leaves fresh weight (g) LSD value = 0.2415, Means sharing same letters do not differ significantly	
K_0 (K @ 0 kg ha^{-1})	10.91d
K_1 (K @ 140kg ha^{-1})	12.98c
K_2 (K @ 175 kg ha^{-1})	15.00a
K_3 (K @ 210 kg ha^{-1})	13.75b
Means of phosphorus on leaves' fresh weight (g) LSD value = 0.2091, Means sharing same letters do not differ significantly.	
P_0 (P @ 0 kg ha^{-1})	12.05 c
P_1 (P @ 105kg ha^{-1})	13.40 b
P_2 (P @ 140 kg ha^{-1})	14.03 a

These results are similar to the conclusions of Park *et al.* (1997). It has been observed that phosphorus significantly enhanced the fresh weight of leaves of garlic. Higher fresh weight of leaves (14.03 g) was recorded when phosphorus was applied @ 140 kg ha^{-1} (P_2), while lower (12.0 g) was found with 0 kg phosphorus ha^{-1} (P_0). The combined application of potassium and phosphorus significantly increased the fresh weight of leaves as revealed in Table 7. Maximum fresh weight (16.20 g) of leaves was given by K_2P_2. Minimum of fresh weight of leaves (10.10 g) was found in K_0P_0 (control). These results are similar to that of Islam *et al*. (2007). They found that the combination of potassium and phosphorus gave significantly higher fresh weight of leaves.

Table: 7: Interactive effect of potassium and phosphorus levels on fresh leaves' weight

Interaction	Mean	Interaction	Mean
K_0P_0	10.10 i	K_1P_1	13.11 f
K_1P_0	11.10 h	K_1P_2	13.63 de
K_2P_0	11.54 g	K_2P_1	14.51 c
K_3P_0	11.83 g	K_2P_2	16.20 a
K_0P_1	13.23 ef	K_3P_1	15.63 b
K_0P_2	13.87 d	K_3P_2	13.17 f

LSD = 0.4182, Means sharing same letters do not differs significantly.

4. Dry leaves weight, area and plant bulb: It is evident from Table 8 that maximum (13.06 g) dry weight of leaves of garlic was found when potassium @ 210 kg ha^{-1} (K_2) was applied, while the minimum (11.66 g) dry weight of leaves was obtained when potassium @ 0 kg ha^{-1} (K_0) was applied. Mazrouh and El-B Ragab (2000) reported similar results; potassium enhanced the dry weight of leaves of garlic. It is evident that maximum (12.81 g) dry weight of leaves of garlic was found when phosphorus @ 140 kg ha^{-1} (P_2) was applied, while the minimum (11.12 g) dry weight of leaves was obtained when phosphorus @ 0 kg ha^{-1} (P_0) was applied. Similar results were reported by Patel *et al*. (1996) that dry leaves weight is enhanced by phosphorus application.

Table 8: Effect of potassium and phosphorus on leaves dry weight, area and plant bulb.

Treatment	Mean
Means of potassium on leave dry weight (g) LSD value = 0.4627, Means sharing same letters do not differ significantly.	
K_0 (K @ 0 kg ha^{-1})	11.66 c
K_1 (K @ 140kg ha^{-1})	11.81 c
K_2 (K @ 175 kg ha^{-1})	12.45 b
K_3 (K @ 210 kg ha^{-1})	13.06 a
Means for effect of phosphorus on leaves dry weight (g) LSD value = 0.4007, Means sharing same letters do not differ significantly	
P_0 (P @ 0 kg ha^{-1})	11.12 b
P_1 (P @ 105kg ha^{-1})	12.81 a
P_2 (P @ 140 kg ha^{-1})	12.81 a
Means for effect of potassium on leaf area LSD value = 1.519, Means sharing same letters do not differ significantly	
K_0 (K @ 0 kg ha^{-1})	69.01 d
K_1 (K @ 140kg ha^{-1})	83.26 c
K_2 (K @ 175 kg ha^{-1})	91.29 b
K_3 (K @ 210 kg ha^{-1})	96.26 a
Means of phosphorus for leaf area LSD value = 1.315, Means sharing same letters do not differ significantly	
P_0 (P @ 0 kg ha^{-1})	79.46 c
P_1 (P @ 105kg ha^{-1})	86.11 b
P_2 (P @ 140 kg ha^{-1})	89.29 a
Means of potassium on weight of bulb plant^{-1}(g) LSD value = 0.7954**,** Means sharing same letters do not differ significantly	
K_0 (K @ 0 kg ha^{-1})	31.86 d
K_1 (K @ 140kg ha^{-1})	45.54 c
K_2 (K @ 175 kg ha^{-1})	56.33 a

