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Original Research

Efficacy of Inorganic Phosphorus and Farmyard Manure on Production and Quality of Garlic (*Allium sativum* L.)

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ABSTRACT

Organic and inorganic fertilizers improve soil fertility and give both macro and micronutrients to the soil for better growth of agricultural crops. Therefore, current study was designed to find out the efficacy of inorganic phosphorus (P) alone and in combination farmyard manure (FYM) applied in various doses on production and quality aspects of garlic. A field experiment was organized in a randomized complete block design, replicated thrice using different rates of P in the form of single super phosphate (SSP) and farmyard manure (FYM). Seven different treatments of various levels of P, either using inorganic phosphorus from SSP alone or in combination with organic phosphorus from FYM, i.e. T_0 = control; T_1 = 50 kg P ha^{-1} (SSP); T_2 = 70 kg P ha^{-1} (SSP); T_3 = 90 kg P ha^{-1} (SSP); T_4 = 25 kg P ha^{-1} (SSP) + 25 kg P ha^{-1} (FYM); T_5 = 35 kg P ha^{-1} (SSP) + 35 kg P ha^{-1} (FYM); T_6 = 45 kg P ha^{-1} (SSP) + 45 kg P ha^{-1} (FYM)] were applied to the soil. All the growth, yield and quality parameters recorded showed significant response when P was applied in combination of inorganic and organic sources as compared with control and inorganic P alone. A combined treatment of 45 kg P ha^{-1} (SSP) + 45 kg P ha^{-1} (FYM) gave comparatively better results in terms of plant height (66.87 cm), fresh leaf weight (2.70 g), leaf area plant^{-1} (83.83 cm^2), relative leaf chlorophyll content (11.90), weight of bulb plant^{-1} (42.66 g), diameter of bulb (4.50 cm), number of cloves bulb^{-1} (8.50), bulb yield (4382.96 kg ha^{-1}) and vitamin C content (6.43 mg 100 g^{-1}). Thus, it was concluded from this study that a combined treatment of 45 kg P ha^{-1} (SSP) + 45 kg P ha^{-1} (FYM) should be applied for quality production of garlic under rainfed conditions of Rawalakot.

Keywords: *Organic fertilizer, inorganic fertilizer, growing conditions, crop yield, quality.*

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INTRODUCTION

Garlic (*Allium sativum* L.) belongs to Alliaceae family and originated from Central Asian region. It produces bulbs which are used for many purposes including condiments, treatment for several diseases and controlling insect-pests (Chand et al., 2010). Moreover, garlic is also used in human diets as it contains important medicinal characteristics which provide strength to the human body. Garlic cloves comprise of various nutrients in different concentrations which include moisture (62.0%), carbohydrates (33.5 g), proteins (6.4 g), fat (0.5 g), thiamine (0.06 mg), riboflavin (0.23 mg), niacin (0.4 mg), vitamin C (13 mg), calcium (30 mg), phosphorus (310 mg) and iron (1.3 mg) per 100 g of garlic (Dhaliwal, 2017). However, in countries like, Pakistan, India, Bangladesh, and Afghanistan, leaves of garlic are also eaten as a vegetable, cooked with meat or eggs, and also added as flavoring agent in some vegetables. Preserved and powdered form of garlic cloves are also used as substitute for fresh garlic (Bhandari et al., 2012). It is also a well-known source for treating different kinds of patients including diabetics, hypertension and obese. The green tops and garlic slices are very useful product for seasoning of different foodstuffs (Kilgori et al., 2007). In a recent past, garlic extract has been found very effective to control different insects and pests and also used as repellent (Plata-Rueda et al., 2017).

