

**EFFECT OF MULTI-NUTRIENT ON THE
PRODUCTIVITY AND QUALITY OF
GARLIC IN A MOUNTAIN ACID SOIL
OF HIMACHAL PRADESH**

THESIS

By

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Submitted to



**CHAUDHARY SARWAN KUMAR HIMACHAL PRADESH
KRISHI VISHVAVIDYALAYA PALAMPUR-176 062 (H.P.) INDIA**

IN

Partial fulfilment of the requirements for the degree

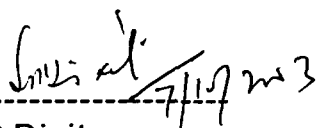
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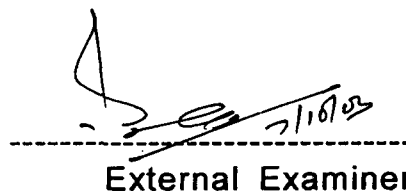
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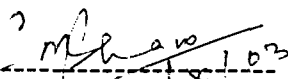
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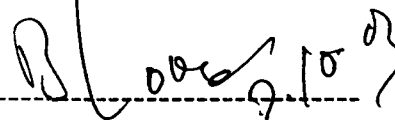
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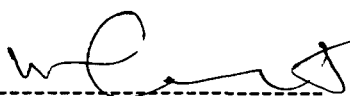
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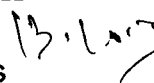
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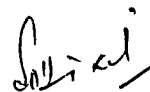
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CERTIFICATE - I

This is to certify that the thesis entitled "**Effect of multi-nutrient on the productivity and quality of garlic in mountain acid soil of Himachal Pradesh**", submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science (Agriculture)** in the subject of **Soil Science** of Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur is a bonafide research work carried out by **Mr. Subhash Kumar** son of **Sh. Mansa Ram** under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been fully acknowledged.



(S.P. Dixit)

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Place : Palampur

Dated: the 26th September, 2003.

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In this highly complex society, no work can be accomplished by a single individual, but it need inspiration and sincere guidance of intellectuals as well as the grace of the almighty.

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Needless to say, all omissions and errors are mine.

Place : Palampur


(Subhash Kumar)

Dated : the 20th September, 2003.

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INTRODUCTION

Chapter-I

INTRODUCTION

Garlic (*Allium sativum*) belonging to the family *Alliaceae* is the most important crop among spices grown throughout the country. It is cultivated as a bulb crop (Sankar *et al.*, 1997). It is a valuable crop and a popular remedy for various ailments and physiological disorders. Its use in different diets has a marked impact on the immune system in human beings and if taken as a component of regular diet, it does not only prevent cancer but also upgrades the cardio-vascular system. It acts as stimulant, carminative, digestive, metabolic corrector and a killer of intestinal worms. It also has a laxative, diuretic expectorant, anti-inflammatory, aphrodisiac and rejuvenative properties. It lowers cholesterol, reduces high blood pressure and in some cases, controls diabetes and arthritis. Its daily use in diet reduces the body toxins (Benjamin, 1999; Koul, 2001; Vatsyayan, 2001). Garlic can inhibit toxic germs in the stomach; promotes secretion of garlic acid juice and stops synthesis of carcinogen (Pandey and Jitendra, 1993). The amino acid 'Allicin', which had a hydrochlorotestrolenic action is present in aqueous extract of garlic, reduces cholesterol concentration in human blood (Augusti, 1977; Mahanto *et al.*, 1980).

Garlic bulb contains a colourless, odourless and waterless soluble amino acid allicin. On crushing, garlic bulb and the enzyme 'allinase' breaks down to allinin to produce allicin, whose principal ingredient is the odoriferous diallyl sulphide. The chief constituent of oil are diallyl disulphate, diallyl trisulphide, allyl propyl disulphide, a small quantity of disulphide and probably diallyl polysulphide. Diallyl sulphide possess the true garlic odour (Shankaracharya, 1974). As regard its nutritonal aspects, garlic has higher nutritive value as compared to other bulb crops besides a rich source of carbohydrates, proteins, phosphorus and high content of ascorbic acid (Pruthi, 1979). Therefore, it act as a medicine for human beings (Benjamin, 1999; Koul 2001).

Raw garlic is an excellent though smelly, natural broad spectrum anti-microbial, anti-viral and therefore the dry cloves of garlic are added to hot oil, for body massage and oleation. Such therapeutic characteristics of the crop imparts it the peculiar characteristic of high value crop with immense remunerative ramifications. Other beneficial effects of the garlic are:

High returns to the small and marginal farmers of state.

Improvement in friabilty and granularity of soil, thereby improvement in soil quality.

Being hardy crop, garlic has the capacity of tolerance to the toxicity of aluminium, iron, manganese, copper and acidity problem in mountain acidic lands.

The global scenario of area under production of garlic shows that it is cultivated in an area of 9.92 lakh hectares on global basis with production of 101.22 lakh tonnes and 10.2 t/ha productivity (FAO, 2001). The countries such as China, India, Korea, Spain and U.S.A. are the major garlic growing countries. The area under garlic cultivation in India is 1.14 lakh hectares with a production of 5.81 lakh tonnes and productivity 4.52 t/ha (FAO, 2001) and large quantities of this crop, are exported to earn foreign exchange. The total production of garlic in Himachal Pradesh is 2.95 thousand tonnes from an area of 1500 hectares, with a productivity of 1.97 t/ha (Arya, 2000). The productivity of garlic in H.P. (1.97 t/ha) is quite low compared with states like Punjab (12.44 t/ha), Haryana (12.00 t/ha) and Maharashtra (6.76 t/ha) (Arya, 2000).

Furthermore, the mountain acid lands in Himachal Pradesh on which garlic is grown are characterised by features like fragility, inaccessibility and marginality, that constitute about 0.15 million hectare area (Panda, 1990). The soils supporting such lands are not only deficient in P and Mg, but also in many other nutrients. Due to high rainfall (2500 mm), leaching of K and NO_3 is also there. Nitrogen

deficiency in Indian soils is almost universal. Phosphorus deficiencies are not far behind with those of N. Moreover, P is a backbone of balanced fertilizer use. The results of long term experiments shows that "if you wish to secure N efficiency, make sure there is no P deficiency" (Tiwari, 2002). Crops in general remove as much or more K than they remove N, but consumption of K_2O/ha is still 8.7 kg, while that of N is 58.7 kg/ha, which is highly imbalanced (Tiwari, 2002). The soils are also becoming sulphur deficient due to use of S free fertilizers. Deficiencies will become even more important and balanced fertilizer use will have to include S along with NPK. The exchangeable Mg in most of the acid soils is less than 1 cmol(P⁺)/kg or less than 10 per cent of soil CEC is occupied by Mg⁺⁺ and acid soils are deficient in Mg (Nambiar, 1994). Use of FYM with multi-nutrient like N, P, K, S and Mg increase nutrients use efficiency, promotes synergistic interactions and keeps antagonistic interactions out of the crop production system and is useful for sustainable agriculture (Singh and Swarup, 2000).

In Himachal Pradesh, almost negligible work related to the role of multi-nutrient on the productivity and quality of garlic has been done so far. However, the productivity and quality of this crop, can be increased manifold by the use of multi-nutrient management skills. Therefore, the present study entitled "Effect of multi-nutrient on the productivity and quality of garlic in ^amountain acid soil of Himachal Pradesh", was formulated with the following objectives:

to study the effect of multi-nutrient nutrition on the productivity, quality and concentration of nutrients in garlic, to monitor the changes in available N, P, K, S and exchangeable Mg status due to different treatments, and to work out the economics of multi-nutrient package through benefit cost ratio/value cost ratio and response yardstick.



REVIEW OF LITERATURE

Chapter-II

REVIEW OF LITERATURE

The name garlic comes from Anglo Saxon garleac in which garl means pointed leaves and leac is a plant. Garlic (*Allium sativum*) is most important spice crop grown in the country. It is consumed both as a green as well as dry form. Garlic is propagated by cloves which are carefully detached from composite bulb. Bigger healthy cloves should be selected for planting. Clove of 8-10 mm is good size to have increased yields of better quality bulbs (Nath, 1976). Use of organics with multi-nutrient not only increases the productivity, quality of crops but also result in sustainable agriculture. The pertinent literature both from India and abroad associated with the research problem entitled "Effect of multi-nutrient on the productivity and quality of garlic in mountain acid soils of Himachal Pradesh" has been reviewed in this chapter under the following heads:

- 2.1 Growth parameters and yield
- 2.2 Nutrients uptake
- 2.3 Quality
- 2.4 Soil properties and nutrients status
- 2.5 Economics

2.1 Growth parameters and yield

In a study, the beneficial effect of P was recorded upto 300 kg/ha in influencing the garlic yield in a positive direction (Ramirez *et al.*, 1973).

Garlic responds well to organic manures application. In a study, it was found that addition of 40 to 50 t/ha of FYM significantly improved the yield of garlic (Nath, 1976). The application of 150 kg N/ha along with FYM at the time of field preparation can give higher yields as compared to N alone (Singh and Singh, 1977).

There was not significant increase in yield of garlic with application recommended rates of 240 kg N, 60 kg P_2O_5 and 200 kg K_2O /ha applied through compound fertilizers (Alindin and Suminto, 1978). Minard *et al.* (1978) in a field experiment on silt loam soil documented that best crop yield 33.9 t/ha (fresh weight) resulted from large cloves (seed) at close spacing, with medium N and K, high dose of P, but low lime application rate. Nitrogen has a great role in increasing the yield of garlic. The response of nitrogen on garlic yield has been well documented in the literature (Escaff and Aljaro, 1982). Nelson (1983) on a trial conducted on a silt loam soil reported that different K rates had no effect on garlic yield or size of bulb.

Moisture and nitrogen increased the yield of garlic in the soils of Moshtohor (Egypt), the results revealed that the yield of garlic was

2.7 to 4.2 t/feddan in plots, receiving the highest N rate and irrigated at 20 per cent moisture depletion (El Beheidi *et al.*, 1984). In another study, it was reported that 60:60:120 dose of NPK (kg/ha) is the best combination for obtaining good yield of garlic (Koltunov, 1984). He also reported that garlic yield increased from 4.6 to 10.6 t/ha as N application rate increased from 0 to 150 kg/ha, but higher dose of N beyond 150 kg/ha reduced yield and phosphorus application had little effect on yield despite the fact that soil P content was low (3 ppm).
(7t/ha)

In West Bengal, highest yield_Λ of garlic was recorded by application of 60 kg each of N as well as P₂O₅ and 120 kg K₂O/ha and there was more yield by their combined effect than individual one (Das *et al.*, 1985).

In another experiment, Katyal and Chadda (1985) reported that the response of potassium upto 60 kg K₂O/ha was there in influencing the garlic yield in a positive direction.

Gallero (1986) reported that there was not significant difference in the height of the plant at maturity due to nitrogen and phosphorus application alone or in combination. Combined application of N, P and K was found beneficial for yield of garlic as well as boldness of cloves and application of 150 kg N, 25 kg P and 75 kg K/ha significantly increased the yield of garlic (Pal and Pandey, 1986).

In an experiment, it was reported that the good yield of underground garlic bulbs (6.48 t/ha) and underground bulbs + aerial bulbils (7.50 t/ha) was obtained with application of 90:90:90 kg/ha N, P_2O_5 and K_2O (Borabash and Kochina, 1987).

Guaddi *et al.* (1988) documented that application of 10 t stubble manure/ha increased fresh marketable yield of garlic from 12.2 kg/plot in the control to 15.2 kg/plot. In an experiment conducted at Ciwidey (Indonesia) N, P and K fertilization at several levels did not significantly affect the bulb diameter, number of cloves/bulb or bulb net weight. In contrast to this, there was significant effect on bulb dry weight and it attained weight with 100 kg urea/ha + 400 kg Zn/ha combined with 150 kg triple super phosphate/ha and 250 kg KCl/ha (Hilman and Noordiyati, 1988). The increase in the total/bulb yield was recorded when S @ 0, 250 and 500 kg/feddan and organic manure @ 0 and 20 t/feddan (feddan = 0.42 ha) applied in combination (Khalf and Taha, 1988).

They also revealed that application of phosphorus combined with nitrogen helped in increasing the yield of garlic significantly over N alone. Panwar (1988) reported that yield of garlic bulb and leaves increased significantly due to phosphorus addition upto 75 kg P_2O_5 /ha. Sulphur content of bulbs was increased and reached maximum at 225 kg P_2O_5 /ha when applied in form of SSP, as it contains S also (Panwar and Patil, 1989).

Setty *et al.* (1989) revealed that application of N showed significant increase in plant height and similar effect was shown by P and K application. The plant height was maximum with 100 kg N+50 kg P_2O_5 + 50 kg K_2O /ha treatment. He also reported that largest bulb diameter (3.67 cm) was observed with the treatment involving 100 kg N+50 kg P_2O_5 + 50 kg K_2O /ha.

In an another report, on the soils of Cairo (Egypt), nitroge addition in the soil increased the productivity of garlic (Shaheen, 1989).

In a field trial, conducted on a clay loam soil application of 50 100 or 150 kg K_2O /feddan and with a mixture of Cu, Zn, and Fe (each at 50, 100 or 500 ppm), the growth parameters (plant height, number of leaves, fresh weight and dry weight) and total yield increased with increasing K application rates upto 100 kg K_2O /feddan as well as increasing micro-nutrients mixture concentration (Eid *et al.*, 1991). Hilal *et al.* (1992) in a field trial in Egypt reported that when garlic was given various combinations of multi-nutrient i.e. 0-3.0 kg S, 0-45 kg P_2O_5 and 30-90 kg N/feddan (1 feddan = 0.42 ha), the increase in yield was recorded by all rates of N, P and S showing good response of these nutrients to the crop.

Oh *et al.* (1991) in a field trial on garlic (cv. Namdro) reported that, the greatest plant height was obtained with the highest rate i.e. 110 kg N/ha with no P

optimum rates of nutrients were 220 kg N, 170 kg P_2O_5 and 250 K_2O /ha to get good yield of garlic

In a field experiment conducted during the winter season in garlic (cv. GAUI), it was found that bulb yield was highest with IW:CPE ratio of 1.2 or 1.4 with N at 50 or 75 kg/ha and P_2O_5 at 50 or 75 kg/ha (Panchal *et al.*, 1992). Largest size of garlic bulb (diameter 3.38cm) was obtained with 140 kg N/ha in a soil of New Delhi (Pandey *et al.*, 1992).

Pandey and Singh (1993) reported that greatest bulb diameter and weight of ten bulbs was obtained with irrigation at 1.5 IW/CPE with N application @ 150 kg/ha in a soil of Jabalpur (Madhya Pradesh).

Wang *et al.* (1992) revealed that in a sand culture, the garlic yield increased significantly as N, P and K were applied together than as individual. The optimum N, P and K requirements established were 260 ppm N, 61 ppm P and 370 ppm K and gave garlic yields upto 18.52 kg/m². In addition to this there was response of N, K and Mg in producing higher yield of the crop. Bull *et al.* (1993) in a green house trial reported that in garlic (cv. Roxo Perola de Cacador), increase in bulb yield was recorded with a decrease in Mn content and an increase in Ca:Mg ratio in foliar tissues, but it was not affected by variation in Ca:Mg ratios. N, P and K application significantly influenced the productivity, average bulb diameter, number of cloves/bulb in a trial on garlic crop at Havana, Cuba (Cardosa *et al.*, 1993). In an experiment

conducted by Grad *et al.* (1993), the response of N (120 kg/ha) and P (90 kg/ha) alone or in combination were studied and it was found that P and N supplied in combination gave more yield and produced taller plants (108 cm height) compared with P alone (101 cm).

Kalloo *et al.* (1993) reported that the yield of garlic enhanced significantly with increase in phosphorus upto 80 kg P_2O_5 /ha, showing response of phosphorus in influencing the productivity of garlic.

In an experiment conducted at Rahuri (Maharashtra) in India by Lawande *et al.* (1993), it was reported that there was slight increase in garlic yield with increase in NPK dose. They also revealed that the yield obtained with 50 kg N, P_2O_5 and K_2O was found to be statistically at par with yield obtained at 150 kg each of N, P_2O_5 and K_2O . In an experiment conducted on clay loam soil of Karnal (Haryana- India) with garlic CV G1, it was found that garlic yield was highest with the application of N @ 150 kg/ha (Pandey and Singh, 1993).

The highest yield of garlic bulbs was obtained with 45 kg N/ha applied before planting instead of applying N in split dose in soils of Mendoza, Argentina (Arbolea and Burba, 1994).

Casanovo *et al.* (1994) reported that in the soils of Tucuman (Argentina), garlic crop responded well to N and P fertilizer application. The highest yield and size of bulb was obtained in 150 kg N + 138 P_2O_5 /ha treatment.

The highest yield of garlic was obtained at 80 kg N/ha and it gave 10-12 per cent increment in yield in a soil of Mendoza Argentina (Lipinski *et al.*, 1994).

In an acidic soils at Kodai Kanal (India), the highest bulb yield of garlic was obtained in treatments involving 100 kg N+75 kg P + 50 kg K; 100 kg N + 50 kg P + 0 kg K or 100 kg N + 50 kg P + 50 kg K + 25 kg ZnSO₄/ha (Sarvanan and Nambisam, 1994).

In a field experiment on garlic (cv. Methupalayam) different combinations of N and K along with 0 and 50 kg MgSO₄ 7H₂O/ha give higher yield in main season than that of autumn crop due to short crop season and uniform moisture throughout (Selvaraj *et al.*, 1994). In a field trials on a sandy dark red latosol, the application of P₂O₅ @ 300 or 450 kg/ha or 0, 10, 20 or 30 t earthworm compost/ha had a significant effect on plant height (Seno *et al.*, 1994). In another study, increasing doses of nitrogen upto 150 kg N/ha increased the bulb yield of garlic in the soils of Kanpur, India (Singh and Singh, 1994). Singh *et al.* (1994) revealed that plant growth and yield (62.07 q/ha) were highest for plant receiving N @ 100 kg/ha.

In an another study, recommended rate of NPK and FYM in a soil of Bijapur (India) significantly increased the yield of garlic leaves and bulbs (Mallanagonda *et al.*, 1995).

K (0, 75, 100 and 150 kg/ha) and MgSO_4 at 0 or 50 kg/ha showed significant increase in bulb yield of garlic (Selvaraj *et al.* 1997).

In an experiment conducted in a dark red podzolic, eutrophic soil at Sao Paulo (Brazil), it was noticed that the combination of irrigation applied every three days plus 20 kg N/ha resulted in the largest bulb weight (1.40 g) and decreased percentage of small bulbs (Seno, 1997).

Application of *Azotobacter* + N @ 75 or 100 kg/ha alone, *Azotobacter* + *Azospirillum* + N @ 50 or 75 kg/ha and *Azospirillum* + N @ 50 kg/ha, all these treatments increased the growth and yield of garlic compared to the respective N doses alone showing the response of N (Wange, 1998).

Wani and Konde (1998) in a green house experiment on garlic documented that P application significantly increased plant height.

Sulphur fertilization increased the plant height and number of cloves per bulb. The highest rate of 40 kg S/ha was more effective in increasing all the growth parameters (Alam *et al.*, 1999).

2.2 Nutrients uptake

In a field trial, it has been reported by Bogatirenko (1975) that to produce one tonne of garlic, the plants removed from the soil, 9.6-12.9 kg of N, 5.5-8.2 kg of P and 6.5-8.0 kg of K. The N, P, K

and sulphur uptake increased due to N, P and K application upto the harvest stage and transference of the nutrients from leaves/stems to bulbs in each case was over 80 per cent. Garlic plants removed 31.3 per cent N; 6.8 per cent, P_2O_5 and 8.6 per cent K_2O from the soil (Bogatirenko and Timchenko, 1976). The sulphur content in garlic plant was significantly higher than other crops and vegetables (Uchida *et al.*, 1976).

Kim *et al.* (1977) in water culture experiment with pH 5.0 -7.0 found that in plants grown without Mg, showed greater uptake of N, P and K than in plants with Mg. Calcium had no effect on uptake of N, P or K, when Mg was supplied, but decreased their uptake in absence of Mg. The decrease in pH reduced Ca uptake, but had little effect on other ions.

Panwar and Patil (1989) conducted a trial on autumn planted garlic for two season, the treatments were P_2O_5 at 0, 75, 150 and 225 kg/ha and sulphur 9, 18 and 27 kg S/ha. A basal dressing of urea and muriate of potash at 100 : 75 kg N : K_2O /ha was also applied. The S content of harvested bulbs increased with P rates and was maximum at 225 kg P_2O_5 /ha.

Eid *et al.* (1991) in the soils of Mohtosor (Egypt) reported that N, K, Cu, Zn and Fe in garlic increased with increasing K application upto 100 kg K_2O /feddan (1 feddan = 0.42 ha). The total nutrient uptake in garlic until the 112th day of crop growth was 431.4 mg N, 325.9 mg

K, 86.5 mg Ca, 57.4 mg S, 47.8 mg P, 40.0 mg Mg showing the uptake of these nutrients (Lisbao *et al.*, 1991). The significant interaction effects among the source and dosage of phosphate fertilizer on the uptake of P, Zn, and Mn were recorded in Andosol at Lembang (Indonesia) (Suwandi and Hilman, 1991).

The results of the experiment conducted at Tamil Nadu Agricultural University, Coimbatore revealed that with the application of N @ 50, P₂O₅ @ 75 and K₂O @ 50 kg/ha at basal and N @ 50 kg/ha at a top dressing after one month of sprouting increased N, P, K, Ca and Mg in bulbs and decreased in leaves and roots. Also Cu, Mn, Zn, Fe and S content decreased the same in leaves and roots and increased in bulbs (Shobahalan and Arumugam, 1991).

Bull *et al.* (1993) in green house trials with garlic reported that an increase in soil Ca:Mg ratios reduced tissue Mg content, but had no significant effect on Ca and Mg uptake. A field trial conducted with different levels of nitrogen, potassium and magnesium on garlic (*Allium sativum*) revealed that the mean uptake of N, P, K and Mg at harvest was 251, 19, 298, and 13 kg/ha, respectively. The combined effect of N, P, K and Mg uptake indicated the highest yield of garlic (22.0 t/ha) and N, P, K and Mg uptake due to application of 75 : 75 : 50 kg of N, K₂O and MgSO₄/ha over addition of basal dose of 25 t FYM and 90 kg of P₂O₅/ha (Selvaraj *et al.*, 1993).

Sarvanan and Nambisan (1994) at Kodai Kandal (Tamil Nadu) revealed that the application of ZnSO_4 @ 12.5 or 25 kg/ha in combination with N, P and K enhanced the N, P and K uptake by plants.

In an experiment conducted at Botucatu (Brazil), it was found that an increase in Mg and Ca promoted an antagonistic and synergistic effect on plant K uptake, respectively (Bull and Nakagania, 1995).

At Bijapur (India), Mallanagouda *et al.* (1995) documented that recommended rate of NPK + FYM exhibited the highest uptake of N, P and K by garlic.

Singh *et al.* (1995) in a field experiment, applied S @ 25, 30 and 100 kg S/ha and found that due to S application N, P, K and S uptake increased significantly.

Bertoni *et al.* (1996) reported that sulphur uptake followed same pattern as of dry matter accumulation with a maximum occurring at a beginning of bulb growth. Determination of the organic and inorganic sulphur fractions in the bulb, leaf and root suggested a re-mobilization of organic sulphur from leaves to bulb during bulb growth.

In the field trial at Korea Republic, workers reported that application of K_2SO_4 increased the content of S-containing aromatic compounds as well as S concentration by two to three times compared with KCl (Park *et al.*, 1997).

Zhang *et al.* (1998) in an experiment conducted in China on NPK reported that combination of organic fertilizer with NPK fertilizers increased the yield (78-118 %) and N, P, K, S, Ca and Mg uptake by garlic crop.

In a green house experiment on garlic conducted in a sterile soil revealed that super phosphate significantly increased the N and P uptake (Wani and Konde, 1998).

Nitrogen, application increased the S content and uptake by garlic crop as reported by Aoyoma *et al.* (2000).

2.3 Quality

In a soil of Chile, there was increase in protein of garlic, as the N rate increased upto 125 kg/ha, however P_2O_5 application had little effect on the protein content (Ruiz, 1985).

In a field trial conducted at Gyongsan (Korea), it was found that the number of cracked bulbs was reduced with the application of K_2SO_4 or $CuSO_4$. But addition of S, Cu, Zn or K did not reduce the number of garlic bulbs and quality was good (Chung, 1987).

Khalaf and Taha (1988) revealed that the organic manure application @ 0 and 20 m³/feddan, (1 feddan = 0.42 ha) and S application @ 0, 250 and 500 kg/feddan were beneficial for bulb quality, bulb volatile oil content as well as N, P, K, and S contents in plant.

Chang *et al.* (1990) documented that in a pot as well as field trial, five fertilization levels of sulphur were tried. The flavour component were also found higher in the volatile oil extracted by steam distillation of garlic bulb, the results showed that there is an improvement in the quality (pungency) of garlic due to S addition.

El-Mansi *et al.* (1990) in an experiment carried out at the experimental farm of the faculty of Agriculture at Zagazig (Egypt) reported that quality of bulb was increased by increasing the application of potassium fertilizer upto highest level (100 kg K₂O/feddan), because it act as a source of resistance against diseases and insects attack in plants.

Increase in garlic (cv. Japanese plants) bulb diameter and weight as well as all chemical constituents (Chlorophyll a and b, carotenoids, N, K, Cu, Zn and Fe) was recorded with the application of K upto 100 kg K₂O/feddan and increased micronutrient concentration in an experiment conducted in Japan (Eid *et al.*, 1991).

An experiment was conducted in Brazil by Lisbao *et al.* (1991), he revealed that with increased application of N, the quality like protein and S concentration of garlic had improved.

The maximum bulb diameter and neck thickness or total soluble solids was achieved with N, P and K at 150, 40 and 50 kg/ha and there was no effect of P and K alone on bulb diameter and TSS of the crop as reported by Pandey *et al.* (1991).

The bulbs contained higher percentage of reducing and non-reducing sugars and proteins than the other two plant parts and there was improvement in protein and total soluble solids due to different nutrients like N, P and K (Shobahalan and Arumugam, 1991).

In an experiment conducted in Japan containing compounds and amino acids were determined by HPLC in thirteen commercially available and eleven cultivated garlic samples. Cycloallinin and allicin were monitored in leaf and bulb and it was found that allinin was the most abundant sulphur compound and arginine was abundant amino acid and was influenced by different nutrient combinations (Ueda *et al.*, 1991).

In a green house experiments in garlic (cv. Messidrome), supply of N increased the bulb growth and quality until the beginning of senescence of the same (Bertoni *et al.*, 1992).

As reported by Singh *et al.* (1993) in an experiment conducted at Nasik (Maharashtra), it was reported that the highest value for total soluble solids was 39.5 - 40.0 per cent in garlic bulb and it was influenced by different nutrients. Selvaraj *et al.* (1994) in an field trial conducted during (April to July) reported that from statistical analysis, it was concluded that excessive N fertilization and thrips infestation were major factors contributing directly to rubberisation.