K_3 (K @ 210 kg ha^{-1})	48.89 b
Means for effect of phosphorus on weight of bulb plant^{-1} (g) LSD value = 0.6889, Means sharing same letters do not differ significantly	
P_0 (P @ 0 kg ha^{-1})	40.74 c
P_1 (P @ 105kg ha^{-1})	46.24 b
P_2 (P @ 140 kg ha^{-1})	49.84 a

It was also revealed that the leaf area of garlic was significantly influenced by the application of potassium. Leaf area was 96.26 cm^2 when potassium @ 210 kg ha^{-1} (K_2) was given, while the minimum (69.01 cm^2) leaf area was achieved when potassium @ 0 kg ha^{-1} (K_0) was applied. Results showed that leaf area positively responded to the increasing levels of potassium as it is responsible for rapid foliage growth and helps in new growth of the plant parts that resulted in an increase in the leaf area. Sakarvadia *et al.* (2009) also reported the results in line with these results, i.e., leaf expansion is promoted by high potassium levels. Phosphorus significantly increased the leaf area as shown in Table 8. Maximum (89.20 cm^2) leaf area was noted when phosphorus was applied @ 140 kg ha^{-1} (P_2), while the minimum (79.46 cm^2) leaf area was observed when phosphorus @ 0 kg ha^{-1} (P_0) was given. Abbas *et al*. (2006) depicted that all the growth and developmental processes significantly increased by the application of phosphorus.

The data regarding the weight of bulb plant^{-1} of garlic showed significant results for potassium. Maximum (56.33 gm) weight of bulb of garlic was observed when potassium @ 175 kg ha^{-1} (K_2) was applied, while the minimum (31.86 gm) weight of bulb was noted when potassium @ 0 kg ha^{-1} (K_0) was applied. There was a close relationship between the applied K levels and garlic productivity. In this regard**,** El Mansi *et al*. (1985) found that garlic plant growth, total yield and its components as well as keeping the quality of bulbs and bulb weight significantly increased by increasing the applied K levels. A comparison of mean values of phosphorus for weight of bulb (g), phosphorus significantly increased the weight of bulb of garlic and is presented in Table 9.

Table 9: Interactive effect of potassium and phosphorus levels on weight of bulb per plant (g).

Interaction	Mean	Interaction	Mean
K_0P_0	29.47 j	K_1P_1	44.33 f
K_1P_0	30.90 i	K_1P_2	48.87 e
K_2P_0	35.20 h	K_2P_1	53.47 c
K_3P_0	37.17 g	K_2P_2	52.38 cd
K_0P_1	48.43 e	K_3P_1	56.77 b
K_0P_2	51.01 d	K_3P_2	59.84 a

LSD = 1.378, Means sharing same letters do not differs significantly.

Maximum (49.84 gm) weight of bulb was obtained when phosphorus was applied @ 140 kg ha^{-1} (P_2), while the minimum (40.74 gm) weight of bulb was noted by the treatment containing 0 kg phosphorus ha^{-1} (P_0). The combination of potassium and phosphorus significantly increased the weight of bulb. Maximum (59.84 gm) weight of bulb was noted in K_3P_2. Minimum (29.47 gm) weight of bulb was obtained in K_0P_0 (control). The other treatments showed in between results. Naruka and Dhaka (2009), and Abbas *et al*. (2006) showed that potassium and phosphorus significantly increased the cloves weight of garlic.

5. Bulb diameter, chlorophyll, phenolic content and ascorbic acid: The observation recorded on bulb diameter of garlic showed a significant difference for potassium (Table 10). Maximum (5.913 cm^2) bulb diameter of garlic was noted when potassium was given @ 210 kg ha^{-1} (K_3), while the minimum (3.347 cm^2) bulb diameter was observed when nitrogen @ 0 kg ha^{-1} (K_0) was applied. El Morsy *et al.* (2004) also reported similar results; potassium application increased the bulb diameter, bulb weight and its quality. Phosphorus significantly increased the bulb diameter of garlic. Maximum (5.233 cm^2) bulb diameter was recorded when phosphorus was applied @ 140 kg ha^{-1} (P_2), while the minimum (4.269 cm^2) bulb diameter was shown in the treatment containing 0 kg phosphorus ha^{-1} (P_0).

The chlorophyll content of garlic leaves significantly increased by application of the potassium. Maximum chlorophyll content (9.86 mg cm^{-2}) of garlic was found when potassium @ 210 kg ha^{-1} (K_2) was applied, while the minimum chlorophyll content (7.02 mg cm^{-2}) was shown when potassium @ 0 kg ha^{-1} (K_0) was used. Potassium enhanced the chemical constituents of garlic, such as, chlorophyll content, total soluble solids and volatile oils (El Sayed and El Morsy, 2012). The results of chlorophyll content of garlic leaves significantly increased by the application of phosphorus. Maximum (9.16 mg cm^{-2}) chlorophyll content of garlic was found when phosphorus @ 140 kg ha^{-1} (P_2) was applied, while the minimum (8.09 mg cm^{-2}) chlorophyll content was observed when phosphorus @ 0 kg ha^{-1} (P_0) was used.