Due to continuous growing of crops, a great decrease in yield of crops has been observed which could be addressed by applying basic doses of important nutrients including nitrogen, phosphorus, and potash. These nutrients should be applied through a proper fertilization program which will help in enhancing the production and overall yield of garlic (Bhandari et al., 2012). In recent years, organic farming has attained a great attention by the consumers due to the health hazard effects of inorganic fertilizers. Therefore, scientists around the world have worked hard to create awareness among consumers and emphasized a lot to limit the utilization of chemical based fertilizers. It is a very well-known fact now that chemical based pesticides and fertilizers are not only creating problems for human health but for the environment as well (Sharma and Singhvi, 2017). On the other hand, fertilizers based on organic materials, in which farmyard manure (FYM) is on the top, are

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providing a good substitution of inorganic fertilizers and helping to improve the organic matter of soil. It is an established fact that application of organic matter helps in increasing the water-holding potential of soil. However, if this organic matter is used in fresh form it could lead to a great damage to the roots of plants and consequently killing of plants (Kumar and Kamboj, 2019).

An improved bulb growth and better yield can be obtained in garlic if a proper dose of nutrients is applied, especially of phosphorus (Kumar et al., 2013). The most important functions of phosphorus include photosynthesis, respiration, protein synthesis, nucleic acid formation and transport of nutrients through plant cells (Singh et al., 2012). Keeping in view, the above-mentioned facts, the current study was designed to find out the efficacy of inorganic phosphorus and FYM on production and quality aspects of garlic grown under Rawalakot (Azad Jammu and Kashmir) conditions.

MATERIALS AND METHODS

Experimental site and design

A field study was performed during 2018-19 at the Agricultural Research Area of University of Poonch, Rawalakot (33-36°N latitude, 73-75°E longitude and elevation 1638 m above the sea level). This area consists of mainly hills and mountains having sub-humid temperate climate. Rainfall ranges from 500-2000 mm per annum, while mean temperature goes up to 30 °C (max.) in summer and 0 °C (min.) in winter. Physiochemical analysis of randomly selected soil samples (Pre-experiment) from experimental site was conducted at Horticulture Lab., University of Poonch, Rawalakot and the results showed that the soil was suitable for growing of garlic crop (Table 1).

Phosphorous (P) was applied to the crop at three different levels i.e. 50, 70, 90 kg ha^{-1}. All the phosphorus was taken either from inorganic source alone or half of the dose from inorganic source and other half from organic source. Single super phosphate (SSP) containing 18% phosphorus was used as inorganic source, whereas well rotten farmyard manure (FYM) containing 0.25% phosphorus was used as organic source. Thus, phosphorus was applied in the form of single super phosphate (SSP) alone or in combination with farmyard manure (FYM). In treatments where FYM was combined with SSP, the SSP rate was reduced to half. Seven different treatments of various levels of P applied were T_0 = control; T_1 = 50 kg P ha^{-1} (SSP); T_2 = 70 kg P ha^{-1} (SSP); T_3 = 90 kg P ha^{-1} (SSP); T_4 = 25 kg P ha^{-1} (SSP) + 25 kg P ha^{-1} (FYM); T_5 = 35 kg P ha^{-1} (SSP) + 35 kg P ha^{-1} (FYM); T_6 = 45 kg P ha^{-1} (SSP) + 45 kg P ha^{-1} (FYM).

Table 1: Physicochemical properties of the experimental soil before planting the crop (n = 3).

Parameters	Average content
pH	7.40
Total N (%)	0.016
Available P (mg kg^{-1})	5.66
Available K (mg kg^{-1})	96.67
Soil organic matter (%)	0.33
Sand (g kg^{-1})	450
Silt (g kg^{-1})	260
Clay (g kg^{-1})	280