In an experiment conducted at CCS Haryana Agricultural University, it was reported that the total soluble solid content increased

upto 90 days. Highest total soluble solids content was maintained in cloves harvested at later stages and stored with foliage in wooden boxes, or tied in bundles and nutrients levels also affected the same (Jatendra *et al.*, 1995).

In a plot experiment in Gujrat (India), Mehta (1995) revealed that application of boronated super phosphate and sulphur fertilizer improved the quality of garlic. In an experiment conducted for quality attributes in garlic at Pantnagar University, it was found that in garlic, sulphur content was 0.896 per cent and total soluble solids 40 per cent and protein content, 9.0 per cent, volatile oil content, 0.12 per cent (Singh *et al.*, 1995).

Kumar *et al.* (1996) in a trial conducted on a sandy loam soil reported that the quality of garlic (cv. White skin) increased with 100 kg N + 80 kg P+60 kg K/ha. Verma *et al.* (1996) documented that the qualitative parameters (TSS, volume, moisture content, dry weight) were increased with increasing rates of N and P applications. In an another study application of P increased allicin, soluble sugar content, sulphur content and decreased vitamin C, Ca and Mg (Cheng *et al.*, 1997).

Savic *et al.* (1997) reported that garlic contains more potassium, phosphorus and iron than other vegetables and fruits therefore garlic is important source of mineral for human diet in terms of quality. In a field trial on soils low in available S in Korea Republic,

it was reported that application of S at 40 kg/ha increased the content allyl disulphide and 5-methyl, 1,2,3-thiodiazole 6-5 times, which is a main quality parameters of the crop (Park *et al.*, 1997).

A field trial was conducted with garlic in Nilgiris hill soil, Tamil Nadu (India) with four rates of N (0, 75, 100 and 150 kg/ha), four rates of K₂O (0, 75, 100 and 150 kg/ha) and two rates of MgSO₄ (0 and 50 kg/ha). The results showed that no bulb rubberisation occurred with N added upto 75 kg/ha, but there was close correlation between percentage sprouting and rubberisation particularly at the highest N rate. Potassium application above 75 kg/ha reduced rubberization by 21.3 per cent (Selvaraj *et al.*, 1998). Application of S resulted in an increase in volatile sulphur compounds in a study on garlic in Japan (Aoyoma *et al.*, 2000).

2.4 Soil properties and nutrients status

In two trials with cultivars Amarantee, Branco and Barbadinho, status of Ca, Mg, K and organic matter in soil reduced where these, nutrients were not applied. Nitrogen application increased acidity, but FYM reduced the losses of soil K and there was build up of the available K status (Sans *et al.*, 1974).

Mosi *et al.* (1975) studied the P fixing capacity of some soil series of Tamil Nadu and reported that about 36.1 per cent of applied P and there is good response of P addition in these type of soils.

In a field trial on garlic, it was observed that shape of Q/I curve (quantity/intensity curve) was not applicably affected by the application of K @ 30, 60, 90 and 120 kg K_2O /ha, although ARek increased. However, there is a need to add K fertilizer to these soils, when grown to garlic if ARek fall below 0.80 mole/liter (Augustin, 1985).

In the soils of Chile, the available N was found closely related with N application upto 150 kg/ha, but the higher dose of N did not increase significantly the available N (Ruiz, 1985).

In an experiment conducted to evaluate soil fertility and chemical properties of garlic, it was reported that the chemical properties of multi-nutrient applied (well grown) soils were higher than those of poor soils. Also, most soils were deficient in pH, organic matter, exchangeable Ca and Mg and excess in available phosphate (Park *et al.*, 1988).

The results of the experiment conducted at Suwon (Korea) reported that the optimum amounts of available phosphate and exchangeable potassium in soil for garlic crop were found to be about 384 ppm and 0.72 me/100g, respectively, at the thawing season. When five levels of phosphate and potassium were studied there was increase in available P and K status in the soil (Jung *et al.*, 1989).

Ranganna *et al.* (1991) tried biogas spent slurry sludge (BGSS) and FYM applied @ 10 t/ha a few weeks before sowing of garlic crop

(local garlic cultivar). The results revealed that biogas slurry compared with FYM resulted in build up of total N, P_2O_5 , K_2O and organic carbon. In garlic, application of 250 - 300 kg/ha of diammonium phosphate (18:46:0) at planting time, depending on the level of available phosphorus in the soil and N @ 120 -140 kg/ha, build up the N and P status in the soil (Casanova *et al.*, 1992). Suwandi and Hilman (1992) in a study conducted in an alluvial soil with initial pH (7.0) at Tanjung Brebes (Central Java) found that the application of P fertilizer @ 180 kg P_2O_5 /ha improved available P and K in the soil, while the increase of N fertilization reduced the soil pH and also the available P status in the soil.

Application of lime and potassium reduced the activity of Fe and Al in acid soil and increased the availability of available P (Dixit and Sharma, 1993).

In a study conducted at Mariana Marcos State University, Batac (Philippines), it was found that in garlic grown soil, available P, K and S decreased, while there was minimum build up of N and organic matter due to effect of multi-nutrient (Gracia *et al.*, 1993).

✓ In another study by Pasricha and Fox (1993) maximum sulphate sorption was observed in S free NPK treated soil suggesting the exhaustion of native S and there is need for supplying fertilizer S along with NPK and organics.

In a field trial conducted on a acidic soil (pH of 5.3) with CEC 14.40 cmol(p⁺)/kg at Kodai Kanal (India), the application of ZnSO₄ @ 12.5 or 25 kg/ha along with various combinations of N, P and K, increased the content of available N, P and K in the soil (Sarvanan and Nambisan, 1994).

✓ Alfisol occurring in arid, semi-arid and sub-humid eco-regions are usually deficient in phosphorus, which is one of the most important factors limiting crop productivity and these soils have high Al and Fe oxides which fix the phosphorus and other anions. The response to various crops due to P application has been reported in the literature (Singh *et al.*, 1996).

✓ In a field experiment conducted on soils low in available S in Korea Republic, it was reported that application of S @ 40 kg/ha showed an increase in available S status in the soil (Park *et al.*, 1997).

Majumdar *et al.* (1998) documented through an experiment conducted at Meghalaya that there was increase in pH from 5.32 (control) to 6.05, when 3.0 t/ha of lime (containing basic cations like Ca and Mg) was applied and there was improvement in nutrients of the soil like N, P, K and exchangeable Mg.

In a study by Santhy *et al.* (1998) reported that 100 per cent NPK + FYM built up the available N, P, K status in the soil and also increased the CEC of soil, which can hold more exchangeable cation.

✓ The increase in available sulphur status and lower sulphate sorption in 100 per cent NPK + FYM treated plot may probably be due to blocking of positively charged sites or by coating of oxide surfaces by organic matter (Reddy *et al.*, 2003).

2.5 Economics

In an experiment conducted at Philippines, the results of the productivity analysis showed that five out of six variables have greater marginal value products (MVP) than their marginal factor costs (MFC), which indicate that increases in area labour, fertilizer, chemicals and seeds will increase total garlic production (Asuncion and De-luna, 1986).

Borabash and Kochina (1987) reported that the yields of underground bulbs and underground bulbs + aerial bulbils in 90:90:90 kg/ha N:P₂O₅:K₂O were 6.48 and 7.50 t/ha, respectively and returns were also highest depicting the importance of N, P and K on garlic crop. The maximum net returns in garlic were achieved with N:P:K at 150:40:50 kg/ha. Phosphorus and potassium (without N) alone had no effect on net returns (Pandey *et al.*, 1991).

Based on data collected from 120 farmers in Jamnagar (Gujrat), Kuchhadiya *et al.* (1992) reported that in garlic cultivation, the profit margin were good and price levels were generally stable when integrated nutrient management was done. In an experiment conducted

by Pandey (1992), the highest net returns (Rs. 10, 328/ha) were obtained with application of 150 kg N/ha. The application of 50 kg each of N, P_2O_5 and K_2O observed to be economical in obtaining higher bulb yield in garlic at Rahuri (India) compared with other nutrient combinations (Lawande *et al.*, 1993). In a field experiment conducted at Mandusar, the highest garlic yield was recorded with 100 kg N/ha and 90 kg K_2O /ha (97.32 and 96.26 q/ha), which also gave the highest net profits (Abbas *et al.*, 1994).

In an another study at Kanpur, the highest net returns and favourable cost benefit ratio was obtained with 100 kg N+80 kg P + 60kg K/ha (Kumar *et al.*, 1996).

In the soils of Gujarat (India), application of 50 kg N and 11 kg P/ha was optimum for garlic productivity, which gave the maximum mean net return of Rs. 9,183 and 8,558/ha, respectively (Sadaria *et al.*, 1997).



MATERIAL AND METHODS

Chapter-III

MATERIAL AND METHODS

To complete the objectives of the research problem entitled "Effect of multi-nutrients on the productivity and quality of garlic in mountain acid soil of Himachal Pradesh", a field study was carried out at the experimental farm of the Department of Soil Science, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur during 2001-2002. The details of the materials used and the experimental methods followed during the course of this study have been described in this chapter under the following heads:

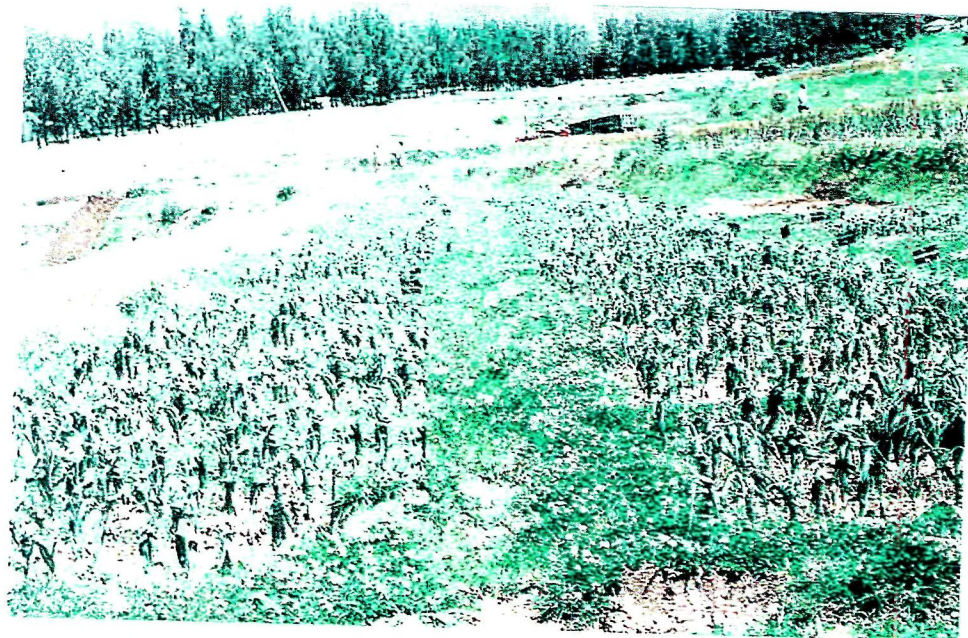
3.1 Experimental site

3.1.1 Location

The experimental farm is located at 32°6' N latitude and 76°3' longitude at an elevation about 1280 metre above mean sea level in sub-temperate mid hill agro-climatic zone of Himachal Pradesh.

3.1.2 Weather and climate

Agro-climatically the experimental site is categorised as Wet temperate with severe winters and mild summers. The annual average rainfall is more than 2500 mm, out of which, about 75 per cent is received during June to September and remaining during rest of the year.



Experiment on garlic (Variety - GHC-1)

The mean weekly meteorological parameters like maximum and minimum temperatures, relative humidity, rainfall, sunshine hours etc. for the experimentation period recorded at the meteorological observatory of CSK Himachal Pradesh Krishi Vishvavidyalaya have been depicted in Fig. 3.1 and appended in Appendix-I.

3.1.3 Soils

The soils of experimental location are classified as "Typic hapludalf" (Verma, 1979) and are acidic in reaction. The rocks to which the soils of area owe their origin are slates, phyllites, quartzites, schists and gneiss. Some of the important properties of the soil before the initiation of the experiment are given below:

Important physico-chemical and chemical properties of the soil before the initiation of the experiment on garlic.

pH	5.7
Organic carbon	9 g/kg
Available N	238 kg/ha
Available P	14.1 kg/ha
Available K	219 kg/ha
Available S	19.8 kg/ha
Exchangeable Mg	1.25 cmol(P ⁺)/kg
CEC	9.2 cmol(P ⁺)/kg

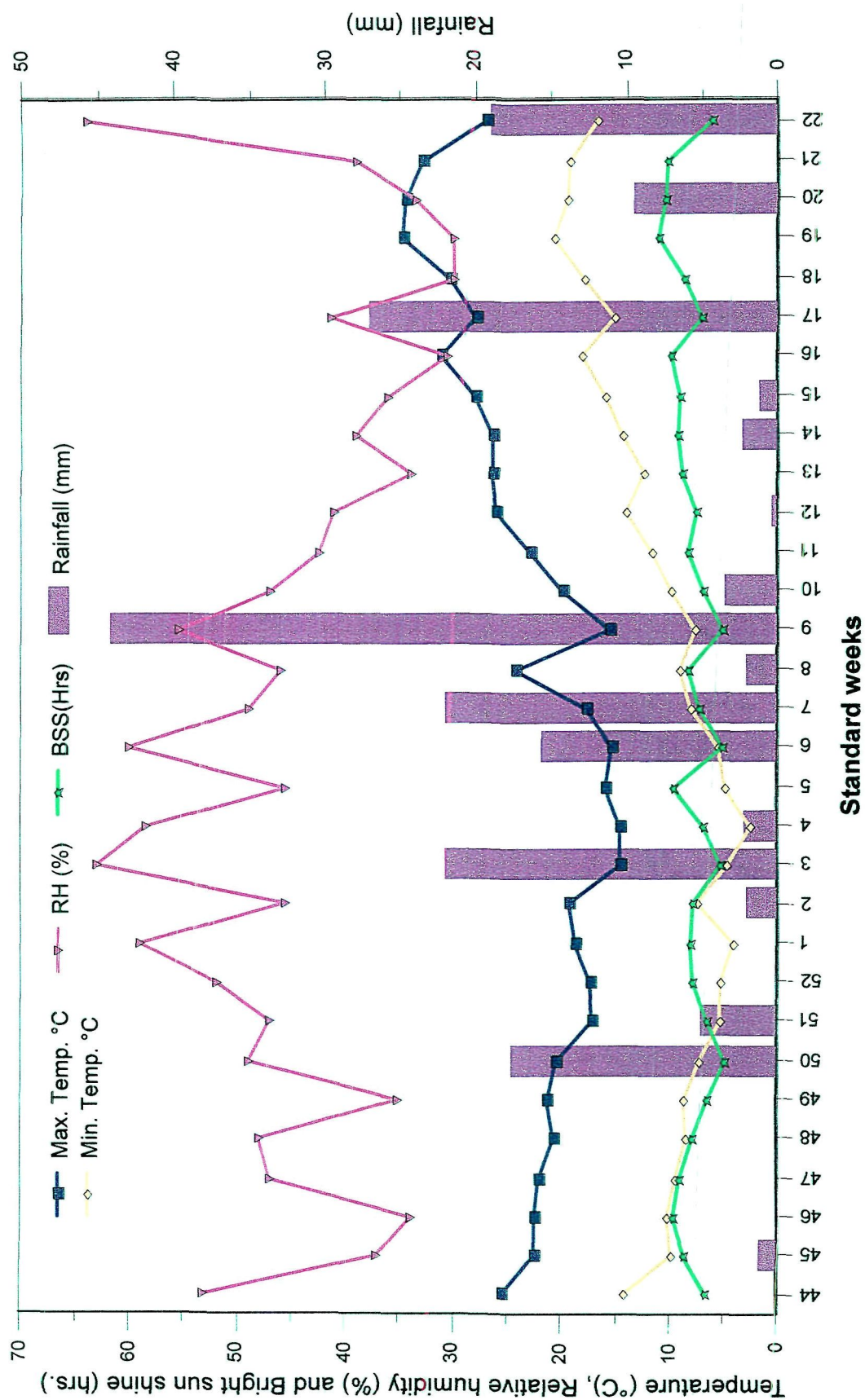


Fig. 3.1 Mean weekly weather data of Palampur for the period from 29 October, 2001 to 3 June, 2002.

Mechanical composition

Sand (%)	25.0
Silt (%)	46.1
Clay (%)	28.7
Texture	Silty clay loam

The status of available N, P and K was medium and that of available S & Mg was low.

3.2 Experimental details

The field experiment was laid out in a randomized block design (RBD). Seventeen treatments, which were replicated three times were imposed on garlic. Before the garlic crop, turmeric was there in sequence, where similar treatments were applied. The size of the plot was 5m². The layout of experiment have been depicted in Fig. 3.2.

3.2.1 Treatments

The detail of treatments imposed in garlic crop is as under:

- | | |
|------------------------------|---------------------|
| 1. Control (FYM alone) | 10. 125% N P K |
| 2. Absolute control (No FYM) | 11. 125% N P K S |
| 3. 100% N | 12. 125% N P K S Mg |
| 4. 100% N P | 13. 150% N |
| 5. 100% N P K | 14. 150% N P |
| 6. 100% N P K S | 15. 150% N P K |
| 7. 100% N P K S Mg | 16. 150% N P K S |
| 8. 125% N | 17. 150% N P K S Mg |
| 9. 125% N P | |

Note: Treatment 3 to 17 means % of recommended.

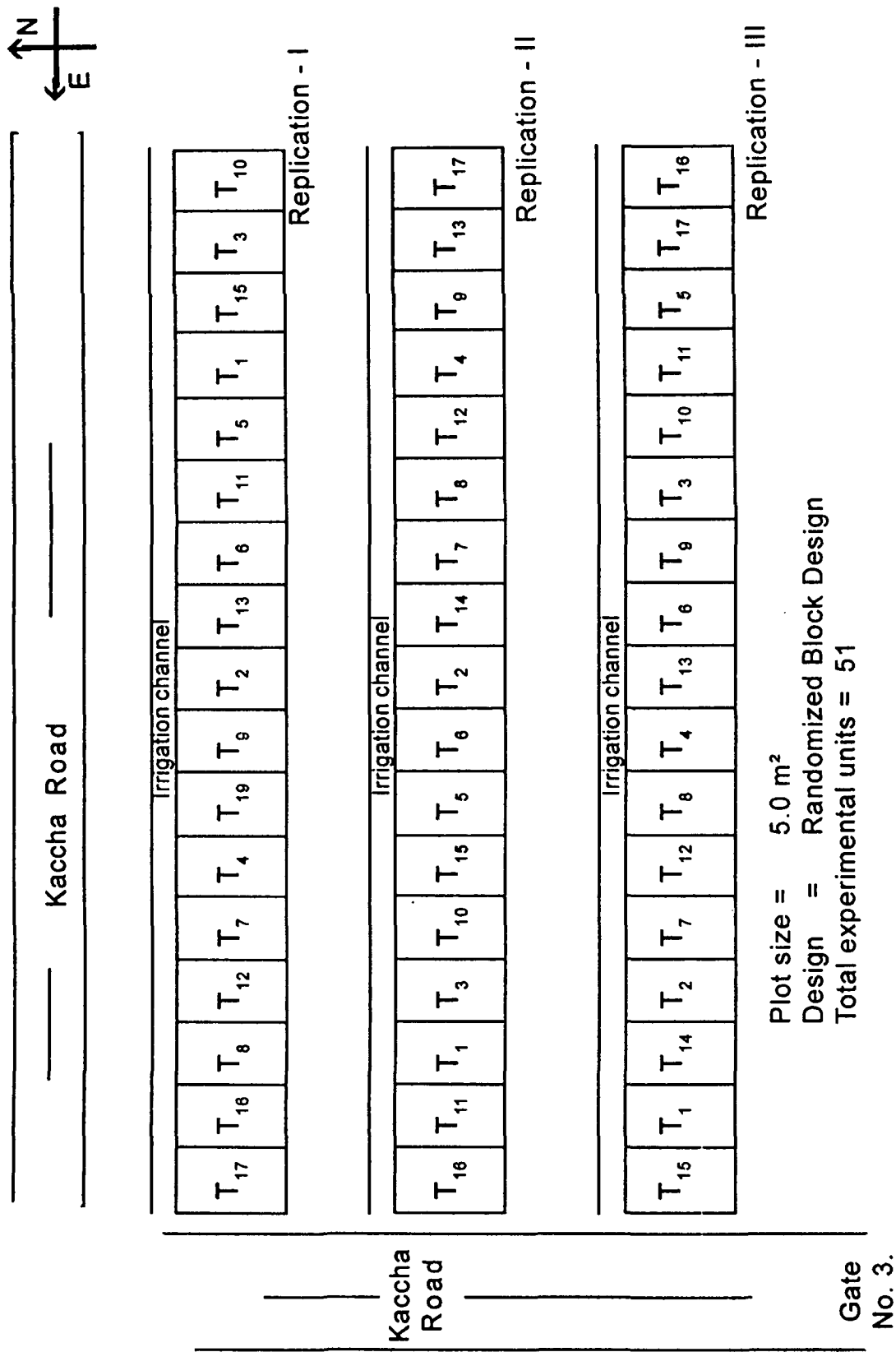


Fig. 3.2 **Layout plan of the experiment**

The recommended dose (100 %) for different nutrients to garlic was, 125 kg N, 75 kg P_2O_5 (32.6 kg P/ha), 60 kg K_2O (50 kg K/ha), 30 kg S, and 15 kg Mg/ha. Garlic crop (variety GHC-1₁)^{ie Garlic Hurdle Collec} was sown on 23rd November, 2001 and harvested on 15th May, 2002. The seed rate of 6 q/ha with planting distance 20cm (row to row) x 10 cm (plant to plant) was kept for the crop. Farm yard manure (FYM) @ 10 t/ha was applied to each plot except absolute control. FYM was consisting of 0.65 per cent N, 0.23 per cent P, 0.49 per cent K, 0.42 per cent S and 0.24 per cent Mg. Phosphorus was applied through dia-ammonium phosphate and N through dia-ammonium phosphate and rest through urea. Potassium, sulphur and magnesium were applied through muriate of potash, gypsum and magnesium chloride, respectively. One third of nitrogen was applied as basal and rest two third in two equal splits at one month interval. P, S, K and Mg were applied as basal

3.3 Field observations

The garlic was harvested at maturity. It was ready for harvesting when tops turned yellowish, brownish and showed signs of drying up. The bulbs were lifted, freed from earth and leaves were tied at the top. The bulbs were cured for 3–4 days in shade before storing them in an ordinary room. Bulbs were removed from the leaves before marketing the produce. Number of leaves per plant was recorded when plant started

drying. However, number of cloves/bulb, diameter of bulb and plant height was also recorded at the time of harvesting. Seven plants were randomly selected for recording their growth parameters and its average was taken.

3.3.1 Soil sampling

Representative soil samples (0–15 cm) were collected from each plot before the start of experiment and at the time of harvest of garlic. The soil samples were dried in shade, ground in pestle mortar and passed through 2 mm sieve.

3.3.2 Plant sampling

The leaves and bulb samples of garlic were collected at the time of harvesting of the crop.

3.4 Laboratory studies

Methods used for various determinations in the laboratory are as under:

Sr. No.	Determination	Method followed
1.	pH (1:2.5 soil : water suspension)	Systronics pH meter (Jackson, 1967).
2.	Organic carbon	Walkley and Black Rapid Titration Method (Piper, 1966).

3. Available N	Alkaline permanganate method (Subbiah and Asija, 1956).
4. Available P	0.5 M NaHCO ₃ , pH 8.5 (Olsen <i>et al.</i> , 1954).
5. Available K	Neutral ammonium acetate method (Merwin and Peech, 1951)
6. Exchangeable Mg	Ammonium acetate method (extraction) and then determination by atomic absorption spectrophotometer (Jackson, 1967)
7. Available S	Turbidimetric method (Chesnin and Yien, 1950).

3.4.1 Preparation and analysis of plant samples

Samples of bulbs as well as leaves first dried in air, then in oven for 2-3 days at 60°C, then powdered and stored for further analysis. The details of chemical analysis is given below:

a) Nitrogen concentration: Bulb samples and leaf samples were digested with H₂SO₄ using digestion mixture and nitrogen determined by micro-kjeldahl's method (Jackson, 1967).

b) Phosphorus concentration: Both bulb and leaf samples were digested with di-acid mixture (HNO₃ : HClO₄ in the ratio of 4:1) and phosphorus was determined by vanadomolybdate phosphoric yellow colour method (Jackson, 1967).

c) Potassium concentration: Potassium content, both in leaves and bulbs was determined using flame emission spectrophotometer from the aliquat obtained by digestion with di-acid mixture (Chapman and Brown, 1950).

d) Sulphur concentration: Extract obtained by digestion with di-acid mixture was used for sulphur determination by turbidimetric method (Chesnin and Yien, 1950).

e) Magnesium concentration: The magnesium content in both leaves and bulb was determined by using atomic absorption spectrophotometer from the aliquat obtained by digestion with diacid mixture (Richards, 1954).

f) Nutrient uptake: The concentrations of nitrogen, phosphorus, potassium, magnesium, sulphur and magnesium were determined and uptake was calculated as follow:

Uptake (kg/ha) = [% concentration of the nutrient x yield of the crop in (oven dry weight basis) q/ha].

g) Protein content: Protein content was calculated as follows:

$$\% \text{ N} \times 6.25$$

h) **Total soluble solids (TSS):** Total soluble solids was determined by refractometer in the fresh garlic bulb samples (A.O.A.C., 1970)

3.5 Statistical analysis

The data obtained during the course of study was analysed statistically using the technique of analysis of variance described by Gomez and Gomez (1984).

3.6 Economic analysis

a) Value cost ratio (VCR)

$$\text{VCR} = \frac{\text{Value of produce in treated plot} - \text{value of produce in control plot}}{\text{Cost of fertilizer (treatment)}}$$

b) Benefit cost ratio (B/C ratio)

$$\text{B/C ratio} = \text{value cost ratio} - 1$$

c) Response yard stick

If increase in yield due to the application of given quantity of nutrient (x kg/ha) = y kg/ha then,

$$\text{Response yard stick} = \frac{\text{Total yield (kg)}}{\text{Total nutrient applied (kg)}} = \frac{y}{x}$$

The above method of economic analysis is given by Dev (1997).