It is evident that maximum (15.591 mg/g) phenolic content of garlic was found when potassium @ 210 kg ha^{-1} (K_3) was applied, while the minimum (12.807 mg/g) phenolic content was obtained when potassium @ 0 kg ha^{-1} (K_0) was applied. Many chemical constituents, including phenolics, were significantly increased with increasing K levels (El Morsy *et al.*, 2004). It is clear that phosphorus significantly increased the phenolic content of garlic. A higher level of phosphorus 100 kg ha^{-1} (P_2) gave maximum (156.3 mg/g) phenolic content, while minimum (143.4 mg/g) phenolic content was obtained when phosphorus @ 0 kg ha^{-1} (P_0) was applied.

The results, regarding contents of ascorbic acid of garlic, showed significant differences to the application of potassium. Maximum (28.90 mg/100 g) ascorbic acid of garlic was recorded when potassium @210 kg ha^{-1} (K_3) was applied, while lower (21.38

mg/100 g) ascorbic acid was observed when potassium was given @ 0 kg ha^{-1} (K_0) (Table 10). The application of potassium fertilizer increased total carbohydrates in leaves and bulb, volatile oils in bulb and ascorbic acid (Park *et al.,* 1997).

Table 10: Effect of potassium and phosphorus on bulb diameter and chlorophyll content.

Treatment	Mean
Means for effect of potassium on diameter of bulb (cm^2)	
LSD value = 0.1157 Means sharing same letters do not differ significantly.	
K_0 (K @ 0 kg ha^{-1})	3.347 d
K_1 (K @ 140kg ha^{-1})	4.858 c
K_2 (K @ 175 kg ha^{-1})	5.210 b
K_3 (K @ 210 kg ha^{-1})	5.913 a
Means of phosphorus on diameter of bulb (cm^2)	
LSD value = 0.1002, Means sharing same letters do not differ significantly.	
P_0 (P @ 0 kg ha^{-1})	4.269 c
P_1 (P @ 105kg ha^{-1})	4.993 b
P_2 (P @ 140 kg ha^{-1})	5.233 a
Means for effect of potassium on chlorophyll content (mgcm^{-2})	
LSD value = 0.2782, Means sharing same letters do not differ significantly.	
K0 (K @ 0 kg ha^{-1})	7.02 d
K1 (K @ 140kg ha^{-1})	8.60 c
K2 (K @ 175 kg ha^{-1})	9.41 b
K3 (K @ 210 kg ha^{-1})	9.86 a
Means for effect of phosphorus on chlorophyll content (mgcm^{-2})	
LSD value = 0.2410, Means sharing same letters do not differ significantly.	
P_0 (P @ 0 kg ha^{-1})	8.09 b
P_1 (P @ 105kg ha^{-1})	8.92 a
P_2 (P @ 140 kg ha^{-1})	9.16 a
Means of potassium on phenolic content (mg/g)	
LSD value = 4.327**,** Means sharing same letters do not differ significantly.	
K_0 (K @ 0 kg ha^{-1})	125.2 d
K_1 (K @ 140kg ha^{-1})	147.5 c
K_2 (K @ 175 kg ha^{-1})	160.3 b
K_3 (K @ 210 kg ha^{-1})	167.9 a
Means of phosphorus on phenolic content (mg/g)	
LSD value = 3.747, Means sharing same letters do not differ significantly	
P_0 (P @ 0 kg ha^{-1})	143.4 c
P_1 (P @ 105kg ha^{-1})	151.0 b
P_2 (P @ 140 kg ha^{-1})	156.3 a
Means of potassium on ascorbic acid (mg 100^{-1} g)	
LSD value = 1.854 ,Means sharing same letters do not differ significantly	
K_0 (K @ 0 kg ha^{-1})	21.38 c
K_1 (K @ 140kg ha^{-1})	24.06 b
K_2 (K @ 175 kg ha^{-1})	27.62 a
K_3 (K @ 210 kg ha^{-1})	28.90 a

CONCLUSION

It is concluded from this study that potassium @ 210 kg ha^{-1} and phosphorus @ 140 kg ha^{-1} gave the best results for days to sprouting, number of leaves per plant, dry weight of leaves, plant height, leaf area, bulb diameter, clove weight bulb^{-1}, chlorophyll content and ascorbic acid. Therefore, the potassium application @ 210 kg ha^{-1} along with phosphorus @140 kg ha^{-1} is the suitable dose for the best production of garlic under Rawalakot condition.

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