Plant material and cultural practices

Garlic bulbs of a local cultivar known as Lehsun Ghulabi were purchased from a vendor in Rawalakot to conduct this study. Healthy and disease-free garlic bulbs were taken and separated into cloves. The required amount of healthy and uniform sized (8-10 mm diameter) cloves were selected for sowing. Planting of cloves was done on 15th August, while harvesting was done on 15th May (9 months after sowing). During sowing, the individual plot size of 3 m^2 was maintained with intra and inter spacing of 10 × 30 cm containing a total of 100 plants per plot. A total of 140 kg nitrogen (as urea) per hectare was applied in three equal split doses (after 80, 160 and 240 days of sowing). While a single dose of potassium 125 kg ha^{-1} per hectare (as potassium sulphate) was applied at the time of soil preparation. Calculated amounts of SSP and FYM were mixed in the soil and application was done at the time of preparation of seedbeds. Irrigation was done soon after the planting of garlic cloves. However, further irrigations were given after an interval of 8-15 days depending on soil and weather conditions. Other cultural practices such as weeding, and hoeing were done on regular intervals or when those were required by the crop. At least three hoeings were practiced to eradicate weeds and proper development of garlic bulbs.

Collection of data

To study the effect of different levels of P (from SSP alone or in combination with FYM) on growth, yield and quality related parameters of garlic, data on various parameters were recorded. For collection of data, ten garlic plants from each sub-plot were randomly chosen and tagged. For data collection on various yield and quality related parameters, the plants were harvested when the tops of the plants turned yellow or brownish, showed signs of drying up and falling (Dhaliwal, 2017).

Number of days to sprout

Number of days taken by garlic cloves to sprout was counted from the date of sowing to the emergence of leaves (sprouting) in all the plots and averages were worked out.

Plant height (cm)

Plant height was measured by using a measuring tape from the soil surface to the top of plant from randomly chosen plants and then average was taken.

Number of leaves plant^{-1}

Number of leaves of the individual plant was counted separately in each sub-plot and then average was calculated.

Leaf length (cm)

Leaf length was recorded in the sampled plants by using a measuring tape from the initiation of leaf lamina from the sheath up to the leaf tip and then average was calculated.

Fresh leaf weight (g)

Leaves from individual plants were collected and weighed on a

Table 2: Efficacy of integrated applications of inorganic phosphorus and farmyard manure at different levels on growth of garlic.

Treatments	Days to sprouting	Plant height (cm)	Number of leaves plant^{-1}	Leaf area plant^{-1} (cm^2)	Leaf length (cm)
T_0 [control]	18.45 c	52.36 e	4.50 d	50.21 e	35.86 c
T_1 [50 kg P ha^{-1} (SSP)]	19.46 b	52.53 e	5.13 c	53.88 e	38.70 bc
T_2 [70 kg P ha^{-1} (SSP)]	19.77 b	56.13 d	5.40 bc	61.97 d	39.13 ab
T_3 [90 kg P ha^{-1} (SSP)]	20.27 b	59.26 c	5.60 b	70.38 c	39.03 b
T_4 [25 kg P ha^{-1} (SSP) + 25 kg P ha^{-1} (FYM)]	21.39 a	62.56 b	6.50 a	82.10 ab	42.20 a
T_5 [35 kg P ha^{-1} (SSP) + 35 kg P ha^{-1} (FYM)]	21.44 a	67.36 a	6.30 a	75.50 bc	40.26 ab
T_6 [45 kg P ha^{-1} (SSP) + 45 kg P ha^{-1} (FYM)]	21.67 a	66.87 ab	6.43 a	83.83 a	39.90 ab
LSD 0.05	0.345	2.099	0.328	7.208	3.119

Means showing different letters were significantly different at $P \leq 0.05$ (LSD test). P: Phosphorus; SSP: Single super phosphate; FYM: Farmyard manure; LSD: Least significant difference.

digital top loading balance. Each leaf was weighed and finally the average was taken.

Dry leaf weight (g)

Leaves collected from each treatment were spread out in open air at room temperature. After one week those leaves were again weighed and average was calculated.

Leaf area plant^{-1} (cm^2)

Three leaves from individual plants were collected and leaf area was measured with a leaf area meter and average was noted.

Leaf chlorophyll content (SPAD values)

Relative chlorophyll content of leaves was measured using portable SPAD Chlorophyll meter (SPAD 502, Minolta Japan) from at least five leaves in each treatment and then their averages were computed.