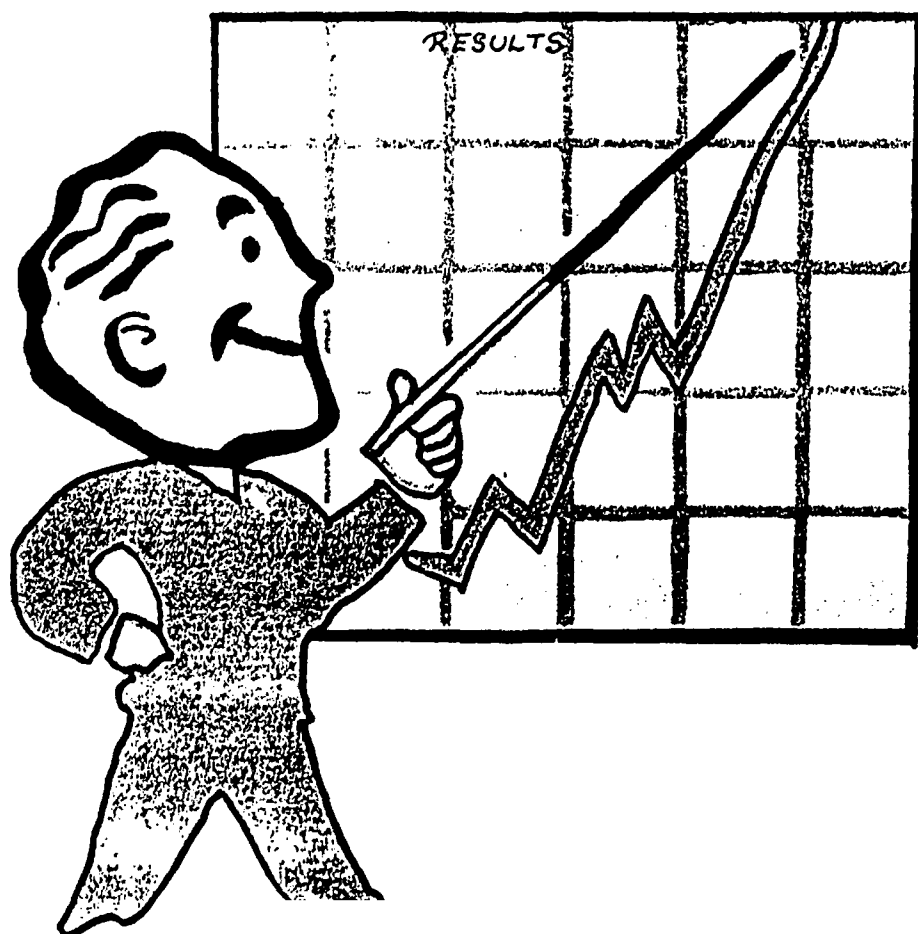
i) Prices of nutrients applied (Rs/kg)

<u>FYM</u>	<u>N</u>	<u>P₂O₅</u>	<u>K₂O</u>	<u>Mg</u>	<u>S</u>
0.40	10.39	17.70	7.36	2000	50

Note: The cost of $MgCl_2$ was very high, because it was taken as pure laboratory chemical.

ii) Price of marketable garlic bulb (Rs/kg)

Garlic bulb = 20.00



RESULTS

RESULTS

The results emanating from the present study entitled "Effect of multi-nutrient on productivity and quality of garlic in^a mountain acid soil of Himachal Pradesh" are presented in this chapter under the following heads:

- 4.1 Effect of multi-nutrient on yield attributing characters
- 4.2 Effect of multi-nutrient on marketable yield (q/ha) of garlic bulb
- 4.3 Effect of multi-nutrient on leaf yield (kg//ha) of garlic (oven dry weight basis)
- 4.4 Effect of multi-nutrient on nutrients concentration (%) in garlic bulb
- 4.5 Effect of multi-nutrient on nutrients uptake (kg/ha) by garlic bulb
- 4.6 Effect of multi-nutrient on nutrients concentration (%) in garlic leaf
- 4.7 Effect of multi-nutrient on nutrients uptake (kg/ha) by garlic leaf
- 4.8 Effect of multi-nutrient on soil properties and nutrients status
- 4.9 Effect of multi-nutrient on quality parameters
- 4.10 Effect of multi-nutrient on economics of garlic

4.1 Effect of multi-nutrient on yield attributing characters

4.1.1 Number of cloves/plant

4.1.1.1 Levels

The number of cloves/bulb at harvesting stage of garlic were influenced significantly due to different levels of nutrients (Table 4.1). The

data revealed that the application of nutrients due to 125 and 150 per cent level significantly increased the clove number over 100 per cent level. Maximum number of cloves (12.8) were obtained in 150 per cent and minimum (12.0) in 100 per cent level. The increase in number of cloves/plant recorded at 125 per cent over 100 per cent and 150 over 125 per cent was 5 and 2 per cent, respectively.

4.1.1.2 Nutrients

Similar to the levels, the effect of nutrients on number of cloves was also significant. The incorporation of FYM in control treatment recorded increase in cloves number (10.7) over absolute control, where no FYM was added (9.2) and the increase was 16 per cent (Table 4.1). Number of cloves also increased by 9 per cent due to the application of N as compared to control (FYM). There was significant increase in cloves number with the application of P over N and Mg over NPKS. The increase was recorded with the addition of S over NPK and was statistically at par. The corresponding increases were 5, 0, 4 and 5 per cent. The application of NPKSMg showed maximum number (13.4) of cloves/plant.

4.1.1.3 Interaction

The number of cloves were not affected significantly due to the interaction influence of levels and nutrients.

4.1.2 Plant height (cm)

4.1.2.1 Levels

The plant height recorded at 125 per cent level showed the significant increase over 100 per cent level of nutrients with per cent increase of 4.1 (Table 4.1). Application of 150 per cent level showed the nonsignificant decrease in plant height (24.9 cm) with decrease of 1 per cent and was statistically at par. The maximum plant height was recorded at 125 per cent level followed by 150 per cent and 100 per cent level of nutrients.

4.1.2.2 Nutrients

Farm yard manure incorporated in control showed increase (20.3 cm) over absolute control (18.7 cm) i.e. 9 per cent increase (Table 4.1). Plant height also increased (12 %) due to the application of N as compared with control (only FYM). The application of P over N and S over NPK showed a significant increase i.e. 5 and 5 per cent. Addition of K over NP and Mg over NPKS caused a nonsignificant increase in the plant height. The per cent increase recorded was to the tune of 3 and 2, respectively. The maximum plant height was recorded at NPKSMg combination of nutrient and followed by NPKS, NPK, NP and N.

4.1.2.3 Interaction

The effect of levels and increasing combination of nutrients on plant height of garlic was nonsignificant.

4.1.3 Bulb diameter (cm)

4.1.3.1 Levels

There was not significant difference with respect to bulb diameter of garlic between 100, 125 and 150 per cent level of nutrients i.e. they were statistically at par with one another (Table 4.1). Maximum bulb diameter was recorded at 125 per cent (4.8 cm) and 150 per cent (4.8 cm) level and minimum was at 100 per cent level (4.6 cm) of nutrients. The bulb diameter at 125 and 150 per cent level of nutrients showed increase of 4 per cent over the 100 per cent level treatment.

4.1.3.2 Nutrients

The application of FYM @ 10 t/ha in control treatment showed increase of 22 per cent in bulb diameter over the absolute control, showing tremendous response of FYM (Table 4.1). In treatment comprised of N application, the bulb diameter (4.6 cm) was higher as compared to control treatment (4.4 cm) i.e. increase of 5 per cent. The effect of P over N, K over NP, S over NPK and Mg over NPKS was nonsignificant in increasing the bulb diameter. Meaning thereby, that there was nonsignificant difference in bulb diameter in N, NP, NPK, NPKS and NPKSMg treatment combinations of nutrients. Maximum increase over N was recorded at NPKSMg nutrient combination (7%) followed by NPKS (2%), NPK (4%) and NP (2%).

4.1.3.3 Interaction

The interaction effect of nutrients and levels was nonsignificant in influencing the diameter of garlic bulb.

Table 4.1 Effect of multi-nutrient on yield attributing characters of garlic

	Number of cloves/bulb	Number of leaves/plant	Plant height (cm)	Bulb diameter (cm)
Levels				
100 %	12.0	6.3	24.1	4.6
125 %	12.6	6.3	25.1	4.8
150 %	12.8	6.2	24.9	4.8
LSD (P= 0.05)	0.4	NS	0.7	NS
Nutrients				
N	11.7	6.3	22.8	4.6
NP	12.3	6.2	24.0	4.7
NPK	12.3	6.3	24.6	4.8
NPKS	12.8	6.1	25.8	4.8
NPKSMg	13.4	6.4	26.3	4.9
LSD (P=0.05)	0.5	NS	NS	NS
Absolute control	9.2	4.7	18.7	3.6
Control	10.7	6.3	20.3	4.4

4.1.4 Number of leaves per plant

4.1.4.1 Levels

The number of leaves/plant at harvesting stage of garlic was statistically same at all the levels of nutrients. A data in Table 4.1 revealed that the application of nutrients at 100 and 125 per cent levels showed maximum number of leaves (6.3) and minimum in 150 per cent level (6.2).

4.1.4.2 Nutrients

The incorporation of FYM in control recorded increase in number of leaves (6.3) over absolute control, where no FYM was added (4.7) and the increase was 34 per cent (Table 4.1). Number of leaves/plant did not increase due to the application of N as compared with control (FYM). As a whole, the effect of different nutrient combinations on this parameter was nonsignificant. There was significant decrease of 2 per cent due to P application over N. However, addition of K over NP increased (2%) the number of leaves per plant, but again there was decrease (3%) due to S over NPK. The application of NPKSMg combination caused maximum number of leaves/plant and it showed 5 per cent increase over NPKS.

4.1.4.3 Interaction

Number of leaves/plant were not affected significantly due to interaction effect of levels and nutrients.

4.2 Effect of multi-nutrient on marketable yield (q/ha) of garlic bulb

4.2.1 Levels

The data presented in the Table 4.2 and Fig. 4.1 shows that the marketable yield of garlic at the 150 per cent of the recommended levels of nutrients was highest (47.2 q/ha) followed by 125 per cent (46.0 q/ha) and lowest at 100 per cent level (43.9 q/ha). The productivity of garlic bulb was higher in 125 over 100 per cent level, but it was nonsignificant. Similarly, the effect of 150 per cent over 125 per cent level of nutrients was there, but it was also nonsignificant. In contrast to this, 150 per cent level of nutrients was significantly superior over 100 per cent level in affecting the productivity of garlic bulb in a positive direction. The increase in productivity of garlic was 4.8 and 2.6 per cent due to 125 per cent over 100 and 150 per cent over 125 per cent level of recommended nutrients, respectively.

4.2.2 Nutrients

The incorporation of FYM @ of 10 t/ha i.e. control treatment increased (25.4 q/ha) the marketable yield of garlic bulb as compared to absolute control (20 q/ha). This shows that there was 27 per cent increase in garlic bulb productivity due to only the application of FYM (Table 4.2 and Fig. 4.1). The addition of all the nutrients i.e. N, P, K, S

and Mg increased the yield over control (FYM alone). The maximum yield of the garlic bulb was recorded in NPKSMg (54.6 q/ha). The yield of garlic bulb was also higher in the N treated plot (36 q/ha) as compared to control (25.4 q/ha). Due to N application over control, the increase in the productivity was 42 per cent. The effect of P over N, K over NP, S over NPK was significant in increasing the bulb yield and the corresponding increases were 13, 11 and 15 per cent, respectively. However, the effect of Mg over NPKS was non significant, but this also slightly increased the same (5 %).

Table 4.2 Effect of multi-nutrient on marketable yield (q/ha) of garlic bulb

Levels	Nutrients					Mean
	N	NP	NPK	NPKS	NPKSMg	
100 %	32.4	38.0	43.4	50.2	53.4	43.9
125 %	37.6	41.0	45.3	52.7	53.4	46.0
150 %	38.0	43.4	46.9	52.7	55.0	47.2
Mean	36.0	40.8	45.2	51.9	54.6	
Absolute control	: 20.0					
Control	: 25.4					

Main effects/Interaction LSD (P= 0.05)

Levels : 2.5
 Nutrients : 3.2
 Interaction : NS

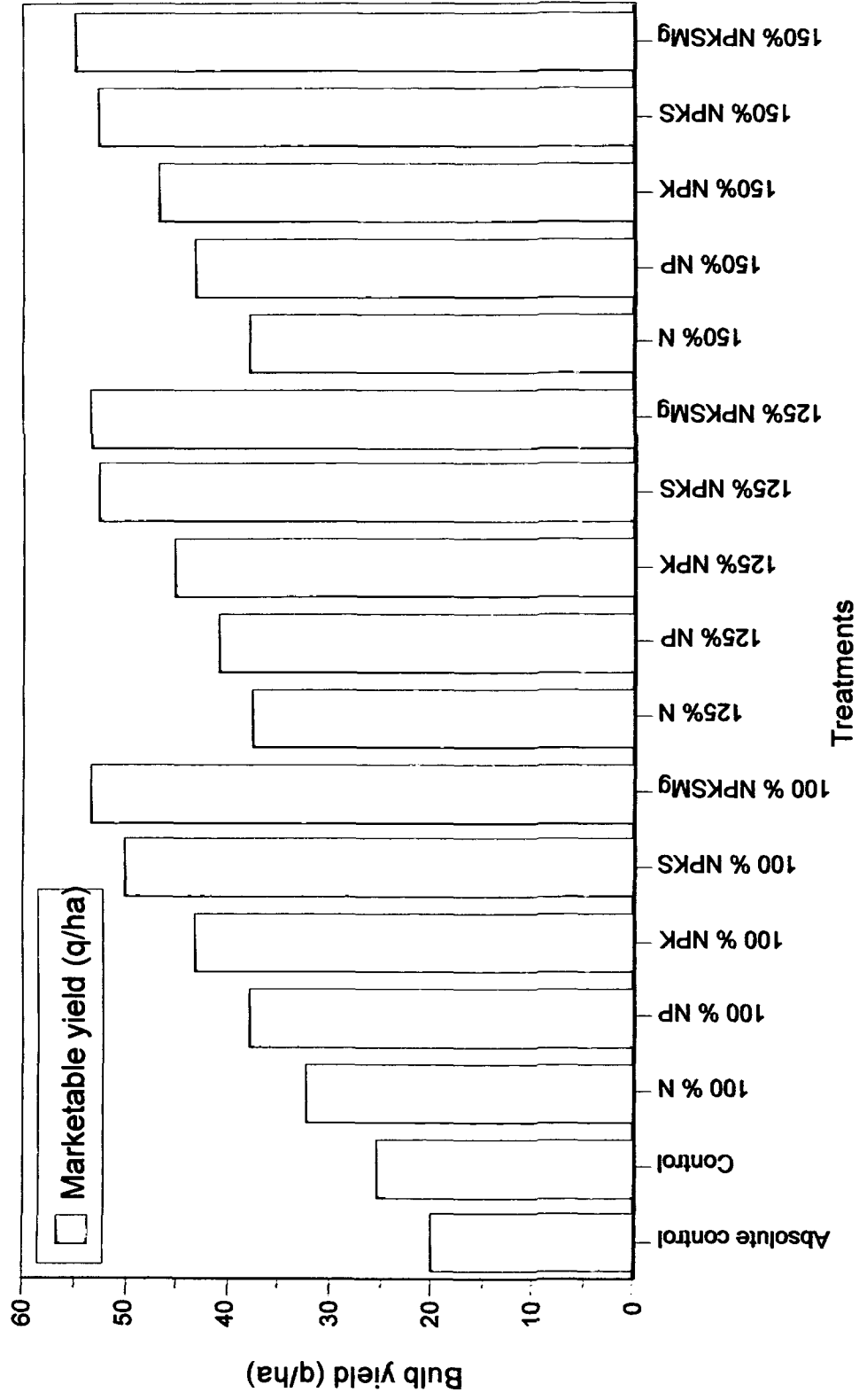


Fig. 4.1 Effect of multi-nutrient on marketable bulb yield (q/ha) of garlic

4.2.3 Interaction

The combined effect of nutrients and levels on marketable yield of garlic bulb could not reach the level of significance. The general trend of the data presented in Table 4.1 shows that at all the levels, there was increase in yield due to introduction of each nutrient. Similarly, with increasing dose of each nutrient, an increase in the yield of garlic bulb was recorded.

4.3 Effect of multi-nutrient on leaf yield (q/ha) of garlic (oven dry weight basis)

4.3.1 Levels

The maximum leaf yield on dry (oven dry weight basis) was recorded at 150 per cent (8.49 q/ha) and minimum at 100 per cent (6.82 q/ha) level of nutrient (Table 4.3). Leaf yield increased significantly due to 125 over 100 per cent as well as 150 over 125 per cent level. The increase on percentage basis was 8 and 15 due to 125 over 100 per cent and 150 over 125 per cent level of nutrients, respectively. The results depict that certainly there is increase in leaf yield due to addition of higher dose of nutrients upto 150 per cent level.

4.3.2 Nutrients

The results in the Table 4.3 revealed that with incorporation of FYM @ 10 t/ha, leaf yield was higher i.e. 5.60 q/ha compared with the

absolute control treatment, where it was 5.00 q/ha. The increase of 12 per cent was recorded due to FYM incorporation alone. The application of N over control also resulted in increased leaf yield and it was 20 per cent. Significant increase (8%) in leaf yield was recorded due to P application over N. However, K addition over NP nutrient combination did not influence yield in a significant way, but still there was increase to the tune of 3 per cent. Furthermore, S inclusion over NPK and Mg over NPKS showed tremendous and significant increase in leaf yield to the tune of 6 and 5 per cent, respectively.

Table 4.3 Effect of multi-nutrient on the leaf yield (q/ha) of garlic (dry weight basis)

Levels	Nutrients					Mean
	N	NP	NPK	NPKS	NPKSMg	
100 %	6.00	6.60	6.70	7.20	7.60	6.82
125 %	6.70	7.10	7.40	7.60	8.00	7.36
150 %	7.50	8.10	8.30	9.03	9.50	8.49
Mean	6.73	7.27	7.47	7.94	8.37	

Absolute control : 5.00

Control : 5.60

Main effects/Interaction LSD (P = 0.05)

Levels : 0.32

Nutrients : 0.41

Interaction : NS

4.3.3 Interaction

The interaction (nutrients x levels) effect on leaf yield was nonsignificant. But general trend of the data in Table 4.9, revealed that leaf yield of garlic increased due to higher dose of nutrients at different nutrient combinations and introduction of new nutrient at different levels. Maximum leaf yield was observed in 150 per cent NPKSMg treatment (9.5 q/ha) and lowest at 100 per cent N (6.0 q/ha).

4.4 Effect of multi-nutrient on nutrients concentration (%) in garlic bulb

4.4.1 Nitrogen

4.4.1.1 Levels

The data in Table 4.4 showed that there was significant difference in 125 per cent over 100 per cent level of nutrients in terms of N concentration in garlic bulb. However, due to 150 per cent level, there was nonsignificant increase over 125 per cent level of nutrients. The increase to the tune of 11 per cent was recorded due to 125 over 100 per cent level of nutrients.

4.4.1.2 Nutrients

The nitrogen content in garlic bulb as influenced by nutrient combinations is shown in Table 4.4. There was 39 per cent increase N concentration, in the plot where FYM @ 10 t/ha was incorporated over

Table 4.4 **Effect of multi-nutrient on concentration of nutrients (%) in garlic bulb**

	N	P	K	S	Mg
Levels					
100 %	2.7	0.15	2.9	0.64	0.18
125 %	3.0	0.16	3.4	0.67	0.17
150 %	3.0	0.17	3.6	0.67	0.16
LSD (P= 0.05)	0.1	NS	0.3	0.02	0.01
Nutrients					
N	3.0	0.13	3.0	0.61	0.17
NP	2.8	0.18	3.0	0.63	0.15
NPK	2.7	0.15	3.4	0.61	0.17
NPKS	2.9	0.17	3.5	0.74	0.16
NPKSMg	2.9	0.17	3.6	0.76	0.20
LSD (P=0.05)	0.2	0.03	0.4	0.02	0.02
Absolute control	1.8	0.06	1.1	0.55	0.15
Control	2.5	0.08	1.9	0.58	0.20

no FYM treated plot. With the application of N increase of 20 per cent was also recorded over control. In contrast to this, there was significant decrease in this parameter due to P application over N and it was of 7 per cent magnitude. The N concentration also decreased (4%) but non-

significantly due to the application of K over NP. However, S application showed significant increase (7%) over NPK. In plots receiving NPKSMg application, the N concentration was statistically same with those having NPKS treatment.

4.4.1.3 Interaction

The interaction effect of levels and nutrients on the N concentration in garlic bulb was there, however, it could not reach the level of significance.

4.4.2 Phosphorus

4.4.2.1 Levels

This effect of different levels of nutrient on P concentration in garlic bulb was nonsignificant (Table 4.4). Minimum amount of P content in garlic bulb (0.15%) was recorded at 100 per cent and maximum (0.17%) at 150 per cent level of nutrients. The per cent increase in P content in garlic bulb was 7 and 6 per cent due to 125 over 100 per cent level and 150 over 125 per cent level of nutrients, respectively.

4.4.2.2 Nutrients

The incorporation of FYM @ 10 t/ha showed increase to the tune of 33 per cent over the absolute control (no FYM), showing the good response of FYM on P concentration in garlic bulbs (Table 4.4).

Application N in the plots showed 62 per cent increase over the control plots, where only FYM was applied. There was significant difference in P concentration due to the application of P over N and the increase was 38 per cent. However, significant difference in P content was not observed with respect to K over NP, S over NPK and Mg over NPKS. There was decrease to the tune of 17 per cent with the application of K over NP levels. The S application over NPK showed increase of 13 per cent, however, Mg over NPKS did not increase the same

4.4.2.3 Interaction

The influence of interaction (nutrients x levels) on P concentration in garlic bulb was nonsignificant

4.4.3 Potassium

4.4.3.1 Levels

The maximum amount of potassium content was recorded at 150 per cent (3.6%) level and minimum at 100 per cent (2.9%) level of nutrients. A close look at the Table 4.4, shows that there was significant improvement in K concentration in garlic bulb due to 125 per cent over 100 per cent level of nutrients and the increase was 17 per cent. In contrast to this, there was not significant difference in 125 and 150 per cent level of nutrients, off-course there was slight increase of 6 per cent.

4.4.3.2 Nutrients

A reference to Table 4.4 indicated that FYM addition @ 10 t/ha in the plots (control) showed increase in K concentration of garlic bulb (1.9%) over the absolute control (1.1%). Similarly, with the application of N, increase in K (57%) content was recorded over the control treatment. However, when P was added over N, K concentration was statistically same. The influence on K concentration due to K over NP, S over NPK and Mg over NPKS was nonsignificant, but still there was increasing trend of K concentration. The corresponding increased were 13, 3 and 3 per cent, respectively.

4.4.3.3 Interaction

There was increase in concentration of K in garlic bulb at all levels of nutrient combinations due to different nutrient level and vice-versa, but it was not significant.

4.4.4 Sulphur

4.4.4.1 Levels

The effect of nutrient levels on S concentration in garlic bulb was significant (Table 4.4). The highest S content in garlic bulb was recorded at 125 per cent as well as 150 per cent and lowest at 100 per cent level of nutrients. The effect of 125 per cent (0.67 %) level of nutrients was the significant in increasing this parameter over 100 per

cent (0.64 %) level of nutrients. However, the increase due to 150 per cent over 125 per cent was nonsignificant and there was not at all increase in its content having same value i.e. 0.67 per cent.

4.4.4.2 Nutrients

Application of FYM (0.58%) caused increase in S content of garlic bulb over absolute control (0.55%) and the per cent increase was 5 (Table 4.4). Application of N also increased the same by 5 per cent over control. The increase (3%) in S content, due to addition of P over N was nonsignificant. However, there was decrease to the tune of 3 per cent with the K treatment over NP nutrient combination. In contrast to this, significant increase was also obtained in it, when S (0.74 %) was applied over NPK (0.61 %) i.e. 21 per cent increase. The highest amount of S content was recorded at NPKSMg (0.76%), combination of nutrients with increase of 3 per cent over NPKS, but statistically in a nonsignificant way. This clearly indicates that NPKS and NPKMg were statistically at par with each other in influencing the S content in garlic bulb, showing no response of Mg over NPKS.

4.4.4.3 Interaction

At 100, 125 and 150 per cent level, maximum S concentration was recorded due to NPKSMg and minimum to N treatment. Similarly, in general with addition of each nutrient over the previous one, there was

improvement in S concentration in garlic bulb at different levels, but in a nonsignificant manner. There was also increase due to enhanced level of various nutrients, off-course statistically in a nonsignificant manner.

4.4.5 Magnesium

4.4.5.1 Levels

Magnesium concentration in garlic bulb decreased due to increase in level of nutrients from 100 to 150 per cent but the effect of 150 over 100 per cent was only significant. Its concentration in garlic bulb was 0.18, 0.17 and 0.16 per cent in 100, 125 and 150 per cent level of nutrients (Table 4.4).

4.4.5.2 Nutrients

A close look of the Table 4.4 shows that Mg concentration in garlic bulb increased from 0.15 per cent in absolute control to 0.20 per cent in FYM treated plot compared with control. Nitrogen application decreased the concentration of magnesium to 0.17 per cent compared with control (0.20 %), phosphorus application over N, K over NP and S over NPK was not significant. However, magnesium application over NPKS significantly increased its concentration. The value of its concentration in garlic bulb in NPKSMg treatment was highest i.e. 0.20 per cent.

4.4.5.3 Interaction

Magnesium concentration in garlic bulb did not affect significantly due to interaction effect of levels and nutrients.

4.5 Effect of multi-nutrient on nutrients uptake (kg/ha) by garlic bulb

4.5.1 Nitrogen

4.5.1.1 Levels

The N uptake by garlic bulb significantly increased due to 125 per cent over 100 per cent level of nutrients. However, maximum N uptake by the crop was recorded at 150 per cent level (52.8 kg/ha), which was higher but nonsignificant compared with 125 per cent level (52.0%). The minimum N uptake was there in 100 per cent level of nutrients (44.4 kg/ha). The increase in N uptake due to 125 and 150 per cent level of nutrients over 100 per cent was 17 and 19 per cent, respectively (Table 4.5 and Fig. 4.2).

4.5.1.2 Nutrients

The N uptake was higher in the control plot, where FYM was only the dose (23.9 kg/ha) than absolute control (13.6 kg/ha) i.e. 76 per cent increase (Table 4.5). Increase in N uptake (71%) due to N nutrient combination over control treatment was also noticed. The effect of P over N and K over NP did not show significant increase in it. But significant

difference was recorded between NPKS and NPKSMg nutrients combination over NPK and the increase was 24 and 27 per cent, respectively. The N uptake in NPKSMg and NPKS nutrients combination was statistically same showing no response of Mg over NPKS.

Table 4.5 Effect of multi-nutrient on N uptake (kg/ha) by garlic bulb

Levels	Nutrients					Mean
	N	NP	NPK	NPKS	NPKSMg	
100 %	31.5	37.1	42.5	55.5	55.6	44.4
125 %	44.9	47.8	48.3	58.5	60.4	52.0
150 %	46.2	46.6	49.7	59.4	62.0	52.8
Mean	40.9	43.8	46.8	57.8	59.4	
Absolute control	: 13.6					
Control	: 23.9					

Main effects/Interaction LSD (P = 0.05)

Levels : 3.3

Nutrients : 4.2

Interaction : NS

4.5.1.3 Interaction

Effect of nutrients and levels interaction on N uptake was nonsignificant. But the general trend of the data depicts that there was increase in N uptake due to addition of each nutrient at all levels. In

case of the effect of levels at different nutrient combinations, the increase was upto 125 per cent at N and NP and upto 150 per cent at NPK, NPKS and NPKSMg levels.

4.5.2 Phosphorus

4.5.2.1 Levels

The data of P-uptake by garlic bulb has been presented in Table 4.6 and Fig. 4.2. The maximum P uptake was recorded at 150 per cent level (3.1 kg/ha) followed by 125 per cent (2.8 kg/ha) and minimum at 100 per cent level (2.6 kg/ha). The 125 per cent level was not significant over 100 per cent level in its effect on P uptake by garlic bulb. Similarly, the increase in P uptake was also recorded due to 150 per cent, but it was statistically same with 125 per cent level. However, 150 per cent level of nutrient was significantly better than that of 100 per cent level in its effect on P uptake. There was 8 and 19 per cent increase in P uptake by garlic bulb due to the application of nutrients @ 125 and 150 per cent as compared with 100 per cent level.

