CHAPTER-V

DISCUSSION
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In general growth and development of crop plants depend on a number of factors specially physico-chemical and biological properties of soil. If a number of millions of waste land and barren land existing in India utilized for cultivation, it will certainly be a boon for Indian economy. Jatropha-peppermint cropping system may be an ideal system for amending the problem soil in presence of plant nutrients such as S and Zn. Considering these facts present experiment entitled “Effect of S and Zn application on peppermint (Mentha arvensis) under jatropha” was conducted. The results presented in different tables and figures in this thesis have been discussed here in light of established theories and principles.

5.1 Effect of S and Zn on fertility status of soil

5.1.1 Available nitrogen

It is evident (Table 4 and fig.1,2) that application of sulphur and zinc either alone or in combination increased the available nitrogen of soil possibly due to improved physico-chemical conditions of the waste land. It is mainly due to sulphur application on the waste land having problem of alkalinity. It is a well known fact that sulphur is an amendment for soils
having alkaline reaction. Sulphur in soil produce sulphuric acid which is able to decline alkalinity of the concerned experimental waste land and ultimately diminish pH of the soil. As a result concerned problem soil has become normal in context of pH. Under normal soil conditions prevailing in the experimental soil, decomposition of organic matter and mineralization of nitrogen has enhanced and escalated nitrogen availability. Lowering of soil pH in turn might also have decreased loss of nitrogen caused by volatilization and increased nitrification in soil causing increase in nitrogen availability. Further, accumulation of organic matter in concerned experimental soil growing jatropha might also have stimulated Nitrosomonas activities and escalated available nitrogen content of the soil. Almost similar findings have been reported by Sharma et al. (1990), Singh and Singh (1982), Dinesh and Dubey (1999).

5.1.2 Available phosphorus

Increase in available phosphorus content (Table 4 and fig.3, 4) is also possibly due to application of S and Zn on the experimental soil. Production of sulphuric acid and decrease in soil pH has possibly increased soil available phosphorus. It is inferred that conjoint use of sulphur and zinc and natural addition of easily decomposable organic matter by fallen leaves of
jatropha and other concerned medicinal crop has resulted an increase in soil available phosphorus. It may also be attributed to production of organic and inorganic acids like H$_2$CO$_3$, H$_2$SO$_4$, H$_2$SO$_3$ in the soil under study, which is an important reason for enhancement of the availability of phosphorus. The organic anions and hydroxyl acids such as tartaric, citric, malonic and malic acid liberated during decomposition of naturally added organic matter through jatropha leaves and other organic resources may have formed complexes or chelates with Zn, iron, aluminium, magnesium, and calcium and thus prevented them from reacting with soluble phosphates to form insoluble phosphates. So, under such conditions increased availability of phosphorus is expected. Therefore it is clear that organic and inorganic acid liberated in soil due to different biochemical soil reactions have solubilizing effect on soil P. Prabhakar et al. (1972) also reported that certain acids formed during decomposition of organic matter have solubilizing effect on phosphates of iron, aluminium, magnesium, calcium etc.

5.1.3 Available potassium

Beneficial effect of sulphur and zinc fertilization on available potassium (Table 4 and fig 5, 6) may be due to improved nutritional environment in the rhizosphere due to improved physico-chemical soil
conditions. Sulphuric acid formed due to S addition has possibly improved physical, chemical and biological conditions of the concerned experimental waste land and escalates the availability of potassium in the amended soil. The beneficial effect of sulphur and zinc in releasing potassium might also be due to chelating action, as reported by Prabhakar et al. (1972).

5.1.4 Available sulphur

The increase in available sulphur (Table 4 and fig 7,8) may be due to application of sulphur that has reclaimed the concerned waste land, suffering from alkalinity problem. So, added sulphur has improved physico-chemical and biological conditions of the problem soil and improved nutritional status. This finding is in close conformity with the findings of Singh and Singh (1982).

5.1.5 Available zinc

The increase in zinc availability of soil may be due to application of zinc fertilizer (Table 4 and fig 9, 10). It has enhanced with increasing levels of Zn application. Rahmathullah (1984) also reported similar results. The increased biological activity in concerned soil may also have hastened the decomposition of organic matter and resulted increased Zn availability. As during decomposition of organic matter (from jatropha and peppermint),
root exudation and microbial synthesis by rhizosphere, different organic acids including amino acids and phenolic compounds may have formed that enhanced available Zn content. Milap Chand et al. (1980) also reported similar results. They found that organic acid like fulvic acid may increase solubility of Zn to the extent of 1000 folds.