Weight of bulb plant^{-1} (g)

Weight of bulb of each randomly selected plant was taken using digital top loading balance in grams and then average weight was estimated.

Diameter of bulb (cm)

Bulb diameter was determined by using the Vernier caliper in each of the sampled plant and average was taken.

Number of cloves bulb^{-1}

Number of cloves was recorded by counting the cloves from each bulb of sampled plants.

Bulb yield per hectare (kg)

Average yield was determined by calculating and weighing the bulbs obtained from each plot and was converted into yield per hectare using the following formula.

$$\text{Yield per hectare (kg)}: \frac{Bulb\ yield\ per\ plot}{Plot\ size} \times 100$$

Vitamin C content (mg 100 g^{-1})

Vitamin C content of bulbs (cloves) was measured using titration against 2,6-dichlorophenol indophenol till appearance of light pink colour and calculated in mg 100 g^{-1} fresh weight (FW) of sample (AOAC, 1990).

Statistical analysis

Statistical design used for this study was RCBD with each treatment replicated thrice. Data collected during this study were subjected to AVONA. Statistical software Statistix 8.1 was used for the analysis, while the treatment means' comparison was done by LSD test at $P \leq 0.05$.

RESULTS AND DISCUSSION

Number of days to sprout

Data on number of days to sprout showed significant ($P \leq 0.05$) differences among the treatments (Table 2). Integrated application of SSP and FYM resulted in delayed sprouting with comparatively more number of days. Results showed that the maximum number of days to sprout was recorded in a combined treatment of 45 kg P ha^{-1} (SSP) + 45 kg P ha^{-1} (FYM), which remained at par with 35 kg P ha^{-1} (SSP) + 35 kg P ha^{-1} (FYM) and 25 kg P ha^{-1} (SSP) + 25 kg P ha^{-1} (FYM). The least number of days to sprout was noted in control. A previous study conducted by Suthar (2009) also presented similar results where he observed that with the application of FYM and NPK, the sprouting of garlic cloves was delayed.

Plant height

The height of plants significantly ($P \leq 0.05$) differed among the treatments (Table 2). Plants applied with integrated treatments of SSP and FYM produced taller plants as compared with control and SSP alone treatments. The maximum height was recorded in the plants applied with 35 kg P ha^{-1} (SSP) + 35 kg P ha^{-1} (FYM), which was statistically similar to 45 kg P ha^{-1} (SSP) + 45 kg P ha^{-1} (FYM). The minimum plant height was observed in untreated control plants, followed by those applied with 50 kg P ha^{-1} (SSP). This phenomenon could be attributed to the fact that enough supply of NPK especially in the crop root zone affected the chemical and biological composition of the soil and consequently helped in proliferation of roots, ultimately helping the crop to

Table 3: Efficacy of integrated applications of inorganic phosphorus and farmyard manure at different levels on yield of garlic.

Treatments	Weight of bulb plant^{-1} (g)	Diameter of bulb (cm)	Number of cloves bulb^{-1}	Bulb yield (kg ha^{-1})
T_0 [control]	23.06 d	2.93 c	6.20 c	2506.90 f
T_1 [50 kg P ha^{-1} (SSP)]	26.86 cd	3.70 b	7.80 b	3509.93 e
T_2 [70 kg P ha^{-1} (SSP)]	28.96 cd	3.80 b	8.20 a	3992.73 bcd
T_3 [90 kg P ha^{-1} (SSP)]	30.10 c	3.86 b	8.30 a	3722.80 de
T_4 [25 kg P ha^{-1} (SSP) + 25 kg P ha^{-1} (FYM)]	37.10 b	4.40 a	8.36 a	4205.43 ab
T_5 [35 kg P ha^{-1} (SSP) + 35 kg P ha^{-1} (FYM)]	38.90 b	4.40 a	8.20 a	4164.10 abc
T_6 [45 kg P ha^{-1} (SSP) + 45 kg P ha^{-1} (FYM)]	42.66 a	4.50 a	8.50 a	4382.96 a
LSD 0.05	5.941	0.327	0.324	279.720

Means showing different letters were significantly different at $P \leq 0.05$ (LSD test). P: Phosphorus; SSP: Single super phosphate; FYM: Farmyard manure; LSD: Least significant difference.

utilize nutrients in a better way. Yadav et al. (2017) found similar outcomes, where they found out that integration of FYM with inorganic fertilizers helped in increasing the plant height of garlic plants.