4.5.2.2 Nutrients

The data shown in Table 4.6 and Fig. 4.2 shows that in plot, where FYM was incorporated (control) was having more P uptake (0.7 kg/ha) than that of absolute control (0.5 kg/ha). There was also increase (157 %) in its uptake with the application of N over control treatment.

When P was applied over N, then also there was significant increase in P uptake (56%). But, with the application of K over NP, decrease of 11 per cent was recorded, which off-course was nonsignificant. When S was applied over NPK, again there was significant increase (32%). Due to Mg application over NPKS, the increase in its uptake (9%) was nonsignificant. The results clearly indicates that the significant improvement in P uptake by garlic was only due to P and S application.

Table 4.6 Effect of multi-nutrient on P uptake (kg/ha) by garlic bulb

Levels	Nutrients					Mean
	N	NP	NPK	NPKS	NPKSMg	
100 %	1.4	2.4	2.3	3.2	3.5	2.6
125 %	2.0	3.1	2.6	3.0	3.2	2.8
150 %	2.2	2.8	2.7	3.7	4.0	3.1
Mean	1.8	2.8	2.5	3.3	3.6	
Absolute control	: 0.5					
Control	: 0.7					

Main effects/Interaction LSD (P = 0.05)

Levels : 0.4
 Nutrients : 0.5
 Interaction : NS

4.5.2.3 Interaction

At all the levels maximum P uptake was recorded at the nutrient combination of NPKSMg and minimum at N only. The interaction effect of levels and nutrients on P uptake by garlic bulb was nonsignificant. The general trend showed that at all levels i.e. 100, 125 and 150 per cent, there was increase in P uptake due to introduction of new element except K. Similarly, at each nutrient combination, there was increase in its uptake, with increasing levels of the same.

4.5.3 Potassium

4.5.3.1 Levels

There was significant increase in K uptake by garlic bulb due to 125 over 100 per cent and 150 over 125 per cent level of nutrients (Table 4.7 and Fig. 4.2). The increase in K uptake in terms of per cent basis was 24 and 41 per cent due to 125 and 150 per cent level over 100 per cent level, respectively. The maximum K uptake by garlic bulb was obtained with the application of 150 per cent level of nutrients (61.0 kg/ha). Minimum uptake was recorded at 100 per cent level (43.4 kg/ha).

4.5.3.2 Nutrients

The application of FYM @ 10 t/ha over absolute control increased the K uptake by garlic bulb from 7.9 to 17.7 kg/ha i.e. 124 per cent, showing good response of FYM (Table 4.7). More K uptake

by garlic bulb was observed due to N application over control. Significant increase in its uptake was also recorded with the application of P over N, K over NP, S over NPK and Mg over NPKS. Maximum increase over control was recorded at NPKSMg followed by NPKS, NPK, NP, N. The increase in K uptake was 18, 26, 17 and 9 per cent due to P over N, K over NP, S over NPK and Mg over NPKS, in a respective manner.

Table 4.7 Effect of multi-nutrient on K uptake (kg/ha) by garlic bulb

Levels	Nutrients					Mean
	N	NP	NPK	NPKS	NPKSMg	
100 %	25.1	33.1	43.4	52.2	63.0	43.4
125 %	37.2	41.6	54.7	68.1	67.4	53.8
150 %	46.1	52.9	62.8	68.0	75.3	61.0
Mean	36.1	42.5	53.6	62.8	68.6	
Absolute control	: 7.9					
Control	: 17.7					

Main effects/Interaction LSD (P = 0.05)

Levels : 3.6
Nutrients : 4.7
Interaction : 8.1

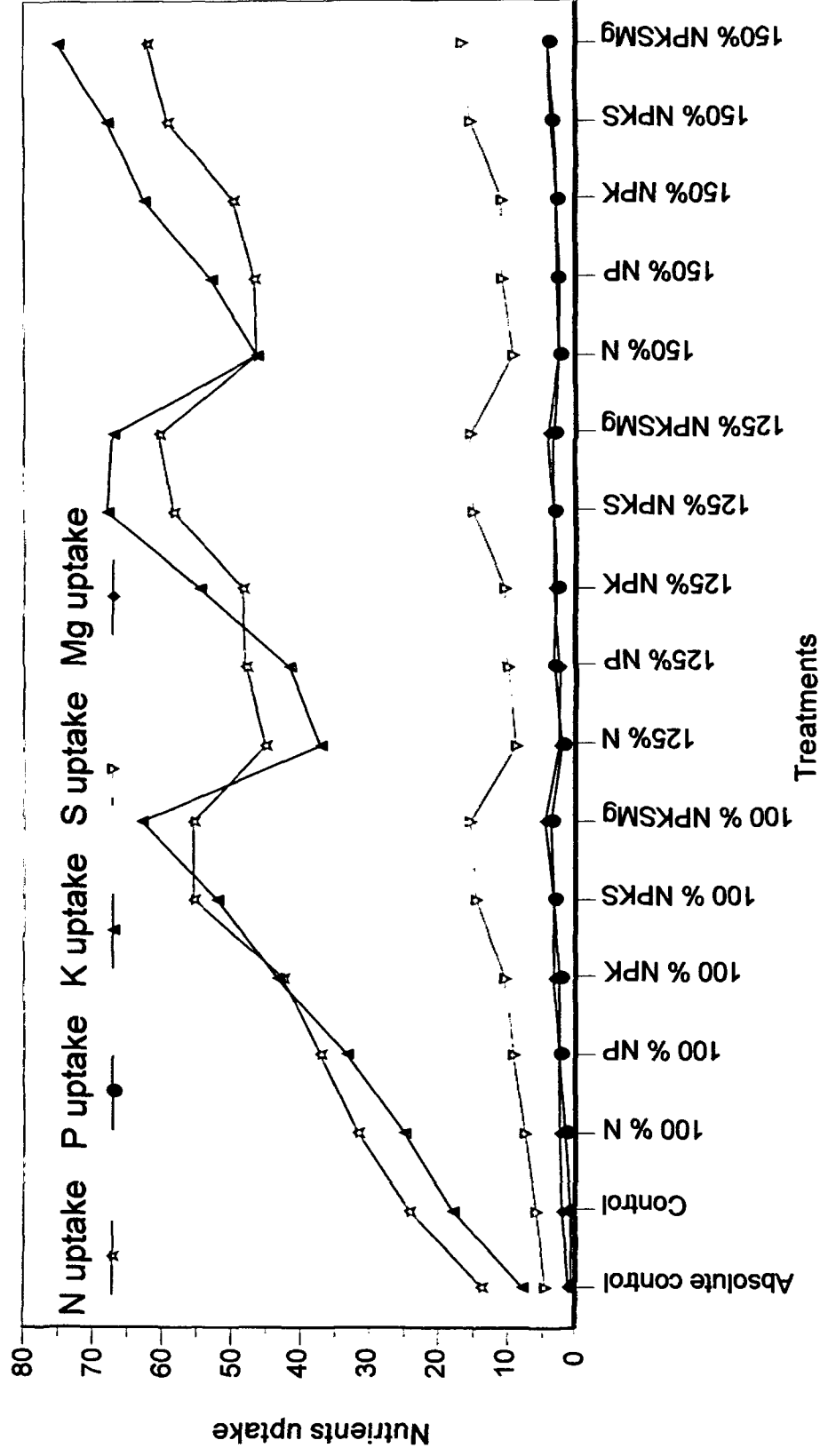


Fig. 4.2 Effect of multi-nutrient on nutrients uptake (kg/ha) by garlic bulb

4.5.3.3 Interaction

The data shown in Table 4.7 shows that the effect of P over N at 100 per cent and 125 per cent was not significant, which reached to a significant level at 150 per cent. At 100 per cent, the influence of K over NP, S over NPK and Mg over NPKS was significantly superior. Similarly at 125 per cent level, significant increase was recorded due to K over NP and S over NPK, but a nonsignificant decrease (1 %) was recorded due to Mg over NPKS. At 150 per cent level the increase @ 8 and 11 per cent was recorded by S over NPK and Mg over NPKS, but statistically in a nonsignificant manner. In contrast to this, there was significant increase in K uptake due to P addition over N.

So far as the effect of levels, at different nutrients is concerned, at N and NP nutrient combinations, there was significant increase in K uptake by the crop upto 150 per cent level of nutrient. But at NPK and NPKS nutrient combination, it narrowed down to 125 per cent level. Contrary to this, in case of NPKSMg nutrient combination, only 150 per cent level was significant in affecting the K uptake as compared to the 100 per cent level.

4.5.4 Sulphur

4.5.4.1 Levels

The application of 125 per cent level of nutrients over 100 per cent showed an increase in S uptake by garlic bulb, but it was not

statistically significant (Table 4.8). Similarly, due to 150 per cent level, there was increase over 125 per cent level, but non-significantly. However, it was significant over 100 per cent level. The increase in S uptake due to 125 per cent over 100 and 150 per cent over 125 per cent level was 5 and 6 per cent, respectively. The maximum uptake of S was recorded at 150 per cent level (12.5 kg/ha) and minimum at 100 per cent (11.2 kg/ha).

Table 4.8 Effect of multi-nutrient on S uptake (kg/ha) by garlic bulb

Levels	Nutrients					Mean
	N	NP	NPK	NPKS	NPKSMg	
100 %	7.3	9.0	10.1	14.4	15.1	11.2
125 %	8.7	9.8	10.3	15.0	15.4	11.8
150 %	9.1	10.6	10.8	15.4	16.7	12.5
Mean	8.4	9.8	10.4	14.9	15.7	
Absolute control	:	4.2				
Control	:	5.6				

Main effects/Interaction LSD (P = 0.05)

Levels : 0.7
 Nutrients : 0.9
 Interaction : NS

4.5.4.2 Nutrients

Application of FYM @ 10 t/ha increased the S uptake by garlic (5.6 kg/ha) over absolute control (4.2 kg/ha), where FYM was not applied (Table 4.8). Nitrogen addition as compared with control showed an increase in S uptake to the tune of 50 per cent. With the application of P over N, there was significantly higher S uptake, but when K was applied over NP, the increase was nonsignificant (6 %). Sulphur application over and above NPK showed a significant increase (43 %). However, NPKSMg nutrient combination was statistically same with NPKS. The S uptake obtained in N, NP, NPK, NPKS and NPKSMg was 8.4, 9.8 10.4, 14.9 and 15.7 kg/ha in a respective manner.

4.5.4.3 Interaction

The combined effect of nutrients and levels on S uptake by garlic crop could not reach the level of significance. The results in Table 4.8 shows that at all the levels, there was increase in S uptake due to addition of each nutrient. Similarly, with increasing dose of each nutrient, S uptake went on increasing.

4.5.5 Magnesium

4.5.5.1 Levels

Decrease in Mg uptake by garlic bulb was noticed due to each increment in level of nutrients upto 150 per cent level. But as a whole the effect of levels on its uptake was not significant (Table 4.9).

4.5.5.2 Nutrients

A considerable improvement in Mg uptake by garlic bulb was recorded due to FYM application over no FYM and it was to the tune of 72 per cent (Table 4.9). Nitrogen introduction also considerably increased uptake (20%) over control treatment. Magnesium uptake by garlic bulb also significantly improved due to K application over NP, Mg over NPKS. The corresponding increases were 28 and 32 per cent. The effect of S over NPK and P over N was nonsignificant in influencing the Mg uptake by garlic bulb.

Table 4.9 Effect of multi-nutrient on magnesium uptake (kg/ha) by garlic bulb

Levels	Nutrients					Mean
	N	NP	NPK	NPKS	NPKSMg	
100 %	2.21	2.32	2.95	3.24	4.51	3.05
125 %	2.43	2.33	3.11	3.20	4.04	3.02
150 %	2.32	2.30	2.83	3.01	3.97	2.89
Mean	2.32	2.32	2.96	3.15	4.17	
Absolute control	: 1.12					
Control	: 1.93					

Main effects/Interaction (LSD = 0.05)

Levels : NS
 Nutrients : 0.34
 Interaction : NS

4.5.5.3 Interaction

The effect of levels and nutrient interaction on its uptake by garlic bulb was not significant.

4.6 Effect of multi-nutrient nutrients concentration (%) in garlic leaf

4.6.1 Nitrogen

4.6.1.1 Levels

A reference to Table 4.10 revealed that highest N concentration was recorded at 150 per cent level (3.23) followed by 125 per cent (3.03%) and lowest at 100 per cent (2.53%). The N content recorded in 125 over 100 per cent level and 150 over 125 per cent level of nutrients was significantly higher. The extent of increase recorded due to 125 and 150 per cent i.e. due to both the levels over 100 per cent level was 20 and 28 per cent, respectively. The results showed that there is positive association between increasing levels of nutrients with N content in leaf.

4.6.1.2 Nutrients

The data with respect to N content in garlic leaf is given in Table 4.10. FYM application increased the garlic leaf N concentration by 29 per cent over absolute control. The N content in NPKSMg nutrients combination was maximum (3.01%) followed by NPKS (2.96%), NPK (2.92%), NP (2.90%) and N (2.87%). There was

increase in N concentration in garlic leaf due to increasing nutrient combinations i.e. N, NP, NPK, NPKS and NPKSMg, but in a nonsignificant manner.

Table 4.10 **Effect of multi-nutrient on nutrients concentration (%) in garlic leaf**

	N	P	K	S	Mg
Levels					
100 %	2.53	0.13	2.54	0.64	0.10
125 %	3.03	0.15	3.14	0.66	0.09
150 %	3.23	0.16	3.38	0.69	0.08
LSD (P= 0.05)	0.15	0.02	0.28	0.02	0.01
Nutrients					
N	2.87	0.11	2.72	0.60	0.08
NP	2.90	0.15	2.81	0.62	0.07
NPK	2.92	0.14	3.15	0.62	0.09
NPKS	2.96	0.16	3.10	0.71	0.08
NPKSMg	3.01	0.16	3.31	0.76	0.11
LSD (P=0.05)	NS	0.02	0.36	0.02	0.02
 Absolute control	 1.03	 0.04	 1.03	 6.46	 0.03
Control	1.33	0.06	1.83	8.33	0.10

the P content of garlic leaf by 14 per cent, but in a nonsignificant manner. The Mg addition over NPKS did not significantly influenced the P concentration of leaf. The effect of NPKSMg, NPKS, NPK and NP combination of nutrients was significant over N alone. The extent of corresponding increases was 36, 27, 45 and 45 per cent. (Table 4.10).

4.6.2.3 Interaction

Phosphorus content in garlic leaf was not influenced significantly by interaction effect between levels and nutrients.

4.6.3 Potassium

4.6.3.1 Levels

Data in Table 4.10 revealed that the highest K per cent in garlic leaf was recorded at 150 per cent (3.38%) and lowest at 100 per cent level of nutrients (2.54 %). The dose of nutrients upto 125 per cent of recommended nutrients significantly increased the K content in garlic leaf. With further increase in level to 150 per cent, there was not significant improvement in K content. The level, where 150 per cent of recommended dose of nutrients was applied also resulted in a significant increase in its concentration over 100 per cent. The quantitative increase due to 125 to 150 per cent level of nutrients was 24 and 33 per cent over 100 per cent level, respectively.

A close look at the Table 4.10 shows that K content in garlic leaf was higher in control (1.83%) treatment, where only FYM was applied compared with absolute control (1.03%) i.e. 78 per cent increase. Similarly, addition of N over control caused increase of 49 per cent in its concentration. The K content of leaf was statistically same, when treatments N with NP, NPK with NP, NPKS with NPK and NPKSMg with NPKS were compared. However, the effect of NPK over N in improving its content was definitely significant.

4.6.3.3 Interaction

The combined effect of nutrients and levels on K concentration in leaf was nonsignificant.

4.6.4 Sulphur

4.6.4.1 Levels

The data in Table 4.10 reveal that the highest S content in leaf was recorded at 150 per cent level (0.69%) and lowest at 100 per cent level (0.64%). Due to 125 per cent level, there was increase in S content in leaf over 100 per cent level of nutrients, but statistically in a nonsignificant way. In contrast to this, S content increased in a significant manner due to 150 per cent and over 100 as well as 125 per cent level of nutrients. The per cent increase was

3 and 8 per cent due to 125 and 150 per cent over 100 per cent level, respectively.

4.6.4.2 Nutrients

Incorporation of FYM in control @ 10 t/ha plot increased the S content of leaf (0.57 %) over absolute control (0.50 %) to an extent of 14 per cent (Table 4.10). Similarly, application of N over control (FYM) resulted in an increase of 5.2 per cent. Phosphorus applied over N and K over NP showed a nonsignificant increase (3 and 0%) in its content. Sulphur addition over NPK and Mg over NPKS caused a significant increase to the tune of 15 per cent and 7 per cent, respectively.

4.6.4.3 Interaction

Effect of nutrients and levels interaction on sulphur concentration in leaf was nonsignificant.

4.6.5 Magnesium

4.6.5.1 Levels

The amount of Mg concentration in garlic leaf significantly decreased only due to 150 per cent over 100 per cent (Table 4.10). The effect of 125 over 100 per cent level and 150 over 125 per cent level decreased its concentration, but in a nonsignificant manner. The per cent decrease in Mg concentration over 100 per cent was 10 and 25 per cent due to 125 and 150 per cent level of nutrients, respectively.

4.6.5.2 Nutrients

FYM application increased the magnesium concentration in garlic leaf, its status was 0.06 per cent in absolute control which increased to 0.10 per cent to higher level of in control plot (Table 4.10). If we see the effect of nitrogen over FYM, it decreased the Mg concentration from 0.10 (in control) to 0.08 per cent (N alone). Phosphorus application decreased the concentration of Mg over N treatment but in a nonsignificant way. There was significant increase in Mg concentration due to K application over NP and Mg over NPKS. Contrary to this, S addition over NPK decreased the Mg concentration, but it was nonsignificant. The values of Mg content in garlic leaf were 0.08, 0.07, 0.09, 0.08 and 0.11 per cent in N, NP, NPK, NPKS and NPKSMg, respectively.

4.6.5.3 Interaction

Magnesium concentration in garlic leaf did not influence significantly due to the interaction effect of levels and nutrients.

4.7 Effect of multi-nutrient on nutrients uptake (kg/ha) by garlic leaf

4.7.1 Nitrogen

4.7.1.1 Levels

A reference to Table 4.11 reveals that highest N uptake by garlic leaf was recorded at 150 per cent followed by 125 per cent and

lowest at 100 per cent level of nutrients. N uptake by garlic leaf increased significantly with the application of nutrients upto 150 per cent level of recommended dose of nutrients. The increase was to the tune of 29 and 23 per cent due to 125 over 100 and 150 per cent over 125 per cent level of recommended nutrients.

Table 4.11 Effect of multi-nutrient on the N uptake (kg/ha) by garlic leaf

Levels	Nutrients					Mean
	N	NP	NPK	NPKS	NPKSMg	
100 %	14.2	16.1	16.5	18.9	20.8	17.3
125 %	20.1	21.8	22.9	22.5	24.2	22.3
150 %	24.2	25.9	26.6	29.5	31.0	27.4
Mean	19.5	21.3	22.0	23.7	25.3	
Absolute control	:	5.1				
Control	:	7.4				

Main effects/Interaction LSD (P = 0.05)

Levels : 1.1
 Nutrients : 1.4
 Interaction : NS

4.7.1.2 Nutrients

FYM application @ 10 t/ha as compared with absolute control (no FYM) showed increase in N uptake by garlic leaf. It increased from 5.1 kg/ha in absolute control (no FYM) to 7.4 kg/ha in FYM plot. i.e. increase of 45 per cent (Table 4.11). There was tremendous increase in its uptake by N application over control (163 %). The N uptake also significantly increased due to addition of P over N, S over NPK and Mg over NPKS. But, when K was applied over NP, there was not significant increase in its uptake. The maximum N uptake was recorded in NPKSMg (25.3 kg/ha) followed by NPKS (23.7 kg/ha), NPK (22.0 kg/ha), NP (21.3 kg/ha) and N (19.5 kg/ha).

4.7.1.3 Interaction

Nonsignificant interaction effect was recorded on N uptake by garlic leaf at all the levels and combination of nutrients. The maximum N uptake was recorded at 150 per cent followed by 125 per cent and 100 per cent level of nutrients and with addition of each nutrient increase was recorded at all the levels.

4.7.2 Phosphorus

4.7.2.1 Levels

The minimum P uptake by garlic leaf was recorded at 100 per cent level (0.89 kg/ha) and maximum at 150 per cent level (1.34 kg/ha)

of nutrients (Table 4.12). The P uptake was significantly higher at 125 per cent level over 100 per cent and 150 per cent over 125 per cent level of nutrients. The per cent increase in P uptake was recorded to the tune of 25 per cent and 21 per cent due to 125 over 100 per cent and 150 over 125 per cent level of nutrients, respectively.

Table 4.12 Effect of multi-nutrient on the P uptake (kg/ha) by garlic leaf

Levels	Nutrients					Mean
	N	NP	NPK	NPKS	NPKSMg	
100 %	0.47	0.86	0.94	1.08	1.09	0.89
125 %	0.74	1.13	1.14	1.24	1.28	1.11
150 %	1.05	1.37	1.25	1.45	1.61	1.34
Mean	0.75	1.12	1.11	1.26	1.33	
Absolute control	: 0.20					
Control	: 0.32					

Main effects/Interaction LSD (P = 0.05)

Levels	: 0.13
Nutrients	: 0.16
Interaction	: NS

4.7.2.2 Nutrients

The increase in P uptake by garlic leaf was recorded with the incorporation of FYM @ 10 t/ha in control plot (0.32 kg/ha) compared

with absolute control (0.20 kg/ha). The increase was 60 per cent due to FYM addition over no FYM. The application of N showed tremendous increase in P uptake (134%) over control treatment (Table 4.12). Phosphorus application resulted in significant increase in P uptake and it caused 49 per cent increase. However, there was decrease (0.89 %) in P uptake, off-course nonsignificant due to K over NP. Sulphur application over NPK and Mg over NPKS showed a nonsignificant increase in it to the tune of 14 and 6 per cent, respectively.

4.7.2.3 Interaction

Different levels and nutrients combination resulted in enhancement of P uptake by garlic leaf, off-course the overall effect was nonsignificant. There was increase in P uptake due to 125 level of nutrients over 100 per cent and 150 over 125 per cent. At all levels, with addition of each nutrient, there was improvement in uptake of P by garlic leaf.

4.7.3 Potassium

4.7.3.1 Levels

The results demonstrating the effect of different levels of nutrients on K uptake by garlic leaf has been shown in Table 4.13. The highest K uptake was recorded at 150 per cent level (28.8 kg/ha)

followed by 125 per cent (23.1 kg/ha) and lowest at 100 per cent level (17.5 kg/ha). The K uptake by garlic leaf increased significantly due to each increment in level of nutrients from 100 to 150 per cent. Meaning thereby upto 150 per cent level, the response of increasing levels was conspicuous and significant. Due to 125 and 150 per cent level of the nutrient, there was increase of 32 and 65 per cent in K uptake over 100 per cent, respectively.

Table 4.13 Effect of multi-nutrient on K uptake (kg/ha) by garlic leaf

Levels	Nutrients					Mean
	N	NP	NPK	NPKS	NPKSMg	
100 %	12.2	15.2	17.6	19.7	22.8	17.5
125 %	19.6	20.9	24.5	24.1	26.7	23.1
150 %	24.0	25.9	29.2	30.4	34.3	28.8
Mean	18.6	20.7	23.8	24.7	27.9	
Absolute control	: 5.2					
Control	: 10.3					

Main effects/Interaction LSD (P = 0.05)

Levels : 2.1
 Nutrients : 2.6
 Interaction : NS

4.7.3.2 Nutrients

Application of FYM @ 10 t/ha in control treatment showed an increase in K uptake (10.3 kg/ha) over the absolute control (no FYM), where the K uptake was 5.2 kg/ha (Table 4.13). The application of N showed increase of 81 per cent over control. Phosphorus applied over N caused a nonsignificant increase of 11 per cent. However, application of K over NP resulted in a significant increase in its uptake and it caused 15 per cent increase. Nutrients combination NPKS showed a nonsignificant increase (4%) and it was statistically at par with NPK nutrient combination. Furthermore, there was significant K uptake by garlic leaf due to NPKSMg over NPKS and was best treatment among different nutrient combinations. Potassium uptake by garlic leaf was 13 per cent due to NPKSMg over NPKS.

4.7.3.3 Interaction

The effect of interaction (levels and nutrients) on K uptake by garlic leaf was nonsignificant. But general trend of the data showed that there was certainly increase in K uptake due to addition of each nutrient and increment in its level.

4.7.4 Sulphur

4.7.4.1 Levels

A look at the data presented in Table 4.14, revealed that maximum S uptake was recorded (5.92 kg/ha) at 150 per cent and

minimum (4.34 kg/ha) at 100 per cent level. Significant increase in S uptake by garlic leaf was recorded due to 125 per cent over 100 per cent level and 150 per cent over 125 per cent level of nutrients. The per cent increase recorded due to 125 and 150 per cent compared with 100 per cent level was 12 and 22 per cent, respectively.

Table 4.14 **Effect of multi-nutrient on S uptake (kg/ha) by garlic leaf**

Levels	Nutrients					Mean
	N	NP	NPK	NPKS	NPKSMg	
100 %	3.39	4.03	4.00	4.90	5.40	4.34
125 %	4.00	4.43	4.46	5.45	5.97	4.86
150 %	4.75	5.18	5.26	6.59	7.83	5.92
Mean	4.05	4.55	4.58	5.65	6.39	
Absolute control	: 2.48					
Control	: 3.23					

Main effects/Interaction LSD (P = 0.05)

Levels : 0.23
 Nutrients : 0.29
 Interaction : 0.51

4.7.4.2 Nutrients

Sulphur uptake by garlic leaf in FYM incorporated plot (control) was higher than that in FYM free plot (absolute control). The increase of 30 per cent in its uptake was recorded due to FYM application alone (Table 4.14). Application of N also showed an increase of 25 per cent over control treatment. Phosphorus application over N, S over NPK and Mg over NPKS also caused significant increase in S uptake by garlic leaf. However, K addition over NP resulted in an improvement in its uptake, but in a nonsignificant way. The trend in terms of S uptake by garlic leaf was $\text{NPKSMg} > \text{NPKS} > \text{NPK} > \text{NP} > \text{N}$ and the corresponding values were 4.05, 4.55, 4.58, 5.65 and 6.39 kg/ha.

4.7.4.3 Interaction

At 100 per cent level, the application of P over N significantly increased the S uptake by leaf (19%). Potassium applied over NP showed a nonsignificant decrease (0.74%). Application of S over NPK and Mg over NPKS caused significant increase of 23 and 10 per cent. A perusal of the data in Table 4.14 indicates that at 125 per cent level, application of P over N and K over NP caused a nonsignificant increase to the extent of 11 and 1.0 per cent, respectively. However, S applied over NPK and Mg over NPKS did not increase its uptake significantly and it was 22 and 10 per cent, respectively. At highest level i.e. 150 per cent, P application over N and K over NP showed a nonsignificant

increase of 9 and 1 per cent, respectively. Sulphur application over NPK and Mg over NPKS also resulted in an increase, but in a significant manner. The extent of corresponding increases were 25 and 19 per cent.