5.1.6 Soil organic carbon

The organic carbon content of experimental plots increased with increasing levels of sulphur (Table 4 and fig. 11, 12). It may be due to the fact that sulphur is an integral part of organic matter and released during decomposition. Therefore, it is significantly and positively correlated with organic carbon and plant residue. So, higher organic carbon through biomass production is expected in sulphur treated soil as also reported by (Jat and Yadav (2006) and Patra et al. (1997) and Singh (2007). Zn also help higher biomass production so also organic carbon in the experimental soil.
5.2 Response of S and Zn on selected physico-chemical properties of soil

5.2.1 Soil pH

It is a well known fact that when sulphur is applied in soil it produces sulphuric acid. Sulphuric acid react with Ca salts to form CaSO₄. CaSO₄ dissolve in water to for Ca and SO₄ ions. Ca ion is able to decline pH by removing Na ion from exchange complex. In this way waste land with high pH become normal in context of pH and other physico-chemical and biological properties (Table 5 and fig. 13, 14). Sulphuric acid directly neutralize soil alkalinity and decline soil pH value. Under such conditions Zn availability is also increased similar to S. Therefore, it is inferred that S may be considered as a good amendment for the improvement of waste lands under experimentation, having high pH value. (Singh 2007 and Verma et al. 2008).

5.2.2 Electrical conductivity

A slight increase in electrical conductivity (Table 5 and fig. 15, 16) may be due to increase in soluble electrolytes due to production of calcium sulphate. Sulphur after oxidation reacted with water to form sulphuric acid which ultimately converted in soluble lime to calcium sulphate. Calcium
sulphate after oxidation produced $\text{Ca}^{++}$ and $\text{SO}_4^{-2}$ ions and increased electrical conductivity of the experimental soil. Singh and Singh (1982) also reported similar result.

5.2.3 Soil bulk density

The increase in bulk density of experimental soil (Table 5) might be due to addition of organic matter through fallen jatropha leaves in soil. Since the density of organic matter particles is less than the mineral soil, the addition of organic matter to soil has decreased the bulk density of soil. Gupta et al. (1977) also reported similar result.

5.2.4 Water holding capacity

An addition of organic matter through jatropha plant to the soil has possibly increased pore space, hence increased the water holding capacity of experimental soil. Addition of S has resulted dissolution of lime present in waste land and formation of CaSO$_4$. As a result physical property in general has improved larger soil aggregates broken to smaller ones and compaction of soil occurred. Compaction caused reduction in water drainage from the soil because of greater force of adhesion between the micro pores and soil water (Table 5). Almost similar findings have been reported by El-Asswal and groeneveit 1985.
5.2.5 Soil porosity

Organic matter added through fallen jatropha leaves to the soil increased porosity of soil (Table 5 and fig. 17, 18). It may be due to the density of organic matter particles which is less than the mineral soil, so addition of organic matter to soil has decreased the bulk density. Gupta et al. (1977) also reported similar results.

5.3 To evaluate the effect of S and Zn on nutrient content of Jatropha and mint

5.3.1 To evaluate the effect of S and Zn on nutrient content of Jatropha

5.3.1.1 Nitrogen content

The content of nitrogen increased significantly with the application of sulphur and zinc (Table 6 and fig. 19, 20). This increase in N content is attributed to application of sulphur to plant that results vigorous root and shoot growth escalating greater absorption of nitrogen from the soil. This is further supported by the fact that sulphur deficiency prevents utilization of nitrogen. Sulphur brings about accumulation of soluble nitrogen within the plants. The increased N content due to sulphur application has also been reported by Sharma et al. (1990) and Chauhan (1998). Further beneficial
role of zinc in increasing the CEC of roots helped in increased absorption of nutrients from the soil. Also, the beneficial role of Zn in chlorophyll formation, regulating the auxin concentration, stimulatory effect on most of physiological and metabolic processes of the plant have helped enhanced absorption of nutrients from soil. Favourable influence of Zn on photosynthesis and metabolic processes augments are in accordance with the findings of Sharma and Bhardwaj (1998) and Dviwedi et al. (2001).