Number of leaves plant^{-1}

Leaf number plant^{-1} significantly ($P \leq 0.05$) varied among the P treatments applied (Table 2). Plants receiving integrated application of SSP and FYM had more numbers of leaves plant^{-1} in comparison to control and SSP alone treatments. The maximum number of leaves plant^{-1} was noted in those plants applied with 25 kg P ha^{-1} (SSP) + 25 kg P ha^{-1} (FYM), followed by 45 kg P ha^{-1} (SSP) + 45 kg P ha^{-1} (FYM) and with 35 kg P ha^{-1} (SSP) + 35 kg P ha^{-1} (FYM). However, these three treatments were statistically at par with each other. The least number of leaves plant^{-1} was observed in control plants. During growth of plants, several physiological processes take place which play important role in their development. These functions are performed in the plants when they are fed with macro and micronutrients through organic manures. These results were further confirmed by a previous study in which it was observed that number of leaves in garlic was improved when the plants were given a combined dose of FYM and inorganic fertilizers (Chand et al., 2010).

Leaf length

Applied P levels with inorganic source alone or in combination with organic source had significant effect ($P \leq 0.05$) on leaf length of garlic (Table 2). Plants applied with both SSP and FYM attained greater leaf length as compared with control and SSP alone treatments. Results showed that the maximum leaf length was recorded in plants applied with 25 kg P ha^{-1} (SSP) + 25 kg P ha^{-1} (FYM), followed by those applied with 35 kg P ha^{-1} (SSP) + 35 kg P ha^{-1} (FYM), 45 kg P ha^{-1} (SSP) + 45 kg P ha^{-1} (FYM) and 70 kg P ha^{-1} (SSP). These four treatments behaved statistically alike. The minimum leaf length was measured in untreated (control) plants, which was statistically similar to those applied with 50 kg P ha^{-1} (SSP). Results from the present study are supported by the findings of different scientists who had reported that recommended dose of phosphatic fertilizers along with equal amount of FYM increased the length of leaves, and improved organic matter of soil considerably (Zaki et al., 2014; Yadav et al., 2017). This might be due to the increase in fertility level by addition of FYM along with inorganic phosphorus which ultimately affected leaf length of garlic plants. Further, it is relevant to note that, FYM seems to be directly responsible in increasing crop growth and yield either by accelerating the respiratory process or by increasing the cell permeability or by hormone growth action or by combination of all these processes (Yadav et al., 2017).