The nutrient level of 125 per cent increased the S uptake significantly over 100 per cent level at N, NPKS and NPKSMg, the extent of increase was 18, 11 and 11 per cent, respectively. However, the effect of 125 over 100 per cent was nonsignificant at NP and NPK combination, still showing an increase of 10 and 12 per cent. The significant increase in its uptake was also recorded at all the nutrient combinations due to 150 over 125 per cent level with increase of 19, 17, 18, 21 and 31 per cent at N, P, K, S and Mg, respectively.

4.7.5 Magnesium

4.7.5.1 Levels

The data in Table 4.15 indicate that with increase in level, there was proportionate increase in Mg uptake by garlic leaf, but statistically it was nonsignificant (Table 4.15).

4.7.5.2 Nutrients

FYM application @ 10 t/ha increased the Mg uptake by garlic bulb to 0.56 kg/ha from a lower value of 0.42 kg/ha absolute control (Table 4.15). Its uptake by garlic leaf decreased by 5 per cent due to N application over control. The values of Mg uptake (0.53 kg/ha) were same

in N and NP treatment. However, there was significant improvement to the tune of 26 per cent to K over NP (0.67 kg/ha) and 47 per cent to Mg over NPKS (0.94 kg/ha) but, Mg uptake in garlic leaf decreased due to S application over NPK and the magnitude of decrease 5 per cent.

Table 4.15 Effect of multi-nutrient on magnesium uptake (kg/ha) by garlic leaf

Levels	Nutrients					Mean
	N	NP	NPK	NPKS	NPKSMg	
100 %	0.54	0.53	0.67	0.58	0.99	0.66
125 %	0.54	0.50	0.66	0.61	0.88	0.64
150 %	0.52	0.57	0.67	0.72	0.96	0.68
Mean	0.53	0.53	0.67	0.64	0.94	
Absolute control	: 0.42					
Control	: 0.56					

Main effects/Interaction LSD (P = 0.05)

Levels : NS
 Nutrients : 0.12
 Interaction : NS

4.7.5.3 Interaction

The interaction effect (levels x nutrients) on magnesium uptake by garlic leaf was not significant.

4.8 Effect of multi-nutrient on soil properties and nutrients status

4.8.1 pH

4.8.1.1 Levels

The application of increasing levels of nutrients from 100 to 150 per cent did not change the pH of the soil at harvest of the garlic. The value of pH at all the levels of nutrients was same i.e. 5.8 (Table 4.16).

Table 4.16 Effect of multi-nutrient on pH of the soil at harvest of garlic

Levels	Nutrients					Mean
	N	NP	NPK	NPKS	NPKSMg	
100 %	5.8	5.8	5.8	5.8	5.8	5.8
125 %	5.8	5.8	5.8	5.8	5.9	5.8
150 %	5.8	5.8	5.8	5.8	5.9	5.8
Mean	5.8	5.8	5.8	5.8	5.9	
Absolute control	: 5.7					
Control	: 5.8					

4.8.1.2 Nutrients

Farm yard manure incorporated plots showed little more pH, i.e. 5.8 as compared to FYM free plots, where the pH was 5.7 (Table 4.16). The different nutrient combination had no impact on change in pH of the soil except Mg, which increased the pH to 5.9 compared with NPKS, where the value was 5.8 i.e. 17 per cent.

4.8.1.3 Interaction

The influence of levels of different nutrients was not there on pH of the soil. The different nutrient combinations were also unable to increase the pH at all the three levels of application rate with the exception of Mg over NPKS, where there was slight increase in pH of the soil.

4.8.2 Organic carbon

4.8.2.1 Levels

A reference to Table 4.17 indicates that organic carbon content in the soil at the harvest of garlic was higher in 125 per cent compared with 100 per cent and 150 per cent with 125 per cent level, but in a nonsignificant manner. The 125 per cent level of application of nutrient showed an increase of 6 per cent over 100 per cent. Similarly, due to 150 per cent over 125 per cent level, the increase was 3 per cent. At nutrient level of 150 per cent, maximum organic carbon status

in soil was recorded (12.2 g/kg) and it was minimum in 100 per cent level (11.1 g/kg).

Table 4.17 Effect of multi-nutrient on organic carbon (g/kg) status of soil at harvest of garlic

Levels	Nutrients					Mean
	N	NP	NPK	NPKS	NPKSMg	
100 %	10.2	10.9	11.5	11.8	11.2	11.1
125 %	11.1	11.2	11.2	12.3	13.0	11.8
150 %	11.7	12.3	12.5	11.3	13.4	12.2
Mean	11.0	11.5	11.7	11.8	12.5	
Absolute control	: 8.8					
Control	: 10.0					

Main effects/Interaction LSD (P= 0.05)

Levels	:	0.9
Nutrients	:	NS
Interaction	:	NS

4.8.2.2 Nutrients

The incorporation of FYM @ 10 t/ha showed an increase of 14 per cent over absolute control (no FYM), depicting good response of FYM application to the crop (Table 4.17). Off-course the effect of

different nutrients on organic carbon was nonsignificant. But, still addition of N over control showed an increase (10 %) in the status of organic carbon. The P addition over N, K over NP, S over NPK and Mg over NPKS increased the organic carbon content by 5, 2, 1 and 6 per cent, respectively. The maximum organic carbon was obtained in NPKSMg treatment combination (12.5 kg/ha) of nutrients and minimum (11.0 kg/ha) in N alone treatment.

4.8.2.3 Interaction

Organic carbon status in the soil at the harvest of the crop, was not affected by the interaction effect of the nutrients and levels. But as such, there was slight increase in its status due to increasing doses of nutrients as well as addition of each nutrient at different levels (Table 4.17).

4.8.3 Available nitrogen

4.8.3.1 Levels

The maximum available N status in the soil at harvest of the crop was recorded in 150 per cent (297 kg/ha) and minimum in 100 per cent (261 kg/ha). A close look at the Table 4.18 reveals that there was significant build-up of available N in the soil due to 125 per cent over 100 per cent and 150 over 125 per cent level of nutrient combination. The per cent increase in its status was to the extent of 10 and 3 per

cent due to 125 over 100 per cent and 150 over 125 per cent level of nutrient combination.

Table 4.18 Effect of multi-nutrient on available N (kg/ha) status at harvest of garlic

Levels	Nutrients					Mean
	N	NP	NPK	NPKS	NPKSMg	
100 %	265	260	256	260	265	261
125 %	288	285	283	287	292	287
150 %	300	295	293	296	300	297
Mean	284	280	277	281	286	
Absolute control	:	205				
Control	:	235				

Main effects/Interaction LSD (P = 0.05)

Levels : 5.0

Nutrients : NS

Interaction : NS

4.8.3.2 Nutrients

The content of available N in the control plot increased with application of FYM @ 10 t/ha over absolute control plot, where no FYM was applied (Table 4.18). An increase in available N status to the tune

of 15 per cent was recorded due to FYM application over no FYM treatment. The nutrient combinations were not significant in its affect on available N status of the soil. Nitrogen application increased the available N status over control (21%). With application of P over N a decrease was noticed (1%). The K application over NP showed decrease to the tune of 1 per cent, but when S was applied over NPK and Mg over NPKS, there was increase of 1 and 2 per cent, off-course all these values were statistically nonsignificant.

4.8.3.3 Interaction

The status of available N in the soil did not affect significantly due to the interaction effect between nutrient combinations and their levels.

4.8.4 Available phosphorus

4.8.4.1 levels

The maximum available P was recorded at 150 per cent level (24.8 kg/ha) and minimum at 100 per cent (22.7 kg/ha). The effect of different levels of nutrients on available P status was significant. There was increase in available P status of soil due to 125 per cent level of nutrient over 100 per cent (Table 4.19). The increase in level of nutrients from 125 to 150 per cent did not show significant increase in its status. The increase in available status of phosphorus in the soil at the harvest

of the crop was 6 and 9 per cent due to addition of 125 and 150 per cent level over 100 per cent level, respectively.

Table 4.19 Effect of multi-nutrient on available P (kg/ha) status at harvest of garlic

Levels	Nutrients					Mean
	N	NP	NPK	NPKS	NPKSMg	
100 %	16.8	22.6	22.7	25.4	26.0	22.7
125 %	17.8	24.1	24.4	26.7	27.5	24.1
150 %	18.0	25.0	25.5	27.4	28.0	24.8
Mean	17.5	23.9	24.2	26.5	27.2	
Absolute control	:	12.0				
Control	:	16.5				

Main effects/Interaction LSD (P = 0.05)

Levels : 1.1

Nutrients : 1.5

Interaction : NS

4.8.4.2 Nutrients

Farm yard manure application @ 10 t/ha in the control plot showed an increase in available P status of the soil over the absolute control (38%). The N application compared with control showed an

increase in its status to the tune of 6 per cent only, which was almost negligible (Table 4.19). However, P application over N caused quite high and significant increase in its status in the soil i.e. 36 per cent. The K addition over NP showed nonsignificant increase (1 %). It is worth mentioning here that application of S resulted in significant increase in its status over NPK (10 %) showing response of S on available P. The combination of NPKSMg showed increase of 3 per cent over NPKS, but it was nonsignificant.

4.8.4.3 Interaction

The interaction effect of levels and nutrients on available P content in soil was off-course nonsignificant. But still, there was improvement in P status of the soil due to addition of each nutrient at all the levels. Similarly, available P status in the soil also increased due to increase in dose of every nutrient.

4.8.5 Available potassium

4.8.5.1 Levels

The data embodied in Table 4.20 shows that maximum value of available K was recorded (255 kg/ha) at 100 per cent and minimum at 150 per cent (216 kg/ha) level of nutrients. Based on statistics, the application of 125 per cent over 100 and 150 per cent over 125 per cent significantly decreased the available K content of the soil. The

decrease in status was 7 and 9 per cent, when level of nutrients increased from 100 to 125 and 125 to 150 per cent, respectively.

Table 4.20 Effect of multi-nutrient on available K (kg/ha) status at harvest of garlic

Levels	Nutrients					Mean
	N	NP	NPK	NPKS	NPKSMg	
100 %	238	266	277	273	260	255
125 %	226	220	295	222	220	237
150 %	217	210	222	220	213	216
Mean	227	219	265	238	231	
Absolute control	:	205				
Control	:	262				

Main effects/Interaction LSD (P = 0.05)

Levels	:	4
Nutrients	:	5
Interaction	:	8

4.8.5.2 Nutrients

The FYM incorporated plots showed more available K (262 kg/ha) in control treatment over absolute control (205 kg/ha) and per cent increase was 28 (Table 4.20). The application of N showed a

nonsignificant decrease in its status over the control and it was 15 per cent. Similarly, there was decrease (4%) in its status due to the application of P over N, but statistically it was same. The available K increased drastically and significantly, when K was applied over NP, the increase was 21 per cent. In contrast to this, sulphur application over NPK followed by Mg over NPKS showed decrease, off-course statistically nonsignificant and it was to the tune of 10 and 3 per cent, respectively.

4.8.5.3 Interaction

Phosphorus application over N was nonsignificant and statistically same at all the three levels of nutrients. However, the application of K at all the levels showed significant increase in available K over NP. Similarly, S effect on available K as compared to NP and Mg over NPKS was nonsignificant and negative (Table 4.20).

So far as the effect of different levels at different nutrient combinations is concerned, at N and NP, there was significant decrease in available K upto 150 per cent level. However, at NPKS and NPKSMg, significant decrease was noticed upto 125 per cent level only. But at NPK level, then with further increase in the level, a nonsignificant decrease was recorded.

4.8.6 Available sulphur

4.8.6.1 Levels

With increase in the level of nutrients from 100 to 125 per cent, there was significant decrease in available S status of soil (Table 4.21). However, the application of 150 per cent over 125 per cent level of nutrient resulted in decrease, but it was statistically nonsignificant. The decrease in available S (kg/ha) status of the soil over 100 per cent level was 9 and 10 per cent due to 125 and 150 per cent, respectively.

Table 4.21 Effect of multi-nutrient on available S (kg/ha) status at harvest of garlic

Levels	Nutrients					Mean
	N	NP	NPK	NPKS	NPKSMg	
100 %	23.0	21.0	20.0	27.0	28.0	23.8
125 %	20.0	21.0	18.0	25.0	24.0	21.6
150 %	20.0	19.0	18.0	24.0	26.0	21.4
Mean	21.0	20.3	18.7	25.3	26.0	
Absolute control	: 15.0					
Control	: 21.0					

Main effects/Interaction LSD (P = 0.05)

Levels	:	1.6
Nutrients	:	2.0
Interaction	:	NS

4.8.6.2 Nutrients

The FYM application @ 10 t/ha in the control (21.0 kg/ha) showed increase over absolute control (15.0 kg/ha), the increase was 40 per cent (Table 4.21). With the application of N, there was increase in available S over control treatment. The application of P over N showed a nonsignificant decrease in its status, which was 3 per cent. Similarly, there was decrease (8 %) in its status due to K application over NP, but it was significant. In contrast to this, the application of S over NPK increased its content significantly (35%). Furthermore, the increase was also recorded due to Mg over NPKS (3%), but it was not significant.

4.8.6.3 Interaction

Available S status in the soil at the harvest of garlic crop was not influenced significantly due the combined effect (interaction) of nutrients and levels.

4.8.7 Exchangeable magnesium

4.8.7.1 Levels

A reference to Table 4.22 shows that exchangeable Mg at the harvest of garlic decreased significantly with each increment in level of nutrient upto 150 per cent level. The exchangeable Mg decreased by 0.03 and 0.06 cmol(p⁺)/kg due to 125 and 150 per cent level of nutrients over 100 per cent, respectively.

Table 4.22 Effect of multi-nutrient on exchangeable magnesium [cmol(p⁺)/kg] status at the harvest of garlic

Levels	Nutrients					Mean
	N	NP	NPK	NPKS	NPKSMg	
100 %	1.09	1.06	1.10	1.05	1.23	1.11
125 %	1.06	1.03	1.07	1.04	1.20	1.08
150 %	1.03	1.00	1.05	1.01	1.18	1.05
Mean	1.06	1.03	1.07	1.03	1.20	
Absolute control	:	1.00				
Control	:	1.10				

Main effects/Interaction LSD (P= 0.05)

Levels	:	0.01
Nutrients	:	0.02
Interaction	:	NS

4.8.7.2 Nutrients

The amount of exchangeable Mg increased in control plot (FYM) over absolute control and the extent of increase was of 0.10 cmol(p⁺)/kg. In contrast to this N application decreased the exchangeable Mg status in soil at harvest of crop and it decreased by 0.04 cmol(p⁺)/kg (Table 4.22). Among the effect of different nutrients, maximum content of exchangeable Mg was recorded in NPKSMg treatment. i.e. 1.20 cmol(p⁺)/kg. Phosphorus addition over N significantly decreased its status (3 %) over N. However, significant increase in its status was recorded due to K application over NP and the increase was to the tune of 4 per cent. But again sulphur

addition significantly decreased (4%) its status over NPK. A significant and considerable increase in exchangeable Mg was recorded due to Mg over NPKS and increase was 17 per cent.

4.8.7.3 Interaction

The interaction effect of levels and nutrients on the status of exchangeable Mg at the harvest of garlic could not reach the level of significance.

4.9 Effect of multi-nutrient on quality parameters

4.9.1 Protein content (%) in garlic bulb

4.9.1.1 Levels

A reference to Table 4.23 indicates that 125 per cent level was significantly superior to 100 per cent level, in its effect on protein content, however, 150 per cent level was statistically at par with 125 per cent level of nutrients. The maximum protein content in garlic bulb was recorded at 125 per cent level (18.6%) and minimum at 100 per cent level of nutrients. An increase of 12 per cent was recorded at 125 per cent over 100 per cent and decrease of 1 per cent due to 150 per cent over 125 per cent level.

4.9.1.2 Nutrients

The data presented in the table shows that the protein per cent in FYM treated plot was more (15.3%) than that of the absolute control

(11.2%), which showed an increase of 37 per cent. When N was applied over FYM alone, there was increase of 22 per cent in protein content (Table 4.23). Application of phosphorus over N and K over NP decreased it, but it was nonsignificant. In contrast to this, significant increase (8%) was recorded due to application of S over NPK. However, the inclusion of Mg over NPKS caused nonsignificant decrease (2%) in it. The results also elaborate that the maximum protein per cent in garlic bulb was noticed in N followed by NPKS, NPKSMg, NP and NPK combination of nutrients in sequence.

Table 4.23 Effect of multi-nutrient on protein (%) in garlic bulb

Levels	Nutrients					Mean
	N	NP	NPK	NPKS	NPKSMg	
100 %	16.0	16.1	16.2	18.2	16.6	16.6
125 %	19.6	19.1	17.5	18.2	18.7	18.6
150 %	20.1	17.7	17.4	18.5	18.6	18.4
Mean	18.6	17.6	17.0	18.3	17.9	
Absolute control	: 11.2					
Control	: 15.3					

Main effects/Interaction LSD (P = 0.05)

Levels	:	0.8
Nutrients	:	1.0
Interaction	:	1.7

4.9.1.3 Interaction

The effect of different nutrients at various levels was significant on protein content (Table 4.24). At 100 per cent level, the maximum protein was recorded at NPKS (18.2%) and minimum at N (16.0%) level of nutrient combination. With the application of P over N and K over NP nonsignificant increase was recorded. However, with the application of S over NPK, significant increase in protein content (12%) was recorded. Furthermore, the application of Mg over NPKS showed a decrease but in a nonsignificant manner. At 125 per cent level, maximum protein in garlic bulb was observed, where N was applied, but the application of P over N and K over P showed a decrease. Effect of S over NPK was significantly positive. Similarly, Mg addition over NPKS showed increase over NPKS, but in a nonsignificant manner. At 150 per cent level, almost same trend was observed in relation to effect of nutrients on protein content.

At N alone, there was significant increase in protein content due to 125 over 100 per cent, but 150 and 125 per cent were statistically same. At NP, NPK and NPKSMg, there was significant increase due to 125 over 100 per cent level, but beyond 125 per cent, there was not significant increase except at NP.

4.9.2 Protein content in garlic leaf

4.9.2.1 Levels

The values of protein content in garlic leaf are presented in Table 4.24. Due to different levels of nutrients, protein content in leaf significantly increased. At 150 per cent level of nutrients, protein content was maximum (20.20%) and at 100 per cent level minimum (15.80%). With increase in level, protein content in garlic leaf increased significantly upto highest level i.e 150 per cent of the recommended dose of nutrients for the crop. The magnitude of increase in protein content was 21 and 28 per cent due to 125 and 150 per cent over 100 per cent level.

Table 4.24 Effect of multi-nutrient on protein (%) in garlic leaf

Levels	Nutrients					Mean
	N	NP	NPK	NPKS	NPKSMg	
100 %	14.79	15.27	15.41	16.44	17.08	15.80
125 %	18.75	19.16	17.94	20.15	19.64	19.13
150 %	20.18	20.00	20.00	20.42	20.41	20.20
Mean	17.92	18.14	17.78	19.00	19.05	
Absolute control	:	6.46				
Control	:	8.33				
Main effects/Interaction LSD (P = 0.05)						
Levels	:	0.93				
Nutrients	:	NS				
Interaction	:	NS				

4.9.2.2 Nutrients

The effect of different nutrient combinations on protein in garlic leaf was nonsignificant (Table 4.24). The maximum amount of protein in garlic leaf was in NPKSMg (19.05 %) followed by NPKS (19.00%), NP (18.14%), NPK (17.78%) and N (17.92%). A decrease in protein per cent was only recorded with the application of K over NP.

4.9.2.3 Interaction

Protein content in garlic leaf as presented in Table 4.23, was not influenced significantly due to interaction effect of levels and nutrients.

4.9.3 Total soluble solids (%) in garlic bulb

4.9.3.1 Levels

It is revealed from the data in Table 4.25 an application of 125 per cent over 100 per cent and 150 over 125 per cent level increased, the value of total soluble solids. But, overall effect of levels of nutrients on total soluble solids was nonsignificant.

4.9.3.2 Nutrients

In control treatment, where FYM was applied @ 10 t/ha, the total soluble solids content was higher (38.40 %) compared with no FYM treatment (37.00%). Total soluble solids (40.23%) in garlic bulb also

increased due to N addition over FYM (38.40%). The concentration of total soluble solids increased significantly only in NPKS and NPKSMg compared with N alone (Table 4.25). The values of total soluble solids in N, NP, NPK, NPKS and NPKSMg were 40.23, 40.42, 41.07, 41.73 and 42.23 per cent, respectively.

Table 4.25 Effect of multi-nutrient on the total soluble solids (TSS) (%) in garlic bulb

Levels	Nutrients					Mean
	N	NP	NPK	NPKS	NPKSMg	
100 %	39.70	40.30	40.70	41.40	42.00	40.82
125 %	40.50	40.90	41.40	41.80	42.30	41.31
150 %	40.50	41.00	41.40	42.00	42.40	41.46
Mean	40.23	40.42	41.07	41.73	42.23	
Absolute control	: 37.00					
Control	: 38.10					

Main effects/Interaction LSD (P = 0.05)

Levels	:	NS
Nutrients	:	0.90
Interaction	:	NS

4.9.3.3 Interaction

The results also shows that the total soluble solids in garlic bulb did not influence significantly due to levels and nutrients interaction.

4.9.4 Effect of individual nutrient

4.9.4.1 Effect of FYM

Application of FYM @ 10 t/ha increased the protein content (15.3 %) over the absolute control (11.0%) plot, where no FYM was added. The increase in terms of percentage was 37.0 (Table 4.26).

The S per cent in garlic bulb also increased due to FYM incorporation. The S content increased to 0.58 per cent over the value in absolute control (0.55%) i.e. an increase of 5.5 per cent.

The FYM incorporation also showed an increase in total soluble solids from 37.0 to 38.1 per cent with the per cent increase of 3.0 over absolute control.

4.9.4.2 Effect of nitrogen

The data in Table 4.26 also depicts that with the application of N over FYM, an increase of 22 per cent in protein content of garlic bulb was recorded. The increase was also recorded in S content (5.2%) due to N application over FYM. Similarly application of nitrogen also showed the increase in total soluble solids (5.6%) over FYM treated plot.

Table 4.26 Effect of FYM and multi-nutrient on quality of garlic

Effect of nutrients	Protein (%)	S (%)	TSS (%)
1. Effect of FYM			
Absolute control	11.2	0.55	37.0
Increase due to FYM	15.3	0.58	38.1
Per cent increase over control	37.0	5.5	3.0
2. Effect of nitrogen			
Quality aspect due to FYM	15.3	0.58	38.1
Increase in quality due to N	18.6	0.61	40.2
Per cent improvement due to N	22.0	5.2	5.6
3. Effect of phosphorus			
Quality aspect due to P	18.6	0.61	40.2
Increase/decrease in quality due to P	17.6	0.63	40.4
Per cent decrease/increase due to P	5.6	3.3	0.5
4. Effect of potassium			
Quality aspect due to NP	17.6	0.63	40.4
Decrease in quality due to K	17.0	0.61	41.1
Per cent decrease over NP	3.5	3.2	1.6
5. Effect of Sulphur			
Quality aspect due to NPK	17.0	0.61	41.1
Increase in quality due to S	18.3	0.74	41.7
Per cent improvement over NPK	7.6	21.0	1.6
6. Effect of Magnesium			
Quality aspect due to NPKS	18.3	0.74	41.7
Increase/decrease quality due to Mg	17.9	0.76	42.2
Per cent decrease/increase over NPKS	2.2	2.7	1.2

4.9.4.3 Effect of phosphorus

As, it is clear from the Table 4.26 application of P decreased the protein content in garlic bulb from 18.6 to 17.6 per cent. Contrary to this, there was increase in S concentration from 0.61 to 0.63 per cent due to P addition over N. Phosphorus applied showed an increase in total soluble solids to the tune of 0.47 per cent.

4.9.4.4 Effect of potassium

Like the effect of P on protein, decrease was also noticed due to potassium application over NP. The decrease was from 17.6 to 17.0 per cent. So far as the effect of P on S concentration in plant is concerned, the S content also decreased from 0.63 to 0.61 per cent due to K application over NP. In contrary to this, an increase of 1.6 per cent was recorded in total soluble solids with application of K over NP (Table 4.26).

4.9.4.5 Effect of sulphur

A close look of the data depict in Table 4.26 reveals that sulphur addition over NPK resulted in an increase in protein concentration in garlic bulb from 17.0 to 18.3 i.e. to the tune of 7.6 per cent. Sulphur application over NPK also increased the S content from 0.61 to 0.74 per cent. Similarly, the increase of 1.6 per cent was also recorded in total soluble solids due to the addition of S over NPK.

4.9.4.6 Effect of magnesium

The data also reveals (Table 4.26) that the application of Mg over NPKS resulted in a decrease in protein from 18.3 to 17.3 per cent in garlic bulb. The decrease on percentage bases was 2.2.

In contrast to this, there was slight increase from 0.74 to 0.76 per cent in the bulb due to application of Mg addition over NPKS. The Mg applied over NPKS also showed the increase of 1.2 per cent in total soluble solids.

4.10 Effect of multi-nutrient on economics of garlic

4.10.1 Effect of individual nutrient on response yardstick, value cost ratio and benefit cost ratio

4.10.1.1 Effect of FYM

The FYM applied plot increased the yield of garlic bulb to 25.4 q/ha from 20.0 q/ha in absolute control i.e. 5.4 q/ha increase (Table 4.27 and Fig. 4.3). In terms of per cent basis, the productivity was increased to the tune of 27 per cent due to FYM. The value cost ratio and benefit cost ratio obtained due to FYM application was 2.7 and 1.7, respectively.

Table 4.27 Effect of FYM on additional productivity, response yard stick, value cost ratio and benefit cost ratio in garlic

a) Yield due to absolute control	=	20.0 q/ha
b) Yield due to FYM	=	25.4 q/ha
c) Increase due to FYM	=	5.4 q/ha
d) Per cent increase due to FYM	=	27
e) Response yard stick (kg bulb/kg FYM)	=	0.054
f) Value cost ratio	=	2.7
g) Benefit cost ratio	=	1.7

4.10.1.2 Effect of nitrogen

Nitrogen + FYM treated plot recorded yield of 36.0 q/ha as compared to FYM (25.4 q/ha) as it is very clear from Table 4.28 and Fig. 4.3. The results also demonstrated that the increase in garlic bulb recorded was 10.6 q/ha and in terms of per cent increase it was 42 per cent. The average effect of N on response yard stick was 6.7. This means by applying 1 kg N, increase in bulb yield of garlic was to the extent of 6.7 kg. The value cost ratio and benefit cost ratio due to N over FYM application was 12.9 and 11.9. The results also revealed that by spending Rs. 1 on N application in garlic, Rs. 11.9 benefit was obtained, which is quite economical.