5.3.1.2 Phosphorus content

The application of sulphur and zinc significantly increased the content of phosphorus (Table 6 and fig.21,22). The application of sulphur not only acted as a source of sulphur but it also influenced physical, chemical and biological properties of soil. Drop in soil pH also observed. Kashirad and Bazargani (1991) reported similar result. Release of available nutrients from soil and improvement in soil physico-chemical properties would have increased the absorption of nutrients by crop in general and sulphur in particular. Sharma (19991) and Mina (2000) reported similar results. The increase in phosphorus content with zinc application may be due to increased absorption and translocation of phosphorus from the roots. Similar results have been reported by Choudhary et al. (1997).
5.3.1.3 Potassium content

The positive influence of sulphur and zinc fertilization on potassium content of the plant (Table 6 and fig. 23, 24). Seems to be due to improved nutritional environment both in the rhizosphere and the plant system. The increased availability of nutrients namely in root zone coupled with increased metabolic activity at cellular level might have increased the uptake of nutrients and their accumulation in plant part. Similar findings were reported by Lallu and Saxena (1995).

5.3.1.4 Sulphur content

The increase in sulphur content (Table 6 and fig. 25, 26) might be due to increased concentration of sulphur in soil with the application of sulphur. The higher sulphur content in plant resulted in greater uptake of sulphur in plant. The result of this investigation is conformity with the findings of Chauhan (1998).

5.3.1.5 Zinc content

Increase in Zn content of plant by application of Zn (Table 6) may be due to the beneficial role of Zn in increasing the CEC of roots helped in increased absorption of nutrients from the soil. Further, the beneficial role of Zn in chlorophyll formation, regulating the auxin concentration and its
stimulatory effect on most of physiological and metabolic processes of the plant might have helped the plants in enhanced absorption of nutrients from soil. Thus, the favourable influence of zinc on photosynthesis and metabolic processes augments the production of photosynthates and their translocation to different plant parts which ultimately increased the concentration of nutrients in plants. The results are in accordance with the findings of Sharma and Bhardwaj (1998), Dwivedi et al. (2001), Dubey and Khan (1993), Chakraborti (1994) and Prasad et al. (1996).

5.3.2 To evaluate the effect of S and Zn on nutrient content of peppermint

5.3.2.1 Nitrogen content

The content of nitrogen increased significantly with the application of sulphur and zinc (Table 7 and fig. 27, 28). This increase in N content is attributed to application of sulphur to plant that results vigorous root and shoot growth escalating greater absorption of nitrogen from the soil. This is further supported by the fact that sulphur deficiency prevents utilization of nitrogen. Sulphur brings about accumulation of soluble nitrogen within the plants. The increased N content due to sulphur application has also been reported by Sharma et al. (1990) and Chauhan (1998). Further beneficial
role of zinc in increasing the CEC of roots helped in increased absorption of nutrients from the soil. Also, the beneficial role of Zn in chlorophyll formation, regulating the auxin concentration, stimulatory effect on most of physiological and metabolic processes of the plant have helped enhanced absorption of nutrients from soil. Favourable influence of Zn on photosynthesis and metabolic processes augments are in accordance with the findings of Sharma and Bhardwaj (1998) and Dviwedi et al. (2001).

5.3.2.2 Phosphorus content

The application of sulphur and zinc significantly increased the content of phosphorus (Table 7 and fig. 29,30). The application of sulphur not only acted as a source of sulphur but it also influenced physical, chemical and biological properties of soil. Drop in soil pH also observed. Kashirad and Bazargani (1991) reported similar result. Release of available nutrients from soil and improvement in soil physico-chemical properties would have increased the absorption of nutrients by crop in general and sulphur in particular. Sharma (19991) and Mina (2000) reported similar results. The increase in phosphorus content with zinc application may be due to increased absorption and translocation of phosphorus from the roots. Similar results have been reported by Choudhary et al. (1997).
5.3.2.3 Potassium content

The positive influence of sulphur and zinc fertilization on potassium content of the plant (Table 7 and fig. 31, 32) seems to be due to improved nutritional environment both in the rhizosphere and the plant system. The increased availability of nutrients namely in root zone coupled with increased metabolic activity at cellular level might have increased the uptake of nutrients and their accumulation in plant part. Similar findings reported by Lallu and Saxena (1995).

5.3.2.4 Sulphur content

The increase in sulphur content of peppermint (Table 7 and fig. 33, 34) might be due to increased concentration of sulphur in soil with the application of sulphur. The higher sulphur content in plant resulted in greater uptake of sulphur in plant. The result of this investigation is conformity with the findings of Chauhan (1998).