Fresh leaf weight

Results regarding fresh leaf weight are presented in Fig. 1a,

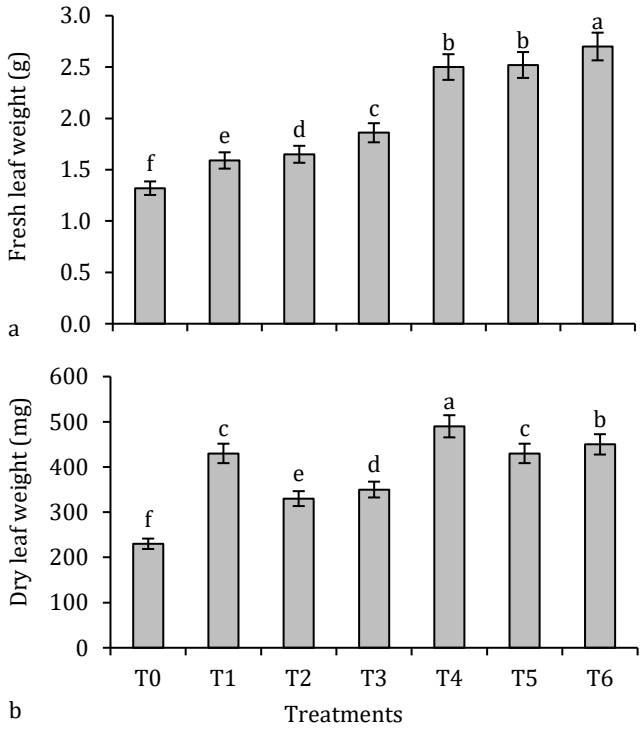

Figure 1: Efficacy of integrated applications of inorganic phosphorus and farmyard manure at different level on (a) fresh leaf weight and (b) dry leaf weight of garlic. Vertical bars represent the standard error of means (SEM) for three replicates. Means with different letters were significantly different at $P \leq 0.05$ (LSD test). T_0 = control; T_1 = 50 kg P ha^{-1} (SSP); T_2 = 70 kg P ha^{-1} (SSP); T_3 = 90 kg P ha^{-1} (SSP); T_4 = 25 kg P ha^{-1} (SSP) + 25 kg P ha^{-1} (FYM); T_5 = 35 kg P ha^{-1} (SSP) + 35 kg P ha^{-1} (FYM); T_6 = 45 kg P ha^{-1} (SSP) + 45 kg P ha^{-1} (FYM).

which indicated that the applied P treatments significantly ($P \leq 0.05$) affected the parameter. Plants receiving integrated treatments of SSP and FYM had significantly higher fresh leaf weight as compared with control and SSP alone treatments. The maximum fresh leaf weight was recorded in plants applied with 45 kg P ha^{-1} (SSP) + 45 kg P ha^{-1} (FYM), while the minimum fresh leaf weight was observed in control treatment. Similar results were reported by Yadav et al. (2017), who found that when FYM in addition to inorganic fertilizers was applied an increase in leaf weight of garlic was recorded.

Dry leaf weight

Results concerning dry leaf weight revealed significant ($P \leq 0.05$) variation due to the applied P treatments (Fig. 1b). Plants applied with both SSP and FYM produced comparatively more dry leaf weight as compared with control and SSP alone treatments. Results showed that the maximum dry leaf weight was recorded in plants applied with 25 kg P ha^{-1} (SSP) + 25 kg P ha^{-1} (FYM), while the minimum dry leaf weight was observed in untreated (control) plants. A previous research study conducted by Shafeek et al. (2015) also reported increase in dry weight of leaves when FYM along with inorganic fertilizer was used in garlic. They also found that same inorganic fertilizers gave less dry weight of leaves when applied alone.

Leaf area plant^{-1}

Results regarding leaf area plant^{-1} showed significant ($P \leq 0.05$) differences among the treatment means (Table 2). Plants applied with integrated treatments of SSP and FYM attained the maximum leaf area plant^{-1} as compared with control and SSP alone treatments. Results depicted that significantly greater leaf area plant^{-1} was measured in the plants applied with 45 kg P ha^{-1} (SSP) + 45 kg P ha^{-1} (FYM), followed by in those applied with 25 kg P ha^{-1} (SSP) + 25 kg P ha^{-1} (FYM); these two treatments were statistically at par. While, significantly lesser leaf area plant^{-1} was observed in control (untreated plants), followed by in 50 kg P ha^{-1} (SSP) treated plants. In a previous study by Bhandari et al. (2012), it was observed that inorganic form of phosphorus applied along with equal amount of FYM gave better results in terms of leaf area of garlic.