Table 4.28 Effect of nitrogen on additional productivity (q/ha), response yard stick, value cost ratio and benefit cost ratio (B:C)

a) Yield due to FYM	=	25.4 q/ha
b) Yield due to N	=	36.0 q/ha
c) Increase in yield due to N	=	10.6 q/ha
d) Per cent increase in yield due to N	=	42
e) Response yard stick (kg bulb/kg N)	=	6.7
f) Value cost ratio	=	12.9
g) Benefit cost ratio	=	11.9

4.10.1.3 Effect of Phosphorus

The data embodied in the Table 4.29 and Fig 4.3 indicates that with the application of P over N an increase of 4.8 q/ha was recorded. The per cent increase in the productivity was to the tune of 14 per cent due only the application of P. The response yard stick recorded was 5.3 kg bulb/kg P_2O_5 applied and the value cost ratio and benefit cost ratio was 6.2 and 5.2, respectively. The results shows P application in garlic is also profitable as by spending 1 Rs. on P_2O_5 , a benefit of Rs. 5.2 has been obtained in garlic crop.

Table 4.29. Effect of phosphorus on additional productivity (q/ha), response yard stick, value cost ratio and benefit cost ratio in garlic

a) Yield due to Nitrogen	=	36.0 q/ha
b) Yield due to NP	=	40.8 q/ha
c) Increase in yield due to P	=	4.8 q/ha
d) Per cent increase due to P	=	14
e) Response yard stick (kg bulb/kg P_2O_5)	=	5.3
f) Value cost ratio (VCR)	=	6.2
g) Benefit cost ratio (B:C)	=	5.2

4.10.1.4 Effect of potassium

The garlic bulb yield in NP and NPK treatment combination was 40.8 q/ha and 45.2 q/ha, respectively (Table 4.30 and Fig. 4.3). The increase recorded of 4.4 q/ha (11 %) was recorded due to the application of K over NP. The value of response yard stick (kg bulb/kg K_2O), value cost ratio and benefit cost ratio recorded were 6.5, 17.6 and 16.6, respectively. This shows that by applying 1 kg K_2O , there was increase of 6.5 kg in garlic bulb and it remunerated Rs. 17.6 (VCR). The results also showed that Rs. 16.6 were obtained as a profit by spending Rs. 1 on K_2O .

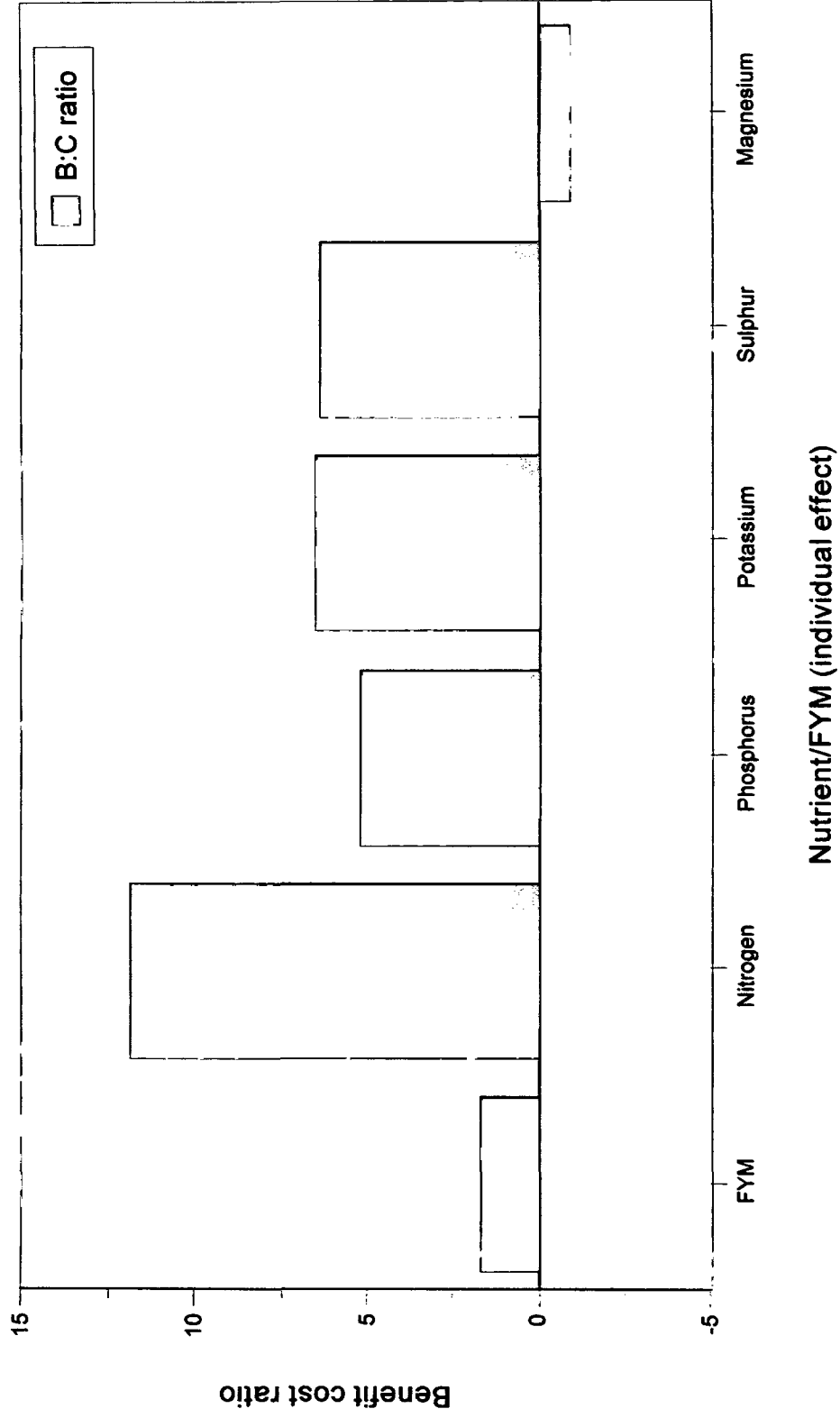


Fig. 4.3 Effect of individual nutrient/FYM on benefit cost ratio in garlic

Table 4.30 Effect of potassium on additional productivity, response yard stick, value cost ratio and benefit cost ratio in garlic

a) Yield due to NP	=	40.8 q/ha
b) Yield due to NPK	=	45.2 q/ha
c) Increase in yield due to K	=	4.4 q/ha
d) Per cent increase due to K	=	11
e) Response yard stick (kg bulb/kg K ₂ O)	=	6.5
f) Value cost ratio	=	17.6
g) Benefit cost ratio	=	16.6

4.10.1.5 Effect of Sulphur

The garlic bulb productivity due to S application (51.9 q/ha) over NPK (45.2 q/ha) showed an increase of 6.7 q/ha (Table 4.31 and Fig. 4.3). In terms of percentage bases, the increase recorded was 15 per cent. The average effects of sulphur on response yard stick (kg bulb/kg S), value cost ratio and benefit cost ratio were 18.3, 7.4 and 6.4, respectively. As is clear from the results the response yard stick was maximum due to S among all other nutrients i.e. 18.3, which means by applying 1 kg S, there is an increase in garlic bulb to the extent of 18.3 kg. The value cost ratio and benefit cost ratio was 7.4 and 6.4, respectively. Sulphur application is beneficial in garlic, as by spending Rs. 1 on S, one can get Rs. 6.4 benefit.

Table 4.31 Effect of sulphur on additional productivity, response yard stick, value cost ratio and benefit cost ratio in garlic

a) Yield due to NPK	=	45.2 q/ha
b) Yield due to NPKS	=	51.9 /ha
c) Increase due to S	=	6.7 q/ha
d) Per cent increase due to S	=	15
e) Response yard stick (kg bulb/kg S)	=	18.3
f) Value cost ratio	=	7.4
g) Benefit cost ratio	=	6.4

4.10.1.6 Effect of magnesium

The yield of garlic bulb in NPKSMg was (54.6 q/ha) and in NPKS 51.9 q/ha showing an increase of 2.7 q/ha (5.2% increase). Response yard stick (kg bulb/Kg Mg) was due to Mg was 11.7 meaning thereby that by applying 1 kg Mg, 11.7 kg garlic bulb yield can be obtained (Table 4.32 and Fig. 4.3). But, the value cost ratio and benefit cost ratios were 0.11 and -0.89, which may be due to the fact that the source of Mg was $MgCl_2$ and it was taken as pure laboratory chemical and its cost was quite high.

Table 4.32 Effect of magnesium on additional productivity, response yard stick, value cost ratio and benefit cost ratio in garlic

a) Yield due to NPKS	=	51.9 q/ha
b) Yield due to NPKSMg	=	54.6 q/ha
c) Increase due to Mg	=	2.7 q/ha
d) Per cent increase due to Mg	=	5
e) Response yard stick (kg bulb/kg Mg)	=	11.7
f) Value cost ratio	=	0.11
g) Benefit cost ratio	=	-0.89

Note: Value of $MgCl_2$ as a source of Mg was Rs. 2000/kg i.e. it was taken as cost of pure chemical, so the B:C ratio was negative.

4.10.2 Comparison of different treatments (economics)

The economics of multi-nutrients application on the productivity of garlic was also compared. Although, the FYM was applied as basal in all the treatments except absolute control, the economics was worked-out taking into consideration, the FYM and different combinations of N, P, K, S and Mg (Table 4.33). The net returns were maximum i.e. Rs. 95,761/- with 125 per cent NPKS+FYM followed by 150 per cent NPKS + FYM treatment, where the value was Rs. 94,645/-. In addition to this, 100 per cent recommended NPKS + FYM was rated third (Rs. 92,007) in influencing the net returns in garlic crop. The treatment, where nothing was applied, the net profit was minimum i.e. Rs. 40,000/-.

Table 4.33 Effect of multi-nutrient application on economics in garlic.

Treatments	Garlic yield (kg/ha)	Value of the yield (Rs.)	Value of yield in treatment – value of yield in absolute control (Rs.)	Cost of fertilizer (Rs.)	VCR	B:C	Net returns (Rs/ha)
Absolute control	2000	40000	-	-	-	-	40000
Control	2532	50700	10700	4000	2.68	1.68	46700
100% N	3240	64800	14100	6700	2.10	1.10	58100
100% NP	3800	76000	36000	6503	5.53	4.53	69497
100% NPK	4336	86720	46720	6945	6.72	5.72	79775
100% NPKS	5028	100460	60460	8453	7.15	6.15	92007
100% NPKSMg	5538	110760	70760	38213	1.85	0.85	72547
125% N	3766	75320	35320	5625	6.28	5.28	69695
125% NP	4096	81920	41920	7122	5.88	4.88	74798
125% NPK	4537	90740	50740	7674	6.61	5.61	83066
125% NPKS	5266	105320	65320	9559	6.83	5.83	95761
125% NPKSMg	5333	106660	66660	46759	1.43	0.43	59901
150% N	3800	76000	36000	5950	6.05	5.05	70050
150% NP	4343	86860	46860	9750	4.80	3.80	77110
150% NPK	4686	93720	53720	8413	6.38	5.38	85307
150% NPKS	5266	105320	65320	10675	6.12	5.12	94645
150% NPKSMg	5500	110000	70000	55315	1.26	0.26	54685

Price of nutrient applied (Rs/kg)

$\frac{\text{FYM}}{0.40}$
 $\frac{\text{N}}{10.39}$
 $\frac{\text{P}_2\text{O}_5}{17.7}$
 $\frac{\text{K}_2\text{O}}{7.36}$
 $\frac{\text{Mg}}{2000}$
 $\frac{\text{S}}{50}$

Price of marketable garlic bulb : Garlic bulb = 20.00 (Rs/kg).

Note: The cost of MgCl_2 was very high because it was taken as pure laboratory chemical.

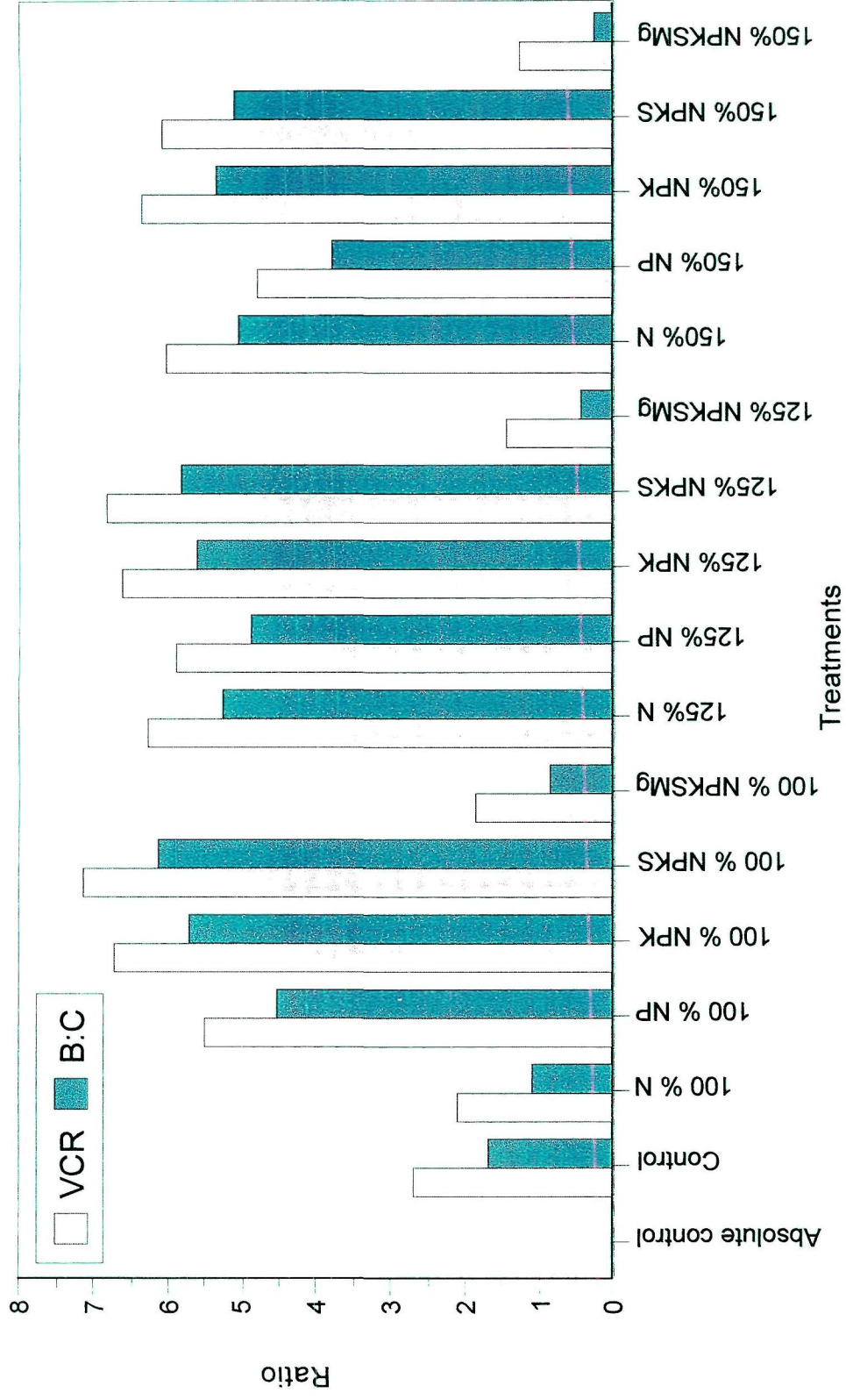
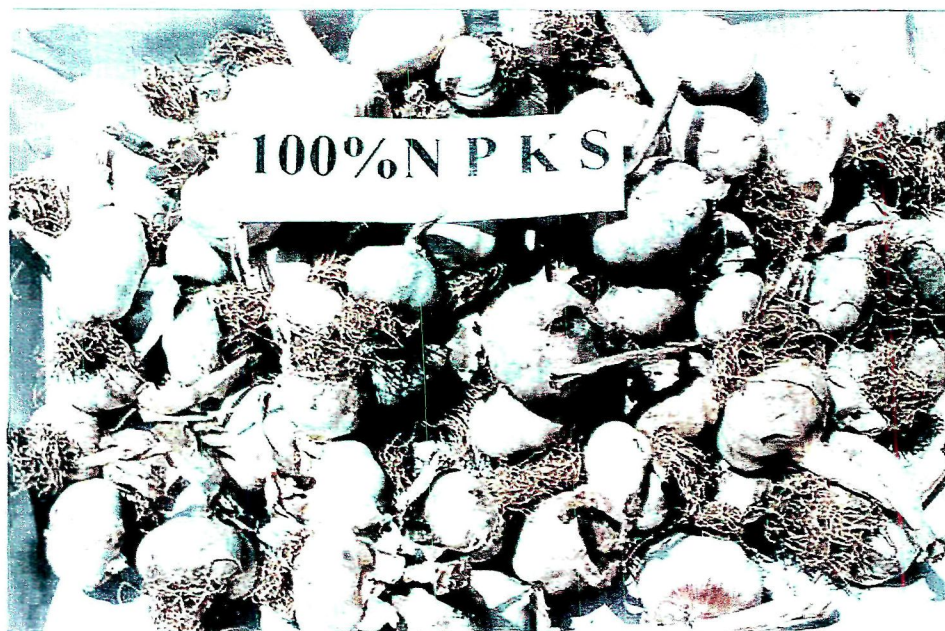


Fig. 4.4 Effect of multi-nutrient on value cost ratio and benefit cost ratio in garlic



Treatment showing maximum benefit cost ratio

It was observed that different nutrient management packages also affected value cost ratio (VCR) and benefit cost ratio (B:C) in garlic crop compared with the absolute control. The benefit cost ratio was maximum (6.15) in 100 per cent NPKS+FYM followed by 125 per cent of recommended NPKS+FYM was applied (5.83) and 100 per cent NPK treatment (5.72) and least was in treatment 150 per cent NPKSMg (0.26). From the economic analysis data, it can be concluded that 125 per cent NPKS is the best treatment combination in getting maximum net returns (Rs. 95,761/ha), if we consider net return parameter (Fig. 4.4 and 4.5).

For small and marginal farmers, who are having less capacity to invest, the benefit cost ratio is important than net returns, therefore, based on benefit cost ratio, the treatment having 100 per cent NPKS+FYM was the best among all.

The order of superiority of different treatments in terms of benefit cost ratio of the crop was 100% NPKS > 125% NPKS > 100% NPK > 125% NPK > 150% NPK > 125% N > 150% NPKS > 150% N > 125% NP > 100% NP > 150% NP > Control (FYM) > 100% N > 100% NPKSMg > 125% NPKSMg > 150% NPKSMg.



DISCUSSION

DISCUSSION

Garlic is one of the cash crop for small and marginal farmers of the state. The productivity of garlic in H.P. is quite low compared with that of the states like Punjab, Haryana and Maharashtra etc. (Arya, 2000). On country basis in India it is lower compared with countries like China, Korea, Spain and USA (F.A.O., 2001). The productivity potential of this crop can be increased with application of multi-nutrient in integration with FYM

In this chapter, attempt have been made to explain the results pertaining to the study entitled "Effect of multi-nutrient on the productivity and quality of garlic in^a mountain acid soil of Himachal Pradesh".

5.1 Effect of multi-nutrient on yield attributing characters and yield of garlic bulb and leaf

Application of different levels of nutrients from 100 to 150 per cent increased the yield attributing characters like, number of cloves per plant, leaves per plant, plant height and bulb diameter. But the effect of levels was significant only in number of cloves per bulb and bulb diameter (Table 4.1).

The results emanating from Table 4.2 indicated that the yield of garlic bulb increased with enhanced rate of nutrients levels of N, P, K

S and Mg upto 150 per cent, but the significant response was only due to 150 over 100 per cent level. The per cent increase in yield of garlic bulb over 100 per cent level was 4.8 and 7.5 per cent due to 125 and 150 per cent level. Whereas the leaf yield of garlic increased significantly due to increasing levels of nutrients upto 150 per cent (Table 4.3). The per cent increase in garlic leaf yield was 7.9 and 24.0 per cent due to 125 and 150 per cent over 100 per cent level. Such a significant increase in yield attributing characters and yield of garlic bulb and leaf due to levels of nutrients can be attributed to the fact that the nutrients such as N, P, K, S and Mg when applied together must have played their role systematically and adequately in enhancing the yield of garlic. The essentiality of these nutrients and effect of their different doses on the yield of garlic is well established. The increase in yield of garlic may also be due to significant increase in number of cloves per bulb and bulb diameter. (Koltunov, 1984; Oh *et al.*, 1991; Wang *et al.*, 1992; Selvaraj *et al.*, 1993; Lawande *et al.*, 1993; Sarvanan and Nambisan, 1994; Sadaria *et al.*, 1997; Krishnamurthy *et al.*, 2000).

Application of FYM @ 10 t/ha also increased all the yield attributing characters compared with no FYM (Table 4.1).

The results presented in the Table 4.2 and 4.3 demonstrated that application of FYM over absolute control (no FYM) showed an increase of 27 and 12 per cent in the yield of garlic bulb and leaf. The

probable reason for increasing trend in yield attributing characters, yield of garlic bulb and leaf may be due to the fact that FYM was containing 0.65 per cent N, 0.23 per cent P_2O_5 , 0.49 per cent K_2O 0.42 per cent S and 0.24 per cent Mg, therefore due to its incorporation in the soil, it might have added these nutrients to the soil and ultimately supplied the same to the plant. Furthermore, it might have improved the physical and microbiological conditions in the soil, which ultimately reflects on its productivity. Similar results were also reported by many workers (Mishra and Kapoor, 1992; Sharma and Gupta, 1994; Kundu and Pillai, 1992).

The addition of N, P, K, S and Mg also increased the yield attributing characters (Table 4.1), but the results were significant only in number of cloves/bulb.

The results also revealed that there was increase in yield of garlic (bulb as well as leaf) due to addition of N, P, K, S and Mg. The increase in yield of garlic bulb was 10.6, 4.8, 4.4, 6.7 and 2.7 q/ha due to N, NP, NPK, NPKS and NPKSMg over control, which was 42, 13, 11, 15 and 5.2 per cent, respectively. The corresponding increases in leaf yield of garlic were 20, 8, 3, 6 and 5 per cent. The increase in productivity and yield attributes of the crop due to N may be because N helps in chlorophyll, green pigments formation, that are receptors of light energy in photosynthesis and through which plants assimilate carbon from atmospheric carbon-dioxide and entrap solar energy. Moreover, it is

a basic constituent of plant life and helps in vegetative growth and protein formation in plant (Das, 1999).

If the effect^{of} individual nutrient is taken into consideration then among N, P, K, S and Mg, the increase in productivity of garlic bulb was maximum due to N followed by S. In garlic leaf also N response was higher among all other nutrients, if seen individually. The reason can be that recommendation for garlic is maximum for N i.e. 125 kg/ha. Secondly, available N status at the time of sowing the crop was 238 kg/ha, which also reduced considerably to 205 kg/ha in absolute control i.e. 33 kg N/ha, showing high extraction of N by the crop. Furthermore, the N is the basic constituent for plant growth, and it was first nutrient applied after FYM. When nitrogen is added, it immediately converts to NO_3^- by nitrification. As compared to P, rate of diffusion of NO_3^- is much higher, so its efficiency is also more compared with P and K as reported by Barber (1974). He also reported that plant take N as nitrate, more anions are absorbed than cations, and OH^- or HCO_3^- is released to balance the charge. Hence, the pH of the root environment will increase which will increase, the availability of other nutrients and ultimately productivity.

Application of each graded level of P increased significantly the garlic yield^{may be} due to increase in root proliferation resulting in higher nutrient uptake to increase plant height, vigour and more number of

cloves/bulb and it helps in cell division and multiplication and formation of reproductive primordia of the plant. As reported by Hinsinger (1998) rates of diffusion of P in the soil solution are low and usually insufficient to match the rates of uptake by roots. Consequently, P in the rhizosphere soil solution is rapidly depleted, creating a concentration gradient for the diffusion of P towards roots, which in turn increases the rate of desorption and solubilization of P from soil minerals. Organic acids exuded from roots influence the flux of P toward roots and hence the rate of replenishment of P in the rhizosphere. The uptake ^{of} H_2PO_4^- and HPO_4^{2-} into roots occurs against a massive concentration gradient as the concentration of inorganic P in the cytosol of root tissue is several orders of magnitude higher than that in the soil solution. The results in close agreement with findings of Ghanwat (1998).

Potassium addition resulted in better plant growth thereby resulting in an optimum foliage and bulb characteristics (Eid *et al.*, 1991; Lawande *et al.*, 1993; Selvaraj *et al.*, 1993). Furthermore, potassium helps in better stomatal regulation, improves the resistance in plant, promotes metabolism and increase the production of carbohydrates (Das, 1999). The increase in productivity and yield attributes of the crop due to S may be due to its role in chlorophyll formation, vegetative growth, root system and synthesis of various amino acids like methionine, cysteine and cystine etc. (Tisdale *et al.*, 1995). Moreover, the sulphur

requirement of garlic and onion is also quite high (Kamprath, 1956). Garlic is S loving crop and has more requirement for S, as it contain various S-compounds, therefore S response may also be tremendous. Magnesium also helps in chlorophyll formation, photosynthesis ultimately more biomass production plays a role in production of carbohydrates, protein, fats and vitamins and translocation of carbohydrates and fats, which might be the probable reason for its role in increasing the yield of the garlic leaf and bulb (Kanwar and Parihar, 1962; Maurya and Bhuyan, 1982).

5.2 Effect of multi-nutrient on nutrients concentration

5.2.1 Nitrogen

The N concentration in garlic bulb and leaf increased due to 125 over 100 per cent and 150 over 125 per cent level, but it was significant only in garlic bulb that too due to 125 over 100 per cent level (Table 4.4 and 4.10). The increase in N concentration due to 125 and 150 per cent level over 100 per cent level was 11 and 11 per cent in garlic bulb and 20 and 28 per cent in garlic leaf. The results also derive support from the earlier work done on this aspect elsewhere in country and abroad (Khalaf and Taha, 1988 and Shobahalan and Arumugam, 1991; Pevicharova, 1998).

The data in Table 4.10 shows that N concentration in garlic leaf increased to 1.33 per cent in FYM treated plots (control) from 1.03 per

cent in absolute control. Similarly, there was increase of 39 per cent in N concentration by garlic bulb due to FYM application. The increase in N concentration in garlic crop may be due to the reason that it might have improved the physical, chemical and microbiological condition in the soil resulting in improved mineralization reaction and building up the available N status in the soil. Moreover, FYM was containing 0.65 per cent nitrogen, which is also added directly in the soil (Kundu and Pillai, 1992).

Application of nitrogen over FYM also increased the N concentration in garlic bulb which was to the tune of 20 per cent. However, phosphorus application over N and K over NP decreased the N concentration and the corresponding decreases were 7 per cent and 4 per cent. In contrast to this, sulphur application increased the N concentration to 2.9 per cent from 2.7 per cent in NPK treatment. Mg treated plot showed same higher N per cent (2.9 %) compared with NPKS (2.9%). The effect of different nutrients on nitrogen concentration in garlic leaf was nonsignificant.

The increase in N concentration in garlic bulb due to N over control may be due to the fact that its application increased the available N status in the soil (Table 4.18). Phosphorus and K application decreased the N concentration, which may be due to dilution effect, as in dry matter production was higher in these plots. The marginal increase

in N concentration due to sulphur addition may be because of the reason that S application increased the available N status in the soil due to narrowing of N:S ratio. Magnesium also increased the available N status in the soil by 5 kg/ha (Table 4.18), which would not be sufficient for increasing the N concentration in garlic bulb to a significant extent. The results are in close relation with the earlier ones reported by Novais *et al.*, (1974); Om *et al.* (1978); Pandey and Singh (1990) and Arboleya and Burba (1994).