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Increase in Zn content of plant by application of Zn (Table 7) may be due to the beneficial role of Zn in increasing the CEC of roots helped in increased absorption of nutrients from the soil. Further, the beneficial role of
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5.4 To assess the growth parameters of Jatropha and peppermint as influenced by S and Zn

5.4.1 To assess the growth parameters of Jatropha as influenced by S and Zn

5.4.1.1 Plant height

Finding clearly indicates that taller plants were obtained in plots subjected to receive 45 kg S and 10 kg Zn ha⁻¹ (Table 8). So it may be inferred that with increasing supply of S and Zn the process of tissue differentiation from somatic germination to reproductive, meristematic activity and development of floral primordial have increased, resulting in
higher plant growth in terms of plant height. *Singh and Verma (1989) have also reported identical results.*

### 5.4.1.2 Number of branches

Significant increase in number of branches with increasing supply of S and Zn may be due to increase in biomass. It may also be ascribed to the overall improvement in plant organs that are associated with faster and uniform vegetative growth under the influence of S as also reported by *Singh (2001), Upasani and Sharma (1986).*

### 5.4.1.3 Number of leaves

It was also observed that numbers of leaves were higher in plants receiving both S and Zn. It may be due to sulphur which caused vigorous root and shoot growth and in turn greater absorption of nitrogen from the soil as also observed by *Charlier and Carpentiers (1956).* Greater absorption of Zn was also observed by concerned slant. The findings are in close conformity with those reported by *Singh, et al. (1996) and Sharma et al. (2000).*
5.4.2 To assess the growth parameters of peppermint as influenced by S and Zn

5.4.2.1 Plant height

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5.5 To study the response of *Jatropha* on growth and yield of peppermint

5.5.1 To study the response of *Jatropha* on growth of peppermint

The increase in plant height and branches of mint due to jatropha
cropping is possibly due to beneficial effect of Jatropha on physical and physico-chemical conditions of concerned soil that enhanced the growth of mint. Probably excreted gelatin, respirational carbon dioxide and minerals from jatropha roots helped in improved physical condition of experimental soil. It is a known fact that root hairs make the soil particles cling together and subsequently cause aggregate formation. Further, organic matter from fallen jatropha leaves served as a food for microbes and improved soil biological conditions. Therefore, leaves and roots of jatropha resulted ideal soil properties that increased plant height of mint. Jenny and Raychaudhuri (1960) also reported similar result.

5.5.2 To study the response of Jatropha on yield and quality of peppermint.

Data show that the herbage yield and oil content of peppermint significantly increased under jatropha over fallow (i.e. non jatropha cultivated) plot during both the years of experiment. Jatropha cultivation also increased the quality (menthol %) of mint oil. This is also due to the same reason as discussed elsewhere i.e. gelatinous excretion from roots, pressure of roots, respirational carbon dioxide and excreted minerals of jatropha which helped improved soil physical and biological properties. This ultimately enhanced vigorous root and shoot growth resulting in greater
absorption of nutrients from the soil as also reported by Charlier and Carpentiers (1956).

5.6 To identify the role of S and Zn on yield and quality of mint oil

5.6.1 To identify the role of S and Zn on yield of mint

With successive increase in S application the increase in oil yield may be due to positive role of S in biosynthesis of Indol Acetic Acid (IAA) which enhanced photosynthesis that resulted better herbage yield and oil content. The findings of present investigation are supported by Singh et al. (1996), Sharma et al. (2000), Singh and Bairarthi (1980), Somani et al. (1988), Chauhan (1996), Islam et al. (1997) and Sharma et al. (2009).

As mentioned earlier (Table 13) application of Zn up to 10 kg ha\(^{-1}\) significantly increased the oil content of mint. It may be due to beneficial effect of Zn on absorption of different nutrients from the soil. Further, the beneficial role of zinc in chlorophyll formation, regulating the auxin concentration and its stimulatory effect on most of physiological and metabolic processes of the plants might have helped the plants in enhanced absorption of nutrients from soil. Thus, the favorable influence of zinc on photosynthesis and metabolic processes augments the production of photosyrithates and their translocation to different plant parts including
grain, which ultimately increase the concentration of nutrients in plants. The results are in accordance with the findings of *Sharma and Bhardwaj (1998)* and *Dwivedi et al. (2001)*

**5.6.2 To identify the role of S and Zn on quality of mint oil (menthol)**

Application of S and Zn resulted in gradual increase in menthol percent of oil with progressive increment of S, due to beneficial effect of S and Zn in chlorophyll formation. S regulates auxin concentration. As auxin has stimulating effect on most of the physiological and metabolic processes of the plant so also on photosynthesis. It has further enhanced absorption of nutrients from the soil. In other words, the favourable influence of S and Zn on photosynthesis and metabolic processes is possible. Therefore, enhancement of photosynthates and translocation of metabolic products to different plant parts have increased the menthol percentage in mint oil. These results are in close conformity with the findings of *Sharma and Bhardwaj (1998)* and *Dwivedi et al. (2001).*