Relative leaf chlorophyll content

Chlorophyll content of leaves was significantly ($P \leq 0.05$) influenced by the applied P treatments (Fig. 2a). Plants receiving integrated treatments of SSP and FYM had higher chlorophyll content as compared with control and SSP alone treated plants. The maximum chlorophyll content was recorded in plants applied with 45 kg P ha^{-1} (SSP) + 45 kg P ha^{-1} (FYM), followed by in those applied with 25 kg P ha^{-1} (SSP) + 25 kg P ha^{-1} (FYM). The minimum chlorophyll content was observed in control plants. FYM contains essential macro and micronutrients and its application helps in improving nutritional status of the soil. However, this effect could be enhanced further if FYM and inorganic fertilizers are mixed and then applied to agricultural crops. It is a consensus that if the chlorophyll content of leaves of any crop is higher, the overall yield and quality of that particular crop will be improved and the same happened in case of present study (Chand et al., 2010; Nori et al., 2012).

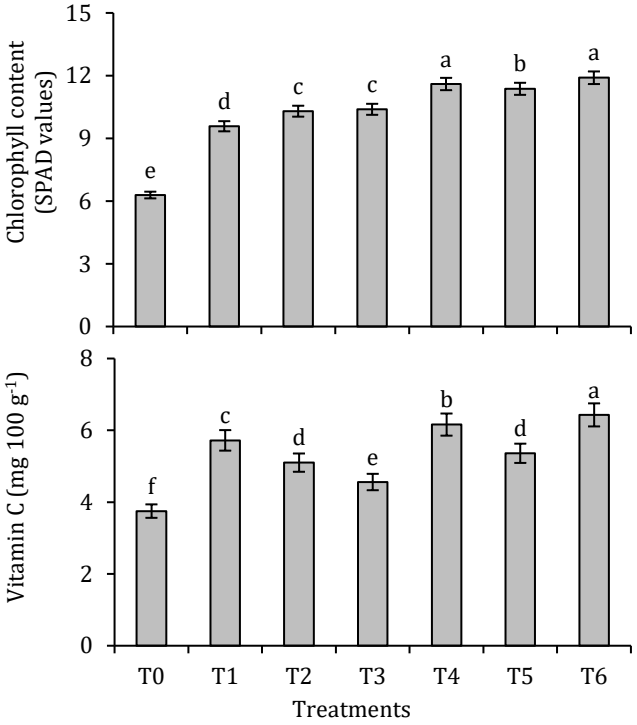

Figure 2: Efficacy of integrated applications of inorganic phosphorus and farmyard manure at different level on (a) leaf chlorophyll content and (b) vitamin C content of garlic. Vertical bars represent the standard error of means (SEM) for three replicates. Means with different letters were significantly different at $P \leq 0.05$ (LSD test). T_0 = control; T_1 = 50 kg P ha^{-1} (SSP); T_2 = 70 kg P ha^{-1} (SSP); T_3 = 90 kg P ha^{-1} (SSP); T_4 = 25 kg P ha^{-1} (SSP) + 25 kg P ha^{-1} (FYM); T_5 = 35 kg P ha^{-1} (SSP) + 35 kg P ha^{-1} (FYM); T_6 = 45 kg P ha^{-1} (SSP) + 45 kg P ha^{-1} (FYM).

Weight of bulb plant^{-1}

Applied P treatments significantly ($P \leq 0.05$) affected the average bulb weight (Table 3). Plants fed with both sources of P (SSP and FYM) had higher bulb weight plant^{-1} as compared with control and inorganic source of P alone (SSP). It was observed that about 46% more bulb weight plant^{-1}was noted in plants applied with 45 kg P ha^{-1} (SSP) + 45 kg P ha^{-1} (FYM) as compared with control. Similar to these findings, the increase in weight of bulb has been reported when inorganic fertilizers and organic manures were used together rather than sole application of those fertilizers (Sevak et al., 2012). Maximum bulb weight in garlic crop was also recorded when organic and inorganic fertilizers were applied in combinations rather than using alone (Yadav et al., 2017).