The effect of interaction (nutrients x levels) on N concentration in garlic bulb and leaf could not reach the level of significance.

5.2.2 Phosphorus

Phosphorus concentration in garlic bulb and leaf was maximum at 150 per cent level of applied nutrients and minimum at 100 per cent level. Effect of levels on P concentration in garlic bulb was nonsignificant. In case of garlic leaf, 150 per cent level, significantly increased its content compared with 100 per cent level. The increase in P content in garlic bulb was 6.6 and 13 per cent due to 125 and 150 per cent over 100 per cent respectively. The corresponding increases in leaf P concentration were 15 and 23 per cent.

The FYM incorporation @ 10 t/ha increased its content in bulb only to the tune of 33 per cent over absolute control. Similarly, P concentration in leaf was (0.06%) compared with absolute control, where

it was 0.04 per cent. The increase in P concentration in plant due to FYM may be attributed to addition of P directly from FYM to the soil and indirectly through improved P use efficiency, as FYM form phospho-humate complex, which are readily assimilated by plants as a source of P. Furthermore, different types of acids produced from the FYM act as chelate and form a coating on the surface of the Fe and Al sesquioxides and do not allow the H_2PO_4^- to fix. In garlic bulb and leaf, with application of N an increase by 63 per cent and 83 per cent in P concentration was recorded over the control. The application of P over N treated plot caused significant increase in P content in bulb and leaf which was 38 and 36 per cent, respectively. Potassium inclusion over NP showed a nonsignificant decrease in its content to the tune of 20 and 7 per cent in garlic bulb and leaf, respectively. In garlic bulb and leaf, S application over NPK showed significant increase of 13 and 14 per cent. The effect of Mg over NPKS in influencing the P concentration in garlic leaf and bulb was same.

Due to N application, NO_3^- – N might have released H_2PO_4^- from the exchange site, thereby improving in P concentration in plant (Sinha, 1972). The increase in P concentration in garlic bulb and leaf due to P application may be attributed to increase in P content in soil and then its extraction by roots. However, the decrease in P content in plant due to S and K may be due to dilution effect, as the productivity

of crop was higher in S and K treated plots than those, where these were not applied. Such findings are in close agreement with the findings of Purewal and Dargan (1961) and Khalf and Taha (1988).

5.2.3 Potassium

Potassium concentration both in garlic bulb and leaf was affected by levels of nutrients. Treatment having 150 per cent level of nutrients recorded maximum K content (3.6 and 3.4%), whereas, 100 per cent level of nutrient recorded minimum amount of K concentration in bulb and leaf (2.9 and 2.5%), as is clear from the Table 4.4 and 4.10. There was a significant increase in K concentration in garlic leaf and bulb due to 125 per cent over 100 per cent level, the increase being 17 and 24 per cent.

In the contrast to this, the increase in K content in bulb and leaf was not affected significantly, when level of nutrients, further, increased from 125 to 150 per cent. The quantitative increase due to 150 per cent level of nutrients over 125 per cent was 5.8 and 7.6 per cent in garlic bulb and leaf, respectively.

A close look of the data in Table 4.4 and 4.10 reveals that K content in garlic leaf as well as bulb in control was higher than in absolute control. The content of K was 1.9 per cent in FYM treated plot compared with its value 1.1 per cent in absolute control plot. Similarly,

K concentration in garlic leaf was 1.8 per cent in FYM treated plot and 1.03 per cent in absolute control plot.

FYM was containing 0.49 per cent K_2O and therefore, its addition in the soil enhanced the available K status and ultimately its concentration in plant. The organic acids produced by FYM act as coating on the exchange complex of soil and not allow K to fix on the exchange sites (Kundu and Pillai, 1992).

In case of garlic bulb, the application of N, increased the K content (57 %) over the control treatment. However, P addition over N did not influence the same in a significant manner. The K concentration due to K application over NP, S over NPK and Mg over NPKS increased the K content, but in a nonsignificant manner. Furthermore, among all the nutrients, K resulted in more increase in its concentration than did other nutrients. In case of garlic leaf, the K content of leaf was statistically same when treatment NP and N, NPK and NP, NPKS and NPK and NPKSMg and NPKS were compared together. However, the effect of NPK over N in improving its content was definitely decernible. Among all the nutrients tried, the K concentration both in garlic leaf and bulb increased comparatively to a larger extent due to K application in the soil. The reason may be ascribed to the fact that it increased the available K status in the soil to a higher magnitude compared with other nutrients (Jang *et al.*, 1989; Baghla, 2001).

5.2.4 Sulphur

The results in the Table 4.4 revealed that S content in garlic bulb was significantly influenced by application of different levels of nutrients. The effect of 125 per cent level of nutrient was significant in influencing the S concentration which was 0.67 per cent over 100 per cent (0.64 % S) level of nutrients. However, the increase due to 150 per cent over 125 per cent was nonsignificant and there was not at all increase in its content, the values were same i.e. 0.67 per cent. Similarly, in garlic leaf highest S content was recorded at 150 per cent level (0.69 %) followed by 125 per cent (0.66 %) and lowest at 100 per cent level (0.64%). Off-course, due to 125 per cent level, there was increase in S content in leaf over 100 per cent level of nutrients, but it was statistically nonsignificant. In contrast, S content increased significantly due to 150 per cent over 100 as well as 125 per cent level of nutrients. The magnitude of increase was 3 and 8 per cent due to 125 and 150 per cent over 100 per cent level, respectively.

FYM application @ 10 t/ha increased the S concentration by 5.0 per cent in garlic bulb and 14.0 per cent in garlic leaf compared with absolute control.

Increase in S concentration in garlic and leaf due to FYM application may be because of sulphur addition directly and indirectly by enhancement in S use efficiency of the native pool.

Application of N over FYM increased the S content in garlic leaf and bulb by 5.2 and 5.2 per cent, respectively. In garlic bulb and leaf, the S content increased due to addition of P over N, but it was nonsignificant. However, there was a decrease in its content in garlic bulb, due to K over NP and in leaf there was no change. In contrast to this, significant increase was obtained both in bulb (21 %) and leaf S content (15 %), due to S over NPK. The highest amount of S content in garlic bulb and leaf was recorded in NPKSMg treatment.

Nitrogen applied in the soil immediately mineralized to nitrate form which might have exchanged with sulphate, in the same way as did H_2PO_4^- and HPO_4^{2-} on the clay colloid and increased the available S as is very clear from Table 4.21. These results are in agreement with findings of many workers (Chang *et al.*, 1990; Shobahalan and Arumugam, 1991; Mehta, 1995; Cheng *et al.*, 1997).

Further, the potassium application as depicted in Table 4.4 and 4.10, showed improvement in its content in the bulb and leaf yield of garlic, which might have diluted the sulphur concentration in plant tissue, this may be the probable reason for decrease in its concentration due to K addition. Similar reasoning can be given for effect of magnesium on S concentration in garlic crop, as there was also not tremendous increase in its content due to Mg addition in the soil. Almost similar

results have been reported by other workers (Panwar and Patil, 1989; Ueda *et al.*, 1991; Singh and Tiwari, 1995; Bertoni *et al.*, 1996).

The interaction effect (level x nutrients) on S concentration in garlic leaf and bulb could not reach the level of significance.

5.2.5 Magnesium

Magnesium concentration both in garlic bulb and leaf decreased due to increase in level of nutrients from 100 to 150 per cent, but it was nonsignificant.

The FYM application increased the Mg concentration both in garlic bulb and leaf, the reason may be that exchangeable Mg status of soil was higher in FYM treated plots than no FYM. Nitrogen application decreased its concentration in leaf as well as in bulb over control. The effect of P over N, S over NP was not significant and there was decrease in its concentration. Potassium addition over NP, increased its concentration, but it was significant only in garlic leaf. Proportionate increase in Mg concentration in garlic leaf as well as bulb was significantly higher in Mg treated plot over NPKS treatment. The reduction in Mg concentration in garlic bulb and leaf due to N, P and S may be due to the reason that the status of exchangeable Mg in these treatments was comparatively less. The status of exchangeable Mg was higher of in K and Mg applied treatments as compared to other

treatments and that can be considered for higher concentration of Mg in these plots. The results corroborate the findings of Novais *et al.* (1974) Bull *et al.* (1993); Selvaraj *et al.* (1994) and Selvaraj and Nanjan (1996).

5.3 Effect of multi-nutrient on nutrients uptake

5.3.1 Nitrogen

The N uptake by garlic bulb/leaf increased with increasing levels of nutrients from 100 per cent upto 150 per cent level. The increase in uptake by garlic bulb was 7.6 and 8.4 kg/ha due to 125 and 150 per cent level over 100 per cent level i.e. 17 and 19 per cent. Similarly, N uptake by garlic leaf increased by 29 and 58 per cent due to 125 and 150 per cent level over 100 per cent level. Due to increasing levels of different nutrients, there was increase in productivity of garlic leaf as well as bulb, the reason can be ascribed that more is the yield, more would be the N uptake.

The results presented in the Table 4.5 and 4.11 also reveals that the N uptake by bulb as well as leaf, increased in the control plot, where FYM was incorporated compared with absolute control. The increase in N uptake in the garlic bulb and leaf was 75 per cent and 45 per cent over absolute control, respectively. The increase in N uptake due to FYM may be attributed to the fact that it contains 0.65 per cent N, which is also be added in the soil by FYM (Kundu and Pillai,

1992). FYM also might have improved root, shoot and bulb yield, which ultimately increased the uptake of nutrients including N (Mishra and Kapoor, 1992; Sharma and Gupta, 1994). Furthermore, FYM addition might have reduced the leaching losses of N, due to the formation of organo-manural complexes, which ultimately result in increase in its uptake (Pandey *et al.*, 2001).

The application of N, NP, NPK, NPKS and NPKSMg showed an increase of 17.0, 2.9, 3.0, 11.0 and 1.6 kg/ha in N uptake by garlic bulb i.e. 71, 7, 7, 23 and 3.0 per cent over control treatment. The corresponding increase in N uptake by leaf was 12.1, 1.8, 0.7, 1.7 and 1.6 kg/ha i.e. 164, 9, 3, 8 and 7 per cent.

Due to N application, the increase in its uptake is well understood because it will not only add N in the soil but also due to increased yield and more extraction of N from the soil. Increase in N uptake due to P, K, S and Mg may be due to enhancement in productivity of the crop. Phosphorus application might have increased the root growth and ultimately more extraction of N from soil native source (Ghanwat, 1998). Potassium addition also increased both leaf and bulb yield, which might have resulted in higher N uptake over no K. A profuse vegetative growth and higher yield due to S application might have enhanced N uptake by garlic leaf and bulb (Joshi *et al.*, 1991) Magnesium

has increased the availability of N as is shown in Table 4.18, which may be one of the probable reason for its effect in increasing N uptake.

Due to interaction of levels x nutrients, there was increase in N uptake of garlic leaf and bulb, which may be due to enhancement in productivity of the crop. Such results have also been reported by other workers (Uchida *et al.*, 1976; Buwalda, 1986; Kusumainderawati, 1986; Selvaraj *et al.*, 1993; Sarvanan and Nambisan, 1994; Kumar *et al.*, 1996; Resende *et al.*, 2000).

5.3.2 Phosphorus

Maximum P uptake by garlic bulb was recorded at 150 per cent level (3.1 kg/ha) followed by 125 per cent (2.8 kg/ha) and 100 per cent level (2.6 kg/ha). The increase in its uptake was 0.2 and 0.3 kg/ha due to 125 per cent over 100 per cent and 150 over 125 per cent level of nutrients, respectively. Similarly, P uptake by leaf at 150 per cent level was maximum (1.34 kg/ha) and minimum at 100 per cent level (0.89 kg/ha). The increase in P uptake in respective order due to 125 and 150 per cent over 100 per cent level was 0.22 and 0.23 kg/ha. The increase in P uptake by the crop due to increase in the level of application of N, P, K, S and Mg may be because of the increasing trend in the productivity due to these nutrients. These are essential nutrients and with increase in their level, the P uptake has also increased. The increase in

uptake may be due to increase in root proliferation and other growth parameters (Ghanwat, 1998). These results were in agreement with findings of Lionness, 1959; Kim *et al.* (1977); Almaguer *et al.* (1984); Suwandi and Hilman (1991); Sarvanan and Nambisan (1994); Mellanagonda *et al.* (1995) and Wani and Konde (1998).

Phosphorus uptake both by garlic bulb and leaf in FYM treated plot increased with an increase of 0.12 and 0.2 kg/ha (60 and 40 %) over absolute control. This increase may be due to the beneficial effect of FYM to make soil porous and pulverised, thereby enhancing the growth and development of roots and bringing an immense improvement in root surface area and nutrient uptake like P (Xiong and Liu, 1992). The soil available P status increased with the application of FYM as it helps in promotion of solubilization of P caused by addition of humic substances excreted by roots in the soil (Bhakare and Sonar, 2000). Furthermore, property of FYM of mobilizing both native and applied P reflects its influence in higher P uptake (Hampiah and Sinha, 1982).

The application of different nutrients also increased the P uptake by garlic leaf and bulb. The increase in P uptake by garlic bulb due to NP, NPK, NPKS and NPKSMg was of 56, 11, 32 and 9 per cent over the N treated plot. The corresponding increases in P uptake by garlic leaf were 134, 49, 14 and 6 per cent (Table 4.12).

Nitrogen application also increased the productivity of crop, which might have also increased the P uptake by garlic. McLean *et al.* (1956) have found that the addition of nitrogen has increased the cation exchange capacity of the roots of the plants. Postulating that increase in the cation exchange capacity, roots of plants would generally be expected to aid in the release and uptake of additional phosphates. Riley and Barber (1971) in soil fertilized with nitrate found that the change in the soil pH towards neutrality near the root caused by nitrate uptake affected the P uptake by the crop. Phosphorus application, built the status of available P in the soil as is clear from Table 4.19, which may be one of the reason for increase in its uptake due to P addition. The probable reason for increase in P uptake due to K and Mg might be due to increased yield in K and Mg treated plots in addition to creation of favourable pH for growth of microbes for good P mineralization from organic pool (Haynes, 1992). Furthermore, P adsorption site on plant roots are activated by K (Adepatu and Akapa, 1977), this may also be one of the reason for increase in P uptake. The possible reason for increased P uptake by the crop due to S addition could be the anion exchange phenomena as addition of S release SO_4^{2-} , which might have replaced the H_2PO_4^- and HPO_4^{2-} ions and make these readily available to the plant. Magnesium application also increased the productivity of garlic which may be the reason for

increased P extraction from the soil due to good root system and ultimately its supply to the plant.

5.3.3 Potassium

The results demonstrating the effect of different levels of nutrients on K uptake by garlic bulb/leaf have been presented in Table 4.7 and 4.13. The results reveal that maximum K uptake by garlic bulb was obtained with the application of 150 per cent level (61.0 kg/ha) and minimum at 100 per cent (43.4 kg/ha). The increase in its uptake due to 125 and 150 per cent level over 100 per cent was 24 and 40 per cent, respectively. Similarly, in leaf sample, the highest K uptake was recorded at 150 per cent level (28.8 kg/ha) followed by 125 per cent (23.1 kg/ha) and 100 per cent level (17.5 kg/ha). The increase recorded due to 125 and 150 per cent over 100 per cent level was to the tune of 32 and 64 per cent.

Due to increase in level of various nutrients, both leaf as well as bulb yield of garlic increased. Therefore, more is the yield more is the extraction of nutrients due to more proliferated root system, ultimately K uptake of higher magnitude. Such findings derive support from the work of many scientists elsewhere in country and abroad (Bogatirenko and Timchenoka, 1976; Eid *et al.*, 1991; Lee and Cheon, 1991; Bull and Nakaganian, 1995; Singh *et al.*, 1995; Zhang *et al.*, 1998).

A close look at the Table 4.7 and 4.13 shows that the application of FYM @ 10 t/ha over absolute control caused an increase in K uptake by garlic bulb and leaf over absolute control. The increase in K uptake due to FYM application may be due to reduction in K fixation and more release of K due to organic matter interaction (Bhardwaj and Omanar, 1994). The K uptake by garlic leaf and bulb also increased due to application of different nutrient combinations. The increase in K uptake by garlic bulb due to N, NP, NPK, NPKS and NPKSMg was 18.4, 6.4, 11.1, 9.2 and 4.8 kg/ha and in terms of percentage, it was 104, 18, 26, 17 and 9 per cent over absolute control. Similarly, N, NP, NPK, NPKS and NPKSMg uplifted the K uptake by garlic leaf by 8.3, 2.1, 3.1, 0.9 and 3.2 kg/ha, i.e. 81, 11, 15, 4 and 13 per cent, respectively.

The increase in K uptake by garlic bulb and leaf due to N, P and S may be attributed to a profuse vegetative growth and higher yield, which might have increased its uptake (Joshi *et al.*, 1991). The increase in K uptake by the crop due to potassium application is self understood and can be explained on the ground that due to K addition water soluble and exchangeable K in soil may increase, which ultimately reflect on higher K uptake (Narwal, 1985). Calcium, Mg and K perform one nonspecific function of maintaining a level of ionic balance in plant system. The viets effects named after F.G. Viets who first observed,

states that higher Ca and Mg concentration in outer solution either enhances the uptake of K or reduces the loss of K ions. Hence, K concentration will increase and ultimately its uptake (Ganeshamurthy and Srinivasa Rao, 2001).

5.3.4 Sulphur

The data presented in Table 4.8 and 4.14 reveals that in both bulb and leaf, the maximum S uptake was recorded at 150 per cent level followed by 125 and 100 per cent level. The increase in S uptake was 0.6 and 0.7 kg/ha by garlic bulb and 0.52 and 1.06 kg/ha by garlic leaf due to 125 per cent over 100 per cent and 150 over 125 per cent level of nutrients. The garlic crop responded well to increased levels of all the applied nutrients viz., N, P, K, S and Mg in terms of S uptake. As already discussed in the yield section, due to increase in dose productivity of garlic increased, therefore, higher is the nutrient dose, more would be the S uptake.

Application of FYM @ 10 t/ha increased S uptake both by bulb as well as leaf over absolute control. The increase in its uptake due to FYM application was 30 and 33 per cent in bulb and leaf, respectively. Mineralization of organic sulphur might have enhanced availability of sulphur from FYM and ultimately its uptake (Saha *et al.*, 1995).

Addition of N, NP, NPK, NPKS and NPKSMg caused an increase in S uptake to the tune of 33, 50, 17, 6, 43, 5 in bulb and 30,

25, 12, 0.66, 23 and 13 per cent in leaf over control, respectively. This may be because of the reason that application of these nutrients with FYM increased the organic carbon content (Table 4.17) due to increased root biomass in the soil, which have additive effect on its uptake. The findings are in close line with those reported by Kher and Singh (1993). When N is applied to the soil nitrification occurs and it converts to NO_3^- – N by nitrifying bacteria. If the NO_3^- concentration will increase, it can replace the SO_4^{2-} ions from the exchange complex and making more SO_4^{2-} available to plant, which ultimately may increase the S uptake. Similar may be the case with H_2PO_4^- , when P was added. Potassium and magnesium application increased the S uptake, this may be due to increase in yield by these nutrients, more removal of S from the soil there might be improvement in S content of the plant (Singh and Singh, 1990). The results can be supported by the work done by other workers (Joshi, 1961; Panwar and Patil, 1989; Suwandi and Hillman, 1992; Singh *et al.*, 1995; Park *et al.*, 1997; Aoyoma *et al.*, 2000).

5.3.5 Magnesium uptake

The effect of levels of nutrients on Mg uptake on garlic leaf as well as bulb was not significant. A look of Table 4.9 and 4.15 shows that there was considerable improvement in Mg uptake by garlic leaf as well as bulb due to FYM application @ 10 t/ha over no FYM. For this,

the reason may be that, due to FYM addition, there was increase in Mg concentration as well as productivity of garlic leaf and bulb.

N application also increased Mg uptake by garlic bulb and leaf over FYM. The effect of P over N and S over NPK was not significant on its uptake by garlic leaf and bulb. However, there was significant increase in its uptake K over NP and Mg over NPKS. The significant increase in its uptake by the crop due to potassium and Mg may be because of increased Mg concentration as well as productivity in K and Mg treated plots. The results are in close association with the findings of Selvaraj *et al.* (1993), Shobahalan and Arumugam (1991) and Zhang *et al.* (1998).

5.4 Effect of multi-nutrient on soil properties and nutrients status

5.4.1 Soil pH

The application of increasing levels of nutrients from 100 to 150 per cent did not change the pH of the soil at harvest of the garlic (Table 4.16). The value of pH at all levels of nutrients was same i.e. 5.8. The results can be supported by the findings of several workers (Sumi *et al.*, 1986; Sarvanan and Nambisan, 1994; Majumdar *et al.*, 1998).

Farm yard manure incorporated plots showed little higher pH i.e. 5.8 compared to FYM free plots, where the value of pH was 5.7. The different nutrient combination had no impact on the pH value of the soil, except Mg treatment, where increase in pH was noticed to a value

of 5.9. However, in N, P, K and S treated plots, the pH value was same i.e. 5.8. Magnesium treated plot exhibited slight increase in pH of the soil at harvest of garlic crop, it may be due to the reason that it is a basic cation like Ca (Gupta, 1980). Such work has also been reported by other workers (Park *et al.*, 1988; Suwandi and Hilman, 1992; Majumdar *et al.*, 1998).

5.4.2 Organic carbon

The organic carbon content increased due to 125 per cent compared with 100 per cent and 150 per cent with 125 per cent, but in a nonsignificant manner. The increase in its status was 6.3 and 9.9 per cent due to 125 and 150 per cent level over 100 per cent. The maximum amount of organic carbon (12.2 g/kg) was recorded at 150 per cent and minimum (11.1 g/kg) in 100 per cent level of nutrients.

The FYM addition resulted in the build up of organic carbon content in the soil to the extent of 10 g/kg as compared to the value of 8.8 g/kg in absolute control. Farm yard manure directly adds organic carbon to the soil, therefore its addition in the bulid up of organic carbon is understandable.

The different combinations did not influence significantly, the organic carbon status in the soil, but, still the results in Table 4.17 indicates that due addition of each nutrients i.e. N, P, K, S and Mg, an improvement in the organic carbon status of the soil was recorded

The slight increase in its status due to different nutrient additions may be due to the reason that the crop productivity was more pronounced in the plots treated with different nutrient, which added higher amount of root biomass in soil than the untreated control plots. Sinha (1972) reported that the reason for increase in organic carbon due to P compared with N, may be due to its role in root development. Among C, H, O, N, S, P contained in organic matter, all the constituents except P are added primarily from the atmosphere, therefore, phosphorus in plant material may earn the accumulation of organic matter in soil. Such results have also been reported by many other workers (Buckman and Brady, 1967; Sans *et al.* 1974; Park *et al.*, 1988 and Casanova *et al.*, 1992). The organic carbon status was not affected by nutrients and levels interaction in a significant manner.

5.4.3 Available nitrogen

The results emanating from the Table 4.18 revealed that application of 125 and 150 per cent level of nutrients showed an increase of 26 and 10 kg/ha in available N status in the soil after harvest of garlic and the per cent increase obtained was 10 and 3.4, respectively.

The content of available N in control plot increased with application of FYM @ 10 t/ha and the increase was (30 kg/ha). The increase in available nitrogen due to FYM may be due to greater

multiplication of soil microbes caused by the addition of organic matter and enhanced rate of conversion of organically bound N to inorganic form (Badanur *et al.*, 1990). As reported by Saha *et al.* (1995), FYM application enhances microbial mineralization of organic matter and it is universally accepted that it also add N to the soil directly.

Application of N also increased its status by 21 per cent over control but P applied over N and K over NP resulted in decrease in available N by 1.4 and 1.1 per cent, respectively. However, an increase was again recorded due to NPKS (1.4%) over NPK and NPKSMg (1.7%) over NPKS.

Such an increase in available N due to N application has been recorded by many workers (Bogatirenko, 1975; Ruiz, 1985 and Jung *et al.*, 1989), it is clear in itself if you added more N, there will be increase in its status of the soil. The decrease in its status due to P and K application may be attributed to the fact that P and K addition caused more removal of N due to increase yield and there was higher N removal from the available pool in the soil. In contrast to this, S addition released SO_4^{2-} ions and there is narrowing of N- S ratio, which might have enhanced the rate of mineralization of organic matter, so resulted in increasing available N status in the soil. The order of absorption of different anion is phosphate > molybdate > sulphate > chloride > nitrate. Therefore, sulphate will replace easily nitrate from the

exchange complex. Nitrate is weakly absorbed sesquioxide by electrostatic extraction. Therefore, sulphate will easily replace nitrate so it will increase available N in soil (Parfitt, 1978). Magnesium addition might have increased the mineralization of organic N and number of ammonifiers and nitrifiers as reported by Black (1973), which may be one of the reasons for increased status of available N due to Mg application.

5.4.4 Available phosphorus

The effect of different levels of nutrients on available P status was also significant. Increase in available P status of soil was notified due to 125 per cent over 100 per cent level of nutrient. The increase in available P in the soil at the harvest of the crop, was 6.1 and 9.2 per cent due to 125 and 150 per cent level over 100 per cent level.

The results presented in Table 4.19 reveal that FYM application @ 10 t/ha in the control plot increased the available P content in soil over absolute control. Increase in available P with FYM application might be due to solubilization of the native P in the soil through release of various organic acids. The organic material forms a protective cover on sesquioxides contained in acid soils and thus reduces phosphate fixing capacity of the soil (Tandon, 1987; Acharya *et al.*, 1988). Furthermore, FYM along with inorganic fertilizer help in recycling of nutrients and solubilization of native nutrients and protect them from further adsorption/

precipitation reactions (Das *et al.*, 1991). Organic phosphorus in soil solution may be important to P nutrition of plants in that phosphatases enzymes, excreted by the plant roots could hydrolyze this fraction, thus releasing P (Moon and Lee, 1980). The increasing combination of nutrients N, NP, NPK, NPKS and NPKSMg showed an increase of 1.0, 6.4, 0.3, 2.3 and 0.7 kg/ha over control. The corresponding increases in its status on per cent basis were 6, 37, 1, 10 and 3.

There was not significant change in available P status of soil due to N application over control, showing that N application is not so much effective in increasing the status of available P in soil and other reason may also be higher P uptake in N applied plots over control. Little enhancement in its uptake may be due to the reason that P deficiency in plant, in N treated plot might have increased phosphatase activity (Sinha, 1972; Dalal, 1977). The probable cause of higher available P status in P over N treatment may be because of the fact that when any P fertilizer is added in the soil, it will release $\text{H}_2\text{PO}_4^{2-}$ i.e. readily available P. Kamprath *et al.* (1956) showed that sulphate was effective in reducing phosphate adsorption, so there can be increase in available S in soils. Due to more release of H_2PO_4^- and HPO_4^{2-} ions by SO_4^{2-} ions by anion exchange phenomena might have increased the status of available P in the soil in S treated plots over NPK. Furthermore, there may be more solubilization of soil aluminium and iron

phosphates as a result of increased production of organic anions from high cation exchange roots (Grunes, 1959) as the productivity under S treated plot was more. The decrease in available P status due to K and Mg may be due to more P uptake in these plots compared with plots where K and Mg were not applied. Such results are in accordance with the findings of Tyler *et al.* (1988); Jang *et al.* (1989); Jung *et al.* (1989); Suwandi and Hilman (1992) and Sarvanan and Namboisan (1994).

