

**IMPACT OF FARMERS' ORGANIC FARMING
PRACTICES ON SOIL PROPERTIES IN NORTHERN
DRY ZONE OF KARNATAKA**

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I. INTRODUCTION

Organic manures, including animal manures, crop residues, green manures and composts were traditionally and preferentially used in developing countries until 1960's before the inorganic chemical fertilizers began to gain popularity. Chemical fertilizers became easily available and unlike organic manures, they were less bulky and thus, easier to transport, handle and store. They produced greater crop response than many organic manures. This was particularly true during the 'Green Revolution', when high yielding crop varieties were introduced that responded to heavy doses of chemical fertilizers.

The advent of high yielding varieties and increased area under assured irrigation led to a major shift from organic based nutrient application to use of chemical fertilizers. Chemical fertilizers virtually replaced sources of crop nutrients in some developing countries during early 1970s (FAO, 1985). Consequently, there was not only reduction in the consumption of organic manures but also excess use of high analysis fertilizers in an unbalanced manner resulting in additional problems of soil fertility such as acidity, alkalinity, multiple nutrient deficiencies especially of secondary and micronutrients and resulted in total loss of soil health.

Because of recent increase in fossil energy costs, chemical fertilizers have become much more expensive. Due to indiscriminate use of chemical fertilizers without additions of adequate amounts of organic materials to soils, there is often an increase in nutrient runoff, erosion, gradual deterioration of soil physical properties and environment pollution. Thus, organic fertilizers have once again started to regain their popularity.

Organic farming is a production system, which avoids or largely excludes the use of synthetically compounded fertilizers, pesticides and growth regulators. Organic farming is becoming an increasingly important aspect of environmentally sound sustainable agriculture. Organic materials hold a great promise due to local availability as a source of multiple nutrients and ability to improve soil characteristics.

The value of organic materials as fertilizers and soil conditioners is often misunderstood and has been the source of some controversy. The simplest and most common means of estimating the value of organic amendments is by assessing the current market value of the potentially available plant nutrients they contain. Usually, this is done in terms of their macronutrient content *i.e.*, N, P and K. However, many organic materials contain other components which can contribute significantly to increased crop yields, including organic matter, secondary and micronutrients and sometimes lime. In some cases, the organic matter fraction of a particular material may be of greater value than its total nutrient content because of the beneficial effect of organic matter on soil physical properties and soil productivity.

Good quality farmyard manure (FYM) is perhaps the most valuable organic matter applied to a soil. It is the most commonly used organic manure in most countries of the world. It consists of a decomposed mixture of cattle dung, the bedding used in the stable and any remnants of straw and plant stalks fed to cattle. It must be stressed that the value of farmyard manure in soil improvement is due to its content of macro and micronutrients and its ability to i) improve the soil tilth and aeration, ii) increase the water holding capacity of the soil and iii) stimulate the activity of microorganisms that make the plant food elements in the soil readily available to crops.

The beneficial effect of vermicompost was first highlighted by Darwin (1881). Since then, it has taken almost a century to appreciate its important contribution in curbing inorganic pollution and providing top soil in impoverished lands. Worm casts are fine particulate materials, which are rich in available nutrients with considerable potential as soil additive to revive the productivity status of soil. Earthworm casts are usually considered to be responsible for getting a good soil structure and improving soil physical properties. Vermicompost is also considered as biofertilizer because of its richness in humus and nitrogen fixing microorganisms. Vermicompost contains micro sites rich in available carbon and nitrogen (Sudhakar *et al.*, 2002). Worm cast injected soils were also rich in water soluble P (Gratt, 1970) and contained two to three times more available K than surrounding soils (Sudhakar *et al.*, 2002) which encourage better plant growth.

Green manuring is an age old concept of soil fertility management, wherein the succulent green portion of plants such as leaves, twigs and loppings of trees are incorporated into soil. Green manuring crops are known to fix atmospheric nitrogen, improve soil structure and recycle the nutrients.

Decomposition of organic manures in soil results in the release of CO₂, which gets converted into carbonic acid by dissolution in soil water and enhances weathering of minerals and release of plant nutrients. A wide variety of wastes are being generated which are known to contain appreciable amounts of organic matter and plant nutrient elements and can be effectively used as a source of organic manure (Srikanth *et al.*, 2000). Farmers have begun to slowly shift from conventional farming to organic farming in the last two decades. Although the beneficial effects of organic farming are well known, a scientific evaluation of organic farms is lacking. Keeping these facts in mind, the present investigation was taken up with the following objectives.

1. To survey and document farmers' organic farming practices in Northern Dry Zone of Karnataka (Zone-3)
2. To study the type and quantity of organics used by the identified organic farmers and quantifying the nutrients added to soil and
3. To study the effect of organic farming on physical, chemical and biological properties of soils under major cropping systems.

II. REVIEW OF LITERATURE

Organic manures hold a great promise due to their local availability and ability to improve soil characteristics. Cheap sources of plant nutrients like organic manures can replace the inorganic fertilizers under dryland and rainfed conditions (Badanur *et al.*, 1990).

Higher benefits are obtained from recycling of organic materials in soil by overall improvement in soil physical and chemical properties and increase in the availability of plant nutrients (Mandal *et al.*, 1992).

In this regard, the literature pertaining to influence of organic manures like FYM, vermicompost, compost, crop residue, *etc.* on soil properties are reviewed and presented in this chapter under the following heads.

- 2.1 Organic manures as source of plant nutrients
- 2.2 Effect of organic manures on soil physical properties
- 2.3 Effect of organic manures on soil chemical properties
- 2.4 Effect of organic manures on availability of plant nutrients
- 2.5 Effect of organic manures on soil biological properties

2.1 ORGANIC MANURES AS SOURCE OF PLANT NUTRIENTS

Due to continued escalation of fertilizer prices, there is a great thrust either to supplement or replace mineral fertilizers with renewable and cheaper sources of nutrients like organic manures. In India, farmers use both urban and rural organic wastes wherever they are available. Organic materials were considered to be beneficial sources of plant nutrients in soil fertility management (Schoningh and Wichmann, 1990). Thus, incorporation of crop residues, farmyard manure, vermicompost, green manure is important in increasing soil nutrients status.

2.1.1 Farmyard manure (FYM)

Organic material in the form of farmyard manure was the only recognized source of plant nutrients added to the soil before the introduction of chemical fertilizers in the middle 19th century (Hauck, 1982).

Farmyard manure is known to increase crop yield by its favourable effect on physical, chemical and biological factors that determines the productivity and fertility status of soil and supply nutrients in the readily available form to plants. FYM contains approximately 0.5, 0.2 and 0.5 per cent of N, P₂O₅ and K₂O, respectively.

Chatterjee *et al.* (1979) reported that 10 tonnes of well decomposed organic manure by composition on dry weight basis was effective as 40 kg fertilizer N per ha in terms of impact on rice yield and also found that the nutrient content of FYM was 0.64, 0.07 and 0.29 per cent of N, P and K, respectively. Similarly, an assessment of nutrient supply by FYM showed that each tonne of FYM was equivalent to 3 kg fertilizers nutrients in a single crop and 5 kg in double cropping in terms of yield (Tandon, 1983).

Gaur (1986) estimated that 15 tonnes N and 4 tonnes each of P₂O₅ and K₂O were potentially available from 1000 tonnes of fresh cattle dung. Sharma and Mitra (1989) reported that the FYM contained 26.1 per cent carbon, 1.71 per cent of N, 0.24 per cent of P₂O₅ and 2.04 per cent of K₂O on dry weight basis. The FYM used in the experiment by Sriramachandrashekharan *et al.* (1996) contained 1.2 per cent of N, 0.21 per cent of P, 1.96 per cent of K, 29.9 per cent of organic carbon and the C:N ratio was 22.40.

2.1.2 Vermicompost

The complex organics are biodegraded by symbiotic association between earthworms and microbes resulting in vermicompost or vermicasting. The vermicompost, apart from increasing the population of microbes, also provides sufficient energy for them to remain active. Vermicompost can provide the required nutrients to the plants. It provides the

vital macronutrients such as N, P, K, Ca, Mg and micronutrients such as Fe, Zn, Cu, Mn and Mo.

Das and Patra (1979) observed that vermicompost contained 0.47 per cent N. Kale *et al.* (1992) opined that vermicompost was like any other organic manure depending on the nature of wastes used as feed for worms. The nitrogen content varied between 0.5 to 1.2 per cent. Similar variation in respect of phosphorus and potassium content have also been reported. The chemical analysis of vermicompost prepared at University of Agricultural Sciences, Dharwad revealed that it contained 0.8, 1.1 and 0.5 per cent of N, P₂O₅ and K₂O, respectively (Giraddi, 1993). In comparison to FYM, vermicompost contained nearly two times more N, five times more phosphorus and almost equal amount of potassium.

2.1.3 Crop residue

The recycling of various forms of residue has the advantage of converting surplus farm waste into useful product for meeting the nutrient requirement of crops besides maintaining the soil health and improving the overall ecological balances.

Crop residue management considers the use of residue from previous crop as an input resource and with appropriate management practices (Schertz and Bushnell, 1993).

On an average, cereal straw and residue contained about 0.5:0.6:1.5 per cent of N:P₂O₅:K₂O, respectively. The nutrient potential of straw (236 million tonnes) from five crops *viz.*, rice, wheat, sorghum, pearl millet and maize was 1.31, 1.41 and 3.54 million tonnes of N, P₂O₅ and K₂O, respectively (Gaur *et al.*, 1995). Burning of crop residues increased the potential loss of N, C, S and possibly some other nutrients due to volatilization and resulted in unfavourable soil condition (Biederbeck *et al.*, 1980). Hence, its management ensured the recycling of major portion of nutrients and exerted considerable influence on crop performance, primarily through their impact on properties of soil.

2.1.4 Green manures

Use of legumes as green manures contribute to the fertility of soil by way of addition of roots, nodules, leaves, tops *etc.* Green manuring is a possibility and a practice in sub-tropical regions, where winter fallow is common, which found to substitute nearly 50 to 56 kg N per ha (Millhotton and Melville, 1991 and Beaver *et al.*, 1993) apart from increasing soil organic matter. It is felt that legumes as winter cover are environmentally desirable which supply adequate N for cotton production. *In situ* green manuring, as legume intercrops is possible under all conditions and results are also encouraging. Intercropping of legumes *viz.*, sunnhemp, horsegram, cowpea for incorporation as green manure at Coimbatore helped to reduce N requirement of cotton to an extent of 35 to 50 per cent (Anon., 1991).

Cowpea as a green manure provided about 800 to 850 kg dry matter with 2.3 to 2.5 per cent N and 0.24 to 0.26 per cent P at 40 DAS. This material was easily decomposable and contributed 10 to 12 kg N per ha (Tarhalkar *et al.*, 1996).

Dhaincha gave 3500 to 4000 kg of dry matter per ha with 2.5 to 2.6 per cent of N, 0.20 to 0.22 per cent P₂O₅ and 1.9 to 2.0 per cent K₂O. Its fast decomposing leaves provide N during the crucial boll development period of cotton, while the stalk acts as temporary organic mulch (Tarhalkar *et al.*, 1996).

The sunnhemp used by Badanur *et al.* (1990) for a field trial contained 2.30, 0.51 and 0.79 per cent of N, P₂O₅ and K₂O, respectively.

2.2 EFFECT OF ORGANIC MANURES ON SOIL PHYSICAL PROPERTIES

2.2.1 Bulk density

Srikanth *et al.* (2000) found a significant decrease in bulk density (1.27 – 1.18 g/cc) of soil after harvest of second crop in the soil amended with compost compared to the inorganic fertilizers applied soil.

Sharma *et al.* (2000) observed a significant reduction in the bulk density in residues and FYM incorporated soils and this was attributed to the build up of soil organic matter and better soil structure.

Application of composted coir pith and FYM reduced the bulk density appreciably over control and their effects were found to be comparable (Rajkhanan *et al.*, 2001). In Vertisols, the bulk density was reduced significantly from 1.32 to 1.28 g per cm³ in one season itself (Patil *et al.*, 2003).

Biswas *et al.* (1971) observed that bulk density increased with application of inorganic fertilizers, but decreased with addition of organic manures like FYM @ 17.5 tonnes per ha. The increased bulk density was attributed to the deterioration of soil structure due to addition of chemical fertilizer.

Legume residues incorporation decreased the bulk density of soil, while fertilizer application alone increased it. The increase in bulk density might be due to deterioration of soil structure (Bairathi *et al.*, 1974).

Shanmugam and Ravikumar (1980) found that application of FYM @ 25 tonnes per ha brought the reduction in bulk density of soil, which lead to an improvement of physical condition of the soil.

In an eroded alluvial soil, continuous use of inorganic fertilizers significantly increased bulk density (1.49 to 1.56 g/cc). Whereas, treatment with FYM addition reduced the bulk density to 1.41 g per cm³ (Bhatia and Shukla, 1982).

Venkateshwaralu (1984) observed that in Alfisols of Hyderabad, bulk density decreased with incorporation of 20 kg N through crop residues. The incorporation of organic residues and straw manures also decreased the bulk density significantly (1.17 g/cc) from initial bulk density (1.31 g/cc) as observed by Pikul and Allmarks (1986).

Chenkai (1993) reported that incorporation of organic residues not only reduced bulk density but also improved soil porosity and nutrient availability in soil.

In Vertisols of Bijapur, Bellakki and Badanur (1994) observed a significant decrease in bulk density with incorporation of sorghum stubbles and subabul loppings @ 5 tonnes per ha compared to that of only chemical fertilizers application. Similar results with incorporation of FYM and vermicompost as compared to only chemical fertilizer application were observed by Patil (1998) and Babalad (1999).

Itnal (1997) noticed that application of maize straw @ 5 tonnes per ha and cotton residue reduced the bulk density from 1.3 g per cm³ in control to 1.04 and 1.11 g per cm³, respectively. The bulk density was also reduced by combined application of FYM and inorganic fertilizers (Mishra and Sharma, 1997).

2.2.2 Maximum water holding capacity

Addition of organic manures significantly improved the water holding capacity of soil, compared to only inorganic fertilizers application (Biswas and Khosla, 1971).

Bairathi *et al.* (1974) observed that the total porosity and the water holding capacity of soil improved when crop residue alone or FYM alone or in combination with fertilizers were applied.

Prasad and Sinha (1980) concluded that application of FYM increased the water holding capacity of soil, while the use of high dose of only chemical fertilizers decreased the same as compared to the control.

Bhatia and Shukla (1982) reported that use of FYM either alone or in combination with fertilizers increased significantly the water holding capacity and retention of moisture at field capacity. Whereas, regular application of only chemical fertilizers had an adverse effect on the retention of soil moisture.

Bhriguvanshi (1988) observed that application of FYM either alone or in combination with nitrogenous fertilizers played a definite role in improving water holding capacity of soil which was attributed to the improvement in structural condition of the soil.

Acharya *et al.* (1988) quoted that continuous application of N through chemical fertilizers alone decreased the soil moisture retention characteristics as a result of reduced field capacity and permanent wilting point, whereas, application of FYM along with NPK recorded higher soil moisture retention.

Increase in water holding capacity of soil due to addition of wheat straw and cattle manure was observed by Bijay Singh *et al.* (1992).

Jadhav *et al.* (1993) reported that maximum water holding capacity of the soil was increased in the plots which received vermicompost @ 5 tonnes per ha compared to that of control plots.

Bellakki and Badanur (1994) reported that in Vertisols, water holding capacity of soil was increased when sorghum stubbles alone or in combination with subabul lopping were incorporated compared to fertilizer application. Similar results were also observed by Badanur and Malabasari (1995). Soil application of vermicompost @ 2 tonnes per ha enhanced soil moisture content compared to application of 1 tonne per ha (Mastiholi, 1994).

Patil (1998) observed that, incorporation of FYM @ 2.5 tonnes per ha, vermicompost @ 1.0 tonne per ha enhanced the soil moisture content compared to only fertilizer application in the Vertisols of Bijapur.

A study conducted by Sharma *et al.* (2000) revealed that the water holding capacity of soil was significantly improved by application of residues and FYM due to build up of soil organic matter and improvement in soil structure.

Maximum water holding capacity of soil decreased with application of fly ash while it was increased due to increasing FYM level (Patil *et al.*, 2003).

2.2.3 Soil aggregates

Havanagi and Mann (1970) noticed a considerable increase in percentage of water stable aggregates due to incorporation of green manure (sunhemp) and FYM over control.

Balasubramanian *et al.* (1972) observed a significant increase in aggregation of soil particles due to addition of organic matter and maximum aggregation was with the addition of maize stalks applied at the rate of 1 per cent level of organic matter.

In a sandy loam soil of Coimbatore, Subramanian *et al.* (1975) noticed significant influence on formation of soil aggregates by mere incorporation of maize stalks and farmyard manure than fertilizer alone under irrigated condition.

Ravikumar and Krishnamoorthy (1980) compared the effect of organic and inorganic amendments on physical properties of black soil and opined that organic amendments, namely maize straw and farmyard manure were superior to inorganics (basic slag and sewage sludge) in improving the aggregate stability, hydraulic conductivity and available water content of soil. In red soils also the incorporation of organic residues and farmyard manure improved the stability index (Shanmugum and Ravikumar, 1980).

Lal and Akinremi (1983) compared the earthworm castings with adjacent soils and reported that earthworm castings had better aggregate stability.

Pandey *et al.* (1985) noticed an increase in structural index of soil aggregation (greater than 0.25 mm in size) with the incorporation of maize and jowar stalks and wheat and rice straw.

Singh and Chatterjee (1966) observed high aggregation in the alluvial clay soils of Patna due to high clay and CEC of soil and low aggregation in alluvial soils of Sabor due to low clay and organic matter.

Hirekurubar (1989) also observed highly significant correlation between per cent aggregate stability and organic carbon in Vertisols of North Karnataka.

2.3 CHEMICAL PROPERTIES OF SOIL

Incorporation of organic sources profoundly influences many chemicals properties of soil.

2.3.1 pH and EC

Application of different levels of fertilizers and manures did not affect the soil pH (Vig and Bhumbra, 1970). In contrast Formoli and Prasad (1979) observed that application of FYM for three years continuously reduced the soil pH from 8.8 to 8.6, while application of phosphorus and potassium had no effect on soil pH.

Singh *et al.* (1980) studied the effect of continuous application of FYM and chemical fertilizers on soil properties and found a decrease in pH of the soil by about one unit from the initial value and related it to the decomposition and mineralization of organic matter. Similarly, Bajpai *et al.* (1980) observed a slight decrease in pH and EC at later stage of decomposition with application of paddy-straw.

Long term (7 years) application of FYM @ 15 tonnes per ha slightly decreased the pH which was due to production of acids during decomposition of organic matter (Chaudhary *et al.*, 1981). They also observed that unlike pH, EC of soil remained unaffected. Since, the salts added through nutrient sources might have been leached down as it received six irrigations over the cropping period.

Lal *et al.* (2000) reported that incorporation of organic wastes like lantana, water hyacinth subabul leaves, lentil straw, maize stover and rice straw significantly increased pH of an acid clay loam soil.

A study to know the effect of FYM on soil pH showed that there was decrease in pH from 7.99 to 7.65 and each increment of FYM reduced the soil pH significantly due to organic acid production during its decomposition (Patil *et al.*, 2003).

Rathod *et al.* (2003) reported that the pH of the sodic soil was reduced significantly by application of FYM at 5 tonnes per ha which was on par with the pH value that had been reduced by 50 per cent gypsum requirement. Similarly electrical conductivity was also found to be reduced significantly by application of the FYM.

An increase in pH from 8.8 to 8.9 in control plot was noticed by Nalatwadmath *et al.* (2003) in a 15 years experiment, whereas, application of ammonical fertilizer or FYM reduced the pH significantly from 8.9 to 8.7, which was mainly attributed to the production of acids on decomposition of organic manure and use of ammonical fertilizers due to their acidic residual effect.

2.3.2 Organic carbon

Organic carbon content of soil changes rapidly with addition of organic manures. Immobilization and mineralization of nutrients are two important processes that takes place simultaneously in soil with the addition of organic manures. A slight but consistent increase in organic carbon even under tropical condition had been reported by Sundara Rao and Anoop Krishnan (1963).

Gattani *et al.* (1976) studied the effect of continuous use of chemical fertilizers and manures on soil properties for five years and reported that the organic carbon level of the soil was increased to 0.24 from 0.19 per cent by manure application.

Chaudhary *et al.* (1981) reported that organic carbon content of the soil increased by 0.143 per cent over eight years with the application of 15 tonnes of FYM every year. Even application of 60 kg P₂O₅ alone increased the organic carbon by 0.042 per cent but potassium application had no significant effect.

Grewal *et al.* (1981) noticed that the organic carbon content of the soil increased to 1.87 from 1.28 per cent with application of FYM and compost. Similarly, Helkian *et al.* (1981) found that application of compost significantly increased organic carbon (0.49%) over the control (0.32%) in black soil.

In a twenty years long term manurial experiment, application of FYM alone or in combination with chemical fertilizers had given higher values (0.75% and 0.78%, respectively) of organic carbon than with fertilizer alone (0.61%) as observed by Sinha *et al.* (1983).

Incorporation of residues of sorghum, maize and cotton stalk was found to increase the organic matter content of black soil (Koni, 1983).

In a ten years experiment on sandy loam soils of Ludhiana. Sharma *et al.* (1984) observed a decline in organic carbon content of control plot from 0.25 to 0.19 per cent, whereas organic carbon was significantly higher in plots where organic manures were applied.

Kaushik *et al.* (1984) concluded that the organic carbon content of soil was found higher with application of 15 tonnes of FYM once in a year. The use of N alone maintained the organic carbon at the original level, which was through the residues of crops roots and their subsequent decomposition in soil as N application resulted in better growth of plants including roots.

Singh and Brar (1985) reported that there was a significant increase in organic carbon percentage in the soil after four years of application of FYM and green manures. The accumulation of organic matter was greater with FYM than green manures. This might be due to early decomposition of green manures and humification of FYM.

Rabindra and Honnegowda (1986) studied the long term effect of fertilizers and manures on fertility of red sandy loam soil and found that continuous use of FYM enhanced the organic carbon content of soil.

In clay loam soil, the organic carbon status was significantly improved by continuous application of FYM @ 10 tonnes per ha (0.36 to 0.47%). The combined application of FYM and nitrogenous fertilizers also improved organic carbon content (Bhriuvanshi, 1988).

Srivastav *et al.* (1988) found that the application of 15 tonnes of rice straw during three crop seasons gradually increased the organic carbon content of the soil (0.60%) over control (0.45%). Build up of organic carbon in soil was comparable to initial level at the end of third crop.

Subramanian and Kumaraswamy (1989) observed an increase in the organic carbon status of soil due to addition of FYM either alone or in combination with fertilizers because of an increase in the addition of root biomass to the soil.

A study involving long-term recycling of rice and wheat crop residues at Ludhiana revealed that organic carbon status of soil was significantly increased when crop residues were incorporated in rice-wheat sequence (Bhat *et al.*, 1991).

Bhandari *et al.* (1992) found that the conjunctive use of organic manures such as FYM or crop residues with fertilizers increased the organic carbon content of soil.

Gidnavar *et al.* (1992) observed a favourable contribution of green manures like sunnhemp, cowpea, blackgram, soybean and horsegram on organic carbon status of soil which inturn resulted in possible increase in moisture retention. However, organic carbon content was highest in FYM treated soil.

Hapse (1993) reported that the vermicompost application enhanced the organic carbon content of soil as compared to fertilizer alone.

The results of a study conducted to know the long term effect on continuous use of fertilizers and manures on fertility status of soil have revealed that organic matter of the soil was increased at a steady rate over years due to application of organic manures (Patiram and Singh, 1993).

In a Vertisol, application of 5 tonnes each of FYM, sunnhemp, subabul and sorghum stubbles for successive three years recorded organic carbon per cent of 0.68, 0.61, 0.66 and 0.53, respectively against the initial level of 0.48 per cent (Badanur *et al.*, 1990). Bellakki and Badanur (1994) also observed the same trend by application of subabul and sorghum stubbles.

Mastiholi (1994) reported that after harvest of rabi sorghum organic carbon content of soil was more due to application of vermicompost than fertilizers alone.

Mathur (1997) studied the long-term effect of FYM and fertilizer on soil properties and yield in cotton-wheat rotation at Northwest Rajasthan. He observed that incorporation of 16 tonnes FYM accounted for highest increase in organic carbon content of soil.

Inclusion of organics *viz.*, FYM, vermicompost cotton and safflower stalk enhanced the soil organic carbon as compared to fertilizers alone (Patil, 1998, Babalad, 1999 and Manjappa, 1999).

2.3.3 Cation exchange capacity

Swarup and Ghosh (1979) observed an increase in the cation exchange capacity (CEC) of soil with the application of farmyard manure and further reported that application of the full dose of chemical fertilizers brought about only a small increase in the CEC owing to some marginal increase in the organic carbon content.

The increase in CEC with manure addition probably resulted from both the increase of organic matter and pH associated with manure additions (Magdoff and Amadon, 1980).

Singh *et al.* (1980) reported that application of farmyard manure resulted in significant increase in cation exchange capacity. The increase in CEC was associated with rise in organic matter content. Yaduvanshi *et al.* (1985) reported that application of farmyard manure resulted in a significant increase in CEC.

Patiram and Singh (1993) found increased CEC through manure application. The lowest CEC was found in the soils which received only N without manure. But, there was increase in CEC of soil with grass cultivation even when manure was not applied. Increasing dose of N had tendency to decrease the CEC, although the effect was not significant. Thus, CEC was profoundly improved by continuous use of manure either alone or in combination with N.

2.4 AVAILABILITY OF PLANT NUTRIENTS IN SOIL

2.4.1 Available nitrogen

Anderson and Peterson (1973) found that continuous addition of manures for 20 years increased the soil total and available nitrogen content significantly from 0.05 to 0.083 per cent, while increase was only 0.005 per cent in N fertilizer applied plots as large portion of N was removed by the crop.

Khiani and More (1984) observed a higher available nitrogen content in soil under continuous manuring with FYM over a period of 45 years in cotton–jowar rotation compared to control.

Singh and Brar (1985) reported that the application of organic manures like FYM and green manures increased the available nitrogen.

Gupta *et al.* (1988) noticed that the available nitrogen content of the soil remained almost constant in control plot even after 19 years but, there was significant increase with increased level of FYM application.

Phule (1993) observed significantly higher soil available nitrogen (37%) with application of vermicompost treated plot as compared to fertilizer alone.

Balaji (1994) noticed higher levels of total and available nitrogen with either vermicompost alone or in combination of FYM.

In sunflower–bengalgram cropping system Quereshi *et al.* (1995) noticed that incorporation of cotton stalk @ 5 tonnes per ha significantly increased available nitrogen content of soil.

Pawar (1996) reported that available nitrogen content of Vertisol was increased due to application of vermicompost compared to control.

Bellakki and Badanur (1997) observed an increase in available nitrogen due to organic materials application, which was attributed to the direct addition of nitrogen through organic materials and greater multiplication of soil microbes, which convert organically bound nitrogen to inorganic form.

Inclusion of organic manures such as FYM, vermicompost, cotton and safflower stalk enhanced the soil available nitrogen as compared to recommended dose of fertilizer alone (Patil, 1998 and Manjappa, 1999). Babalad (1999) observed that application of crop residues

recorded significantly higher available nitrogen (13%) as compared to no residue in soybean-safflower sequence.

2.4.2 Available phosphorus

Mineralization and immobilization of phosphorus in soil with the addition of organic source have been reported by number of workers.

Somani and Saxena (1975) observed an increase in phosphorus with incorporation of wheat crop residues and farmyard manure, while inorganic fertilizers alone decreased it when compared with initial status.

Magdoff and Amadon (1980) observed that the extractable phosphorus in the soil decreased due to continuous application of nitrogenous fertilizers but was increased due to continuous application of organic manures.

Incorporation of FYM alone or along with inorganic fertilizers was found to have a beneficial effect on available phosphorus status of soil (Singh *et al.*, 1982). The reason for this was attributed to the enhanced solubilization of native phosphorus and added phosphorus by the decomposition products of organic manures.

Venkateshwaralu (1983) noticed an increase in available phosphorus with the application of organic residues over a period of five years in red soils of Hyderabad.

In a forty five years long term manurial experiment, Khiani and More (1984) found that the available phosphorus was higher with FYM application in cotton-jowar rotation.

Krishnaswamy *et al.* (1984) observed that addition of organic manure had significant effects on increasing the available phosphorus content in soil.

In black soils of Bijapur, Satyanarayana Rao (1987) recorded increased available phosphorus content of soil at harvest due to incorporation of subabul or FYM when compared to control.

Hundekar (1992) indicated that incorporation of crop residues increased the available phosphorus content of black soil of Bijapur.

Bellakki and Badanur (1994) found that the incorporation of subabul loppings alone or in combination with sorghum stubbles either every year or alternate year recorded significantly higher available phosphorus over fertilizer application. Similarly, Badanur *et al.* (1990) also observed significant increase in available phosphorus content of soil with application of FYM, subabul and sunnhemp over fertilizer application.

FYM treated plots showed an increase in available phosphorus than inorganic fertilizers, which was due to coating of sesquioxides by organic materials that reduced phosphorus fixing capacity of soil (Bharadwaj and Omanwar, 1994).

Balaji (1994) reported higher level of available phosphorus with application of either vermicompost alone or in combination with chemical fertilizers application.

Incorporation of cotton stalks @ 5 tonnes per ha was found to increase the availability of phosphorus in sunflower-bengalgram cropping system (Quereshi *et al.*, 1995).

Vasanthi and Kumaraswamy (1996) observed that application of vermicompost alone or in combination with RDF increased the available phosphorus of soil than RDF alone.

Madegowda (1997) reported that application of vermicompost @ 5 tonnes per ha to maize crop resulted in significantly higher available P_2O_5 content as compared to RDF.

Singh *et al.* (1998) reported that the soil available phosphorus was improved appreciably with application of either FYM or green manures. Similar observations were also noticed by Subbaiah and Kumaraswamy (1996).

In Vertisols of Dharwad, Babalad (1999) observed that the application of crop residues significantly improved available phosphorus compared to no residues in soybean-safflower sequence.

Manjappa (1999) found that the incorporation of organics *viz.*, FYM, vermicompost, cotton and safflower stalks enhanced the soil available phosphorus as compared to RDF.

2.4.3 Available potassium

FYM application to five successive crops increased the available soil K to the same degree as K fertilizers did indicating that FYM was a good source of K which also had favourable effect on K availability in soil (Grewal *et al.*, 1981). Similarly, continuous manuring with FYM over a period of 45 years in cotton-jowar rotation, increased the available potassium significantly over unmanuring (Khiani and More, 1984).

Venugopal and Shivashankar (1989) reported that incorporation of maize straw @ 4 tonnes and @ 8 tonnes per ha released available potassium of 104 and 112 kg per ha, respectively as compared to control (88 kg/ha).

Badanur *et al.* (1990) noticed that the available potassium content of soil was highest in jowar stubbles incorporated plot (335 kg/ha) followed by safflower stalk and in both the cases K was higher than green manured and RDF plots in Vertisols of Bijapur.

Application of vermicompost recorded significantly higher available potassium (10%) as compared to fertilizers treatment alone (Phule, 1993) which was attributed to the rich K content of vermicompost.

Balaji (1994) found higher levels of available potassium with either vermicompost alone or in combination with FYM in Vertisols of Dharwad. The availability of potassium could be improved by incorporation of cotton stalk @ 5 tonnes per ha in sunflower-bengalgram cropping system (Quereshi *et al.*, 1995).

More (1994) observed higher amount of available potassium where farmyard manure, wheat straw, pressmud and biogas slurry were incorporated into the sodic Vertisol.

Application of vermicompost @ 5 tonnes per ha to maize crop resulted in significantly higher available potassium content of soil compared to application of RDF alone in deep Vertisols of Dharwad (Madegowda, 1997).

Mathur (1997) observed that application of 100 per cent of FYM significantly increased available potassium over 50 per cent FYM + 50 per cent NPK. Increase in potassium was due to reduction of K fixation in soil.

Increase in available potassium due to FYM and sunnhemp application was observed by Bellakki and Badanur (1997) and it was attributed to direct addition of potassium to the available pool of soil.

Incorporation of organics *viz.*, FYM, vermicompost and cotton stalk enhanced the soil available potassium as compared to RDF alone (Patil, 1998 and Manjappa, 1999).

Nalatwadmath *et al.* (2003) reported a build up of available K only in organic manure treatment which was maximum (33%) as compared to control.

2.4.4 Available sulphur

Immobilization of inorganic form of sulphur occurs when low sulphur energy rich organic materials are added to soils not plentifully supplied with inorganic sulphur. The mechanism is thought to be the same as that of for nitrogen. The energy rich material stimulates microbial growth and the inorganic sulphate is synthesized into microbial tissue. Only when the microbial activity subsides does the inorganic sulphate form again appear in the soil solution. These facts suggest that like nitrogen, sulphur in the soil organic matter may be associated with organic carbon in reasonably constant ratio (Williams, 1967).

Anandaswarup and Ghosh (1980) studied changes in water soluble sulphur as a result of intensive cropping and manuring. They noticed that use of sulphur bearing source *i.e.*, superphosphate, resulted in the higher content of SO₄-S in the soils, maximum being with the use of FYM.

Kanharaju (1992) observed significant increase in available sulphur with incorporation of crop residues. Highest increase was observed in treatment which received maize residue with full dose of NPK fertilizer treatment followed by maize residue with half NPK fertilizer treatment, maize residue alone and NPK fertilizer treatment alone.

2.4.5 Available micronutrients

Sharma and Meelu (1975) found that application of 15 tonnes FYM per ha to every crop increased the available zinc of the soil from initial status of 0.62 ppm to 1.09 ppm after six seasons of cropping.

In a long term field experiment, Anand Swarup and Ghosh (1980) observed that continuous fertilizers application enhanced available iron content of soil by two times. On the other hand, continuous cropping for seven years decreased soil zinc content as compared to fallow land, while continuous phosphatic fertilizers application reduced exchangeable Zn compared to control plot as noticed by Subba Rao and Ghosh (1983). They also recorded enhanced Zn levels due to application of organic manures.

Prasad (1981) found that the natural complexing agent such as organic manure was found to be important in increasing the availability of Zn and Fe to plants even under moderate or acute deficiency condition.

Nemath *et al.* (1987) observed that application of FYM @ 37.4 to @ 69.4 tonnes per ha significantly increased the iron content of soil after harvest of wheat crop.

Rajeev Kumar *et al.* (1993) noticed that available Fe and Zn level in soil declined in all treatments except FYM treated soil. Similarly, FYM application for five years increased the Zn content in the Vertisols of Akola (Rao and Dakhore, 1994).

Incorporation of cotton stalks @ 5 tonnes per ha improved micronutrients availability in sunflower-bengalgram cropping system (Quereshi *et al.*, 1995). Similarly, micronutrients availability significantly increased by application of vermicompost along with RDF than RDF alone (Vasanthi and Kumaraswamy, 1996).

Mathur (1997) reported that the availability of zinc and iron in sandy loam soil decreased due to continuous cropping of cotton wheat sequence. However, application of FYM significantly increased available zinc of soil compared to RDF and other treatments.

Addition of organic materials like FYM and sunnhemp increased the availability of micronutrients (Bellakki and Badanur, 1997). The increased availability was attributed to enhanced microbial activity in the soil and the consequent release of complex organic substances that could have prevented micronutrients from precipitation, fixation, oxidation and leaching and also addition of these nutrients through organic sources.

Sharma *et al.* (2000) observed that the DTPA-extractable micronutrients like Zn, Fe, Mn and Cu enhanced significantly due to crop residues and FYM incorporation compared to chemical fertilizers application.

2.5 EFFECT OF ORGANIC MANURES ON BIOLOGICAL PROPERTIES OF SOIL

2.5.1 Dehydrogenase activity

Biological oxidation of organic compounds is generally a dehydrogenation process and there are many dehydrogenases (enzymes catalyzing dehydrogenation), which are highly specific. Unlike the other enzymes, dehydrogenases do not accumulate extracellularly in soil and are directly related to viability of intact cells. Hence, quantification has been recommended as a useful indicator of biological activity in soil (Schaffer, 1993).

Kavalappa (1989) recorded highest phosphate, dehydrogenase, urease and total biomass contents in the plots treated with FYM and chemical fertilizers. Kukreja *et al.* (1991) noticed that the total microbial biomass and dehydrogenase activity of soil were significantly increased in the plots receiving FYM application annually for 20 years.

Sriramachandrasekharan *et al.* (1997) observed that green manures have potentials to maintain higher dehydrogenase activity over farmyard manure, coir pith compost and paddy straw. Nature of the plant materials incorporated probably governs the type and number of microbial communities that can flourish under given conditions. Baruah and Mishra (1984) noted that dehydrogenase activity was related to soil organic carbon, total N and phosphorus. Higher dehydrogenase activity was negatively correlated with aerobic bacterial count.

Chandravanshi (1998) noticed that microbial biomass, C content and activities of dehydrogenase and phosphatase enzymes in the soil were increased by the application of FYM either alone or in combination with NPK fertilizers.

III. MATERIAL AND METHODS

The material and methods employed to achieve the objectives of the present investigation are presented in this chapter.

A survey was first conducted in Northern Dry Zone of Karnataka (Zone-3) with the help of Department of Agriculture, NGOs, KVKs, Extension Workers to identify the farmers practicing organic farming. Only such of those farmers who were practicing it for