Diameter of bulb

As a result of applied P levels from different sources, treatment means exhibited significant ($P \leq 0.05$) differences for the bulb diameter (Table 3). Plants receiving P in both inorganic and organic forms (SSP and FYM) had significantly greater bulb diameter as compared with control and SSP alone treatments. The maximum diameter of bulb was recorded in plants applied with 45 kg P ha^{-1} (SSP) + 45 kg P ha^{-1} (FYM), which was at par with 35 kg P ha^{-1} (SSP) + 35 kg P ha^{-1} (FYM) and 25 kg P ha^{-1}

(SSP) + 25 kg P ha^{-1} (FYM). The minimum diameter of bulb was observed in control (untreated plants). The results of Shafeek et al. (2015) also confirmed the findings of this study, where it was observed that integrated application of FYM and inorganic fertilizer helped in improving the bulb size of garlic and consequently contributed to the overall yield of garlic. Another study also reported similar results for bulb diameter of garlic when organic and inorganic fertilization program was practiced in combination (Sevak et al., 2012).

Number of cloves $bulb^{-1}$

Results regarding number of cloves $bulb^{-1}$ indicated that the parameter was significantly ($P \leq 0.05$) affected by the applied P treatments (Table 3). Plants applied with integrated treatments (SSP + FYM) and higher levels of SSP had greater number of cloves $bulb^{-1}$ as compared with control and the lowest level of SSP (50 kg P ha^{-1}). However, the minimum number of cloves $bulb^{-1}$ was observed in control plants, which was significantly different from all other treatments applied. These results are in accordance with the findings of Kumar et al. (2013) who found an increased amount of bulblets $bulb^{-1}$ when they applied inorganic fertilizer along with FYM.

Bulb yield per hectare

Results indicated that the bulb yield significantly ($P \leq 0.05$) varied due to applied P treatments (Table 3). Plants receiving both forms of P (SSP and FYM) gave higher bulb yield as compared with control and SSP alone treatments. About 42% more yield was recorded in plants applied with 45 kg P ha^{-1} (SSP) + 45 kg P ha^{-1} (FYM) as compared with control plants. All the three treatments in which both SSP and FYM were applied in combination were statistically at par. The minimum bulb yield was recorded in untreated control plants. These findings are in line with the previous studies conducted by different researchers (Singh et al., 2012; Zaki et al., 2014; Sitaula et al., 2020). They observed that overall garlic bulb yield per hectare was higher in those plots which were treated with integrated application of FYM and inorganic fertilizers. The combined doses of fertilizers not only increased the bulb weight but also enhanced overall yield of garlic.

Vitamin C content

The applied P treatments caused a significant ($P \leq 0.05$) effect on the vitamin C content of garlic cloves (Fig. 2b). Plants with combined application of SSP and FYM had comparatively more vitamin C content in their bulbs as compared with control and SSP alone applied plants. The maximum vitamin C content was recorded in plants applied with 45 kg P ha^{-1} (SSP) + 45 kg P ha^{-1} (FYM), while the minimum vitamin C content was observed in control plants. These two treatments were significantly different from each other as well as from rest of the treatments. This increased amount of vitamin C in garlic bulbs could be due to the effect of phosphorus as it helps in improving nutrient uptake by plant roots, increases leaf chlorophyll content, improves photosynthesis activities and enhances protein content. During growth of plants, several enzymatic reactions take place which play important role in improving quality of final produce. These functions are performed by plants when they are fed with macro and micronutrients through organic manures. The results obtained in the current study regarding the amount of vitamin C in garlic were found similar with the results of Hassan (2015) who observed that combined application of FYM and inorganic fertilizer based on phosphorus gave better results in case of soil nutritional level and production of quality crop.

CONCLUSION

The present study concludes that integration of FYM with inorganic form of phosphorus fertilizer had a great effect on growth, yield and quality related parameters of garlic. The highest garlic bulb weight per plant and yield per hectare were achieved when 90 kg P ha^{-1} was applied with half of the P from inorganic source and other half was from organic source [45 kg P ha^{-1} (SSP) + 45 kg P ha^{-1} (FYM)]. Therefore, it is suggested to local garlic farmers that for achieving higher yield and better-quality garlic, they must use inorganic and organic fertilizers in an integrated manner.

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