5.4.5 Available potassium

The results embodied in Table 4.20 depicted that application of 125 per cent over 100 per cent and 150 per cent over 125 per cent significantly decreased the available K status of the soil at harvest of the crop. The increase in its status was 7.1 and 8.8 per cent, when level of nutrients increased from 100 to 125 and 125 to 150 per cent. This decrease was recorded because of the fact that the removal of K by garlic was higher than the amount added through fertilizers and FYM (Sharma, 1979; Cardosa, 1993; Singh and Singh, 1999)

The FYM incorporated plot showed more available K (control treatment) compared with absolute control i.e. 28 per cent increase. The increase in its status due to FYM may be due to reason that FYM was containing 0.49 per cent K, when it was incorporated into the soil, it has added K in the soil.

The application of N, resulted in a nonsignificant decrease in its status over control. Similarly, there was decrease (54%) in its status due to application of P over N. The decrease in available K status in P and N treated plots, may be due to more K removal by the crop without addition of K in NP treatment. Sulphur application over NPK followed by Mg over NPKS showed a decreasing trend in its status to the tune of 10 and 3 per cent, respectively. Like P and N, in S and Mg treatments there was mismatch between the K removal and K added, so there was decrease in available K status in the soil. Similar results have been reported by Bogatirenko (1975); Singh (1980); Ruiz (1985); Jung *et al.* (1989) and Suwandi and Hilman (1992).

5.4.6 Available sulphur

The results pertaining to the Table 4.21 reveals that nutrients levels from 100 to 125 per cent caused a significant decrease in available S status of soil after harvest of garlic and it was 9.2 per cent. The effect of 150 per cent over 125 per cent also resulted in a decrease (0.93 %) but in a nonsignificant manner. The decrease in available S (kg/ha) status of the soil due to 150 per cent over 100 per cent level was 10 per cent.

The FYM application @ 10 t/ha in the control treatment (21.0 kg/ha) increased its status in the soil compared with absolute control

(15.0 kg/ha), the increase was to the extent of 29 per cent. The increase in available S status due to FYM application may be due to addition of S by increased mineralization of organic sulphur, as with FYM application, organic carbon status increased, which is a source for bacteria including sulphur mineralizing bacteria like *Thiobacillus* spp. (Mahendran and Kumar, 1996). These findings are in close association with work of Gracia *et al.* (1993) and Park *et al.* (1997).

The application of N resulted in an increase in its status over control treatment (FYM alone). The application of P over N caused a nonsignificant decrease (3 %) in its status. Similarly, there was decrease (8 %) in its content due to K application over NP and that too in a significant manner. Contrast to this, application of S over NPK increased its content tremendously and significantly (35%). Furthermore, the magnesium application over NPKS also increased its status by 3 per cent, but it could not reach the level of significance.

Nitrogen application might have exchanged the sulphate from the exchange sites due to anion exchange, so there was increase in available S. The increase in available S status due to sulphur addition is understood in itself, as sulphur addition will release sulphur and ultimately enhance the available S status in the soil.

The decrease in its status due to P and K may be attributed to the more uptake of S (Table 4.8) in P and K treated plots compared to

plots having no P and K treatments. Available S also increased slightly due to Mg application, which may be due to improvement in pH of the soil and consequently more release of S from the organic pool. The available S status was not affected by interaction (level x nutrients) effect.

5.4.7 Exchangeable magnesium

Exchangeable Mg status decreased significantly upto highest level of nutrients i.e. 150 per cent (Table 4.22). The decrease over 100 per cent due to 125 and 150 per cent was 2.7 and 2.7 per cent, respectively. The reduction in its status may be due to more Mg uptake by the crop. Similar findings have been reported by various workers (Sans *et al.*, 1974; Park *et al.*, 1988; Majumdar *et al.*, 1998).

FYM treated plot increased the exchangeable Mg status in soil by 10 per cent over no FYM plot. The reason for this may be that FYM might have added Mg in the soil as, it was containing 0.24 per cent Mg. Not only this, its addition might have mineralized the native source of Mg due to increased microbial activity, as the population of microbes increases with increase in organic carbon status in soil, because they get food for their existence as reported by many workers (Nath, 1976; Cardosa *et al.*, 1993).

The results clearly shows that nitrogen application reached its status in soil over control. Phosphorus addition over N significantly

decreased (2.8 %), its status over N. However, significant increase in status was observed due to K over NP and Mg over NPKS. But, sulphur application over NPK decreased its status over NPK. The decrease in exchangeable Mg status due to N, P and S may be due to higher uptake of Mg by the crop without Mg addition. The slight increase in its status due to K over NP may be because of the fact that K might have replaced Mg from the exchange site due to cation exchange phenomena and brought the same in soil solution.

5.5 Effect of multi-nutrient on quality parameters

5.5.1 Protein content

Protein content in garlic bulb increased due to FYM application @ 10 t/ha over absolute control and the increase was the 37 per cent. Similarly S concentration increased by 5.5 per cent in garlic bulb only due to FYM (Table 4.4). Protein content and sulphur concentration in garlic bulb also improved due to the individual effect of N, P, S and Mg except the effect of P on protein content. Potassium addition decreased the protein as well the sulphur content in garlic bulb. The increase in protein content in different treatments may be due to increase in N concentration in bulb (Kothari and Shaw, 1974; Pandey *et al.*, 1991; Naruka and Dhaka, 2001; Naruka, 2002).

5.5.2 Total soluble solids (%)

As revealed from Table 4.25 the effect of level of nutrients on total soluble solids was nonsignificant, off-course there was little increase.

FYM applied plot showed higher (38.10 %) total soluble sugar in garlic bulb compared with no FYM plot 37.00 per cent. The significant increase in this total soluble solids of garlic bulb was only due to NPKS and NPKSMg compared with N alone. The content of total soluble solids in N, NP, NPK, NPKS and NPKSMg were 40.23, 40.72, 41.07, 41.73 and 42.24 per cent in a respective order. The role of FYM in increasing the quality of crops is well known, since ancient times because of its effect in improving the physical chemical, microbiological condition of the soil (Mishra and Kapoor, 1992 and Sharma and Gupta, 1994). The probable reason for significant increase in total soluble solids in garlic bulb due to NPKS and NPKSMg over N may be due to the beneficial effect of all these multi-nutrient. Similar results have been reported by other workers (Pandey *et al.*, 1991; Jatendra *et al.*, 1995 and Verma *et al.*, 1996).

5.6 Effect of individual nutrient on quality

Protein content in garlic bulb increased due to FYM application @ 10 t/ha over absolute control, the increase was 37 per cent. Similarly

S concentration improved by 6 per cent in garlic bulb only due to FYM addition (Table 4.26). Protein content and sulphur concentration in garlic bulb also influenced in positive direction due to the individual effect of N, P, S, and Mg except the effect of P on protein content. Potassium addition decreased the protein as well as the sulphur content in garlic bulb. The increase in protein content due to FYM and different nutrients might be due to enhancement in N concentration in bulb. The available S status of the soil also increased due to FYM, N, P, S and Mg, which may be one of the reason for higher S concentration in garlic bulb. Total soluble solids also affected by FYM incorporation. The influence of N and S on total soluble solids was higher as compared to other nutrients like P, K and Mg. The beneficial effect on total soluble solids due to FYM and N and S, may be due to their role in improving the carbohydrates concentration in garlic bulb directly or indirectly. Such findings has also been reported by Singh *et al.* (1984); Selvaraj *et al.* (1994); Naruka and Dhaka (2001); Naruka (2002).

5.7 Effect of multi-nutrient on economics of garlic

5.7.1 Individual nutrient (economics)

Application of FYM increased the garlic bulb yield from 20 q/ha in absolute control to 25.4 q/ha in control plot (FYM alone). Increase of 27 per cent was only due to only FYM. By considering the effect of

FYM on response yard stick, the value was 0.05. This shows that by applying 1 kg FYM, the increase was only 0.05 kg. By considering the effect of N, P, K, S and Mg on response yard stick (kg bulb/ha) sulphur followed by Mg, N, K and P. Therefore in terms of response of nutrients on productivity sulphur was the best nutrient. Similar findings are in close association with the findings of Borabash and Kochina (1987); Pandey *et al* (1991); Abbas *et al.* (1994) and Kumar *et al.* (1996)

If value cost ratio and benefit cost ratio are considered the trend of superiority of the nutrients was $K > N > S > P > Mg$ and the value cost ratio was 12.9, 6.2, 17.6, 7.4 and 0.11 due to N, P, K, S and Mg, respectively (Table 4.27 to 4.32). The corresponding values for benefit cost ratio were 11.9, 5.2, 16.6, 6.4 and -0.89. This means potash and nitrogen were superior in affecting the benefit cost ratio in garlic crop.

5.7.2 Comparison of different treatments (economics)

The net returns were maximum i.e. Rs. 95,761/- with 125 per cent NPKS + FYM followed by 150 per cent NPKS + FYM, where the value was Rs. 94,645/-. The treatment involving 100 per cent NPKS + FYM was rated third (Rs. 92,007/-). In terms of benefit cost ratio and value cost ratio 100 per cent NPKS + FYM was the best treatment followed by 125 per cent of recommended NPKS + FYM. The benefit

cost ratio was 6.15 in 100 per cent NPKS + FYM treatment and was the best treatment combination. This means that in addition to 100 per cent NPK, sulphur is also very important in garlic along with FYM, because garlic is a sulphur loving crop.



SUMMARY

Chapter-VI

SUMMARY

Garlic (*Allium sativum*) is the second most important crop among spices grown throughout the country. It has medicinal value as it not only prevent cancer, but also upgrades the cardiovascular system. It acts as stimulant, carminative, digestive, metabolic corrector and a killer of intestinal worms. Its daily use in diet reduces the toxin content in our body (Vatsayan, 2001). It is coming up in a big way in H.P. being a cash crop. The productivity of garlic in the state (1.97 t/ha) as compared with that of the other states like Punjab (12.44 t/ha), Haryana (12.0 t/ha) and Maharashtra (6.76 t/ha) is quite low.

The yield of this crop can be increased by use of multi-nutrient skill and very less work on this aspect, has been done. Keeping this background in view, the present study entitled "Effect of multi-nutrient on the productivity and quality of garlic in^a mountain acid soils of Himachal Pradesh" was done. Field experiment on garlic (GHC-1) was conducted at the experimental farm of the Department of Soil Science, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur during 2001-2002. The soil was silty clay loam in texture, acid^{in reaction} (pH 5.7). The status of organic carbon, available N, P, K, S and exchangeable Mg was 9 g/kg, 238 kg/ha, 14.1 kg/ha, 219 kg/ha, 19.8 kg/ha and exchangeable Mg 1.25

cmol(p⁺)/kg. The cation exchange capacity of soil was 9.2 cmol(p⁺)/kg. There were seventeen treatment combinations, which were replicated thrice. The results of the experiment are summarised as below:

6.1 Yield attributing characters

Number of cloves/bulb, bulb diameter, plant height and number of leaves/plant increased, as the levels of different nutrients increased from 100 to 150 per cent.

FYM application @ 10 t/ha over no FYM also enhanced these growth parameters over absolute control. With the introduction of each nutrient i.e. N, P, K, S and Mg, an improvement was observed in plant height cloves/bulb diameter and number of leaves per plant, showing the response of each nutrient on the growth promoting parameters. All these parameters were maximum in NPKSMg + FYM treated plot and minimum in N + FYM treated plot, if different nutrient combinations along with FYM were considered.

6.2 Bulb and leaf yield

The garlic bulb yield increased due to increase in nutrient levels from 100 per cent upto 150 per cent level. But the significant improvement in productivity of garlic bulb was only due 150 per cent over 100 per cent level. Contrary to this, the influence of 150 per cent over 125 and 125 over 100 per cent level was significant in increase in

the productivity of garlic leaf. The increase in yield of garlic, bulb due to 125 and 150 per cent level over 100 per cent level was 4.8 and 7.5 per cent, respectively. The corresponding increases in of garlic leaf yield was 2.1 and 3.3 per cent.

FYM application @ 10 t/ha also increased the yield of garlic bulb and leaf compared with absolute control. The increase in bulb and leaf yield due to FYM was 27 and 12 per cent, respectively. Nitrogen also increased the yield of garlic leaf as well as bulb over FYM and it was to the tune of 20 and 42 per cent, respectively. The garlic bulb increased significantly due to the application of P over N, K over NP, S over NPK, but Mg over NPKS could not do the same in a significant manner. In case of garlic leaf yield, application of P over N, S over NPK, Mg over NPKS was significant, however, the leaf yield did not increase due to K applied over NP. The increase in garlic bulb yield due to N, NP, NPK, NPKS and NPKSMg was 42, 13, 11, 15 and 52 per cent^{over control}. The corresponding increases in leaf yield was 20, 8, 3, 6 and 5 per cent.

6.3 Nitrogen concentration

N concentration in garlic leaf increased significantly upto highest level of nutrient i.e. 150 per cent, however its effect narrow down to 125 per cent level in case of garlic bulb.

Nitrogen content both in garlic leaf and bulb also increased by 29 and 39 per cent due to FYM application @ 10 t/ha over absolute control, respectively.

The effect of different nutrients on N concentration was significant only in case of garlic bulb. There was increase in N concentration of garlic bulb due to the application of N and S, however P and K and magnesium introduction decreased the same.

6.4 Phosphorus concentration

Phosphorus concentration in garlic bulb was only affected, significantly due to different levels of nutrients, however, it was not influenced significantly in garlic leaf. With increment in levels of nutrients from 100 to 150 per cent, increase in P concentration in garlic leaf was observed.

Increase in content of P in garlic leaf as well as bulb was also to the tune of 33 and 50 per cent due to FYM addition over no FYM. There was also improvement in P concentration in leaf as well as bulb due to N application over FYM. Phosphorus concentration in both the cases increased due to P application over N and S over NPK. However, K application over NP decreased the P concentration in plant, but Mg effect over NPKS was not there.

6.5 Potassium concentration

The application of increasing levels of nutrients significantly increased the K concentration of garlic leaf and bulb only upto 125 per cent level. FYM application over no FYM increased the K concentration in garlic leaf and bulb. Similarly, K concentration increased both in leaf and bulb with the application of N over FYM. There was also improvement in K concentration in plant due to P, K, S and Mg.

6.6 Sulphur concentration

Similar to the effect of different levels of nutrients on N, P and K concentration, increase in S concentration in garlic leaf and bulb was recorded due to increase in levels of nutrients. If the data is looked on the basis of statistical analysis increase in S concentration on garlic bulb was only upto 125 per cent level. However, 125 per cent level was non significant over 100 per cent level in garlic leaf. Sulphur content in garlic bulb and leaf increased due to FYM and N addition. It also increased due to addition of P over N, S over NPK and Mg over NPKS, but K addition over NP decreased the S content in bulb and trend was similar in garlic leaf.

6.7 Magnesium concentration

Magnesium concentration in garlic bulb and leaf decreased due to increase in level of nutrient from 100 to 150 per cent. FYM addition

also increased its concentration in garlic leaf and bulb over control. The effect of N over FYM, P over N and S over NPK was negative on its concentration in garlic leaf and bulb. However, K applied over NP and Mg over NPKS increased the Mg concentration both in garlic bulb as well as leaf.

6.7 Nitrogen uptake

Nitrogen uptake increased significantly with increase in level of nutrients upto 125 per cent in garlic bulb, however, it was upto 150 per cent level in case of garlic leaf. The per cent increase in N uptake was 17 and 19 per cent due to 125 and 150 per cent over 100 per cent level in garlic bulb and 29 and 58 per cent in garlic leaf in a respective order.

The N uptake by garlic leaf and bulb was enhanced to greater magnitude with the application of FYM @ 10 t/ha compared with no FYM. Similarly, N addition over FYM increased the uptake. Increase in N uptake by garlic bulb was also significant due to S over NPK and Mg over NPKS. However, in case of garlic leaf, the significant improvement in N uptake was only due to P, S and Mg.

6.8 Phosphorus uptake

Use of increasing levels of nutrient supply upto 150 per cent increased the P uptake by garlic leaf. However, in case of P uptake by

garlic bulb only the effect of 150 per cent was significant over 100 per cent level.

P uptake by garlic leaf and bulb was also significantly influenced in positive direction by FYM application over no FYM and N over FYM treatment. Uptake of P by garlic bulb (3.6 kg/ha) and leaf (1.33 kg/ha) was maximum in NPKSMg treated plot. Among different nutrient supplied, P uptake by garlic leaf and bulb increased significantly only due to P over N. However the effect of K over NP, S over NPK and Mg over NPKS was nonsignificant.

6.9 Potassium uptake

The trend of uptake of potassium by garlic leaf and bulb was such that there was significant improvement in its uptake upto 150 per cent level of nutrients.

The trend of K uptake by garlic leaf and bulb was same as that of N and P and there was improvement in its uptake due to FYM addition over no FYM and N applied over FYM.

With addition of each nutrient, there was significant increase in K uptake by garlic bulb. However, the pattern of K uptake of garlic leaf was such that only K over NP and Mg over NPKS increased its uptake. So far as the effect of interaction is concerned, application at varying levels, different nutrients and vice versa increased the K uptake by garlic bulb.

6.10 Sulphur uptake

The S uptake by garlic bulb showed increase but in a nonsignificant manner due to 150 per cent over 125 per cent and 125 over 100 per cent, but 150 per cent was significant compared with 100 per cent. Contrary to this, in case of garlic leaf, there was significant addition in S uptake due to 150 over 125 per cent level and 125 per cent over 100 per cent level.

The S uptake by garlic leaf and bulb enhanced with incorporation of FYM @ 10 t/ha incorporation as compared to plot, which was free from FYM treatment. Similarly N addition over and above FYM resulted in an increased uptake in bulb as well as leaf. Similarly, P over N, S over NPK and Mg over NPKS depicted a significant increase, however, K over NP caused a nonsignificant increase in both cases. Furthermore, in S uptake by garlic bulb, there was nonsignificant response over NPKS due to Mg. The interaction (levels x nutrients) effect on S uptake by garlic leaf was also significant.

6.11 Magnesium uptake

Effect of different levels of nutrients on Mg uptake by garlic leaf and bulb was nonsignificant. FYM application enhanced the Mg uptake in garlic bulb as well as leaf over no FYM. The increase in Mg uptake was noticed is recorded due to K addition over NP and Mg over NPKS,

but the magnitude of Mg uptake by garlic leaf and bulb was comparatively higher in Mg over NPKS nutrients combination.

6.12 pH

The pH value of the soil ~~has not shown~~ due to enhanced levels of nutrients from 100 to 150 per cent. The effect of FYM was ~~the~~ more pronounced and it increased the pH to 5.8, compared with FYM free plot where it was 5.7. Various nutrient combinations had no pronounced impact on pH except that of Mg over NPKS, which increased the pH value to 5.9.

6.13 Organic carbon

Organic carbon content of soil increase nonsignificantly with increase in levels of nutrients from 100 to 150 per cent and the increase was 6 and 3 per cent, respectively.

The organic carbon content was higher in FYM treated plot compared with FYM free plot. Nitrogen applied in conjunction with FYM also increased its content (FYM alone). Similarly P application over N, K over NP, S over NPK and Mg over NPKS built up the organic carbon, but overall the effect of different nutrients was nonsignificant, if the data is examined on the basis of statistical analysis.

6.14 Available nitrogen

Available N content of the soil differed significantly at different levels of nutrients. The highest available N content was recorded in 150 per cent followed by 125 and 100 per cent level.

FYM applied @ 10 t/ha increased the available N status in the soil over absolute control. The various nutrient combinations has nonsignificant affect on available N status. Still, N applied over control caused an increase of 28 per cent in FYM treated plot. Contrast to this, a decrease was noticed with application of P over N and K over NP. However, S and Mg applied over NPK and NPKS in a respective manner resulted in a slight enhancement in its status.

6.15 Available phosphorus

The increasing levels of nutrients indicated the significant increase in available P content in soil with its value was maximum at 150 per cent level and minimum at 100 per cent level.

Available P content in the treatment that received no FYM was lower compared with FYM treated plot. N applied over FYM resulted in a slight increase, whereas P over N and S over NPK indicated a significant increase. But application of K over NP and Mg over NPKS caused slight and nonsignificant increase in its status in the soil.

6.16 Available potassium

With increasing levels of nutrients, there was significant and progressive decrease in available K status of the soil and it was to the tune of 7.1 and 8.8 per cent at 125 and 150 per cent level compared with 100 per cent level.

A comparison of FYM and no FYM treated plot depicted that there was increase in available K content due to the N applied over control, however, P over N decreased the available K status. Potassium application over NP resulted in drastic and significant increase in its status. Contrast to this, again a decrease was noticed with application of S over NPK and Mg over NPKS. The effect of interaction between levels and nutrients on its status was also significant.

6.17 Available sulphur

Use of increasing levels of nutrients i.e. 125 and 150 per cent resulted in a significant decrease in the status of available S due to 125 per cent over 100 per cent, but decrease was nonsignificant due to 150 over 125 per cent level.

The available S status was higher in treatment where FYM @ 10 t/ha was applied as compared FYM free plot. Similar was the trend in N treated plot over FYM alone. Phosphorus application over N and K over NP resulted in a decrease in its status. But, there was again a

significant increase (35 %) due to S application over NPK. Increase in its content was also recorded, when Mg was applied over NPKS, but it was in a nonsignificant manner.

6.18 Exchangeable magnesium

The significant decrease in exchangeable magnesium was recorded with increasing level of nutrients upto 150 per cent level.

FYM applied @ 10 t/ha showed an increase in exchangeable magnesium. However, N added in the soil over control decreased the status of exchangeable magnesium. The K application over NP showed a significant increase in exchangeable magnesium, but contrary to this S addition over NPK again resulted in its decrease. The maximum exchangeable Mg was recorded in the plot applied with NPKSMg nutrients combination.

6.19 Protein content

The results revealed that the maximum protein content was recorded at 125 per cent level and minimum at 100 per cent level in garlic bulb. The increase in its content in garlic bulb was upto 125 per cent level. The protein content in garlic leaf increased significantly with the increasing levels of nutrients upto 100 per cent level.

Protein content in garlic bulb increased with the application of FYM and the increase was 37 per cent over FYM free plot. Nitrogen

addition over FYM and S over NPK also resulted in a significant increase in protein content, whereas P over N, K over NP and Mg over NPKS decreased it, but in a nonsignificant manner. The effect of different nutrients on protein in leaf was nonsignificant.

The interaction effect of levels and nutrients on protein content was significant only in garlic bulb and nonsignificant in garlic leaf.

6.20 Total soluble solids (%)

The effect of increasing levels on total soluble solids was nonsignificant. FYM application compared with no FYM increased the total soluble solids in garlic bulb. Among different nutrient combinations NPKS and NPKSMg significantly increased the concentration of total soluble solids compared with N alone.

6.21 Effect of individual nutrient on quality

FYM addition improved the quality i.e. protein, sulphur content and total soluble solids. In garlic bulb protein and sulphur concentration improved due to N, P, S and Mg over FYM alone. But there was little decrease in protein content in garlic bulb due to P application. Contrary to this, a decrease in sulphur concentration and protein recorded due to potassium application. The total soluble solids in bulb comparatively increased to a higher magnitude due to N and S as compared to rest of the nutrients.

6.22.1 Individual nutrient

An increase of 5.4 q/ha in garlic bulb yield was found due to FYM addition over no FYM. The values of response yard stick, value cost ratio and benefit cost ratio were 0.05, 2.7 and 1.7, respectively.

Increase in garlic bulb yield was recorded due to application of each nutrient. The improvement in its yield was 10.6, 4.8, 4.4, 6.7, 2.7 q/ha due to N, P, K, S and Mg. The corresponding values of response yard stick (kg bulb/kg nutrient applied) were 6.7, 5.3, 6.5, 18.3 and 11.7; VCR 12.9, 6.2, 17.6, 7.4 and 0.11 and B:C 11.9, 5.2, 16.6, 6.4 and -0.89.

It can be summarised from the results of the economics of individual nutrient that the response yard stick for garlic bulb was maximum due to sulphur followed by Mg, N, K and P. This clearly shows that in terms of response yard stick sulphur responded efficiently as compared to other nutrients. In contrast, K and N were superior in influencing the benefit cost ratio of garlic.

6.22.2 Comparison of different treatments

The highest net returns Rs. 95761/- were obtained from the treatment involving 125 per cent NPKS + FYM followed by 150 per cent

NPKS + FYM (Rs. 94,645/-). In terms of benefit cost ratio, the best treatment combination was 100 per cent NPKS + FYM.

It can be concluded from the results that for small and marginal farmers, the best treatment combination in terms of benefit cost ratio is 100 per cent NPKS + FYM, which showed maximum benefit cost ratio (6.15) in garlic crop.



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LITERATURE CITED

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APPENDIX- I**Weekly weather data for the year 2001-2002**

Weeks	Temp. (°C)		RH (%)	BSS (hr)	Rainfall (mm)	Rainy day	Evaporation (mm)
	Max.	Min.					
2001							
44	25.5	14.2	53	6.6	0.1	1	4.0
45	22.5	9.8	37	8.6	1.2	1	3.5
46	22.5	10.2	34	9.5	0.0	0	3.6
47	22.1	9.3	47	8.9	0.0	0	2.9
48	20.6	8.4	48	7.8	0.0	0	1.8
49	21.3	8.6	35	6.5	0.0	0	1.6
50	20.4	7.3	49	4.8	17.6	2	1.9
51	17.2	5.2	47	6.4	5.0	1	2.0
52	17.4	5.3	52	7.9	0.0	0	2.8
2002							
1	18.6	4.0	59	8.0	0.0	0	1.7
2	19.3	7.4	45.5	7.9	2.0	1	2.3
3	14.5	4.6	63	5.3	22.0	5	1.5
4	14.6	2.4	58.5	6.8	2.2	1	1.9
5	16.0	4.9	45.5	9.5	0.0	0	2.3
6	15.4	5.5	60	5.1	15.6	4	1.9
7	17.7	8.0	49	7.2	22.0	2	2.3
8	24.2	8.9	46	8.2	2.0	1	2.7
9	15.6	7.6	55.5	5.1	44.2	4	1.6
10	19.9	9.7	47	6.8	3.5	2	2.9
11	22.9	11.5	42.5	8.2	0.0	0	3.7
12	26.0	14.0	41	7.5	0.3	5	2.0
13	26.4	12.4	34	8.8	0.0	0	4.9
14	26.4	14.3	39	9.1	2.4	2	4.4
15	27.9	15.9	36	8.9	1.2	1	6.0
16	31.2	18.0	30.5	9.7	0.0	0	7.0
17	28.0	15.2	41.5	7.0	27.1	4	4.8
18	30.3	17.8	30	8.7	0.0	0	6.2
19	34.7	20.7	30	11.0	0.0	0	8.9
20	34.5	19.4	33.5	10.4	9.5	1	6.9
21	33.0	19.2			0.0	0	8.5
22	26.9	16.7				5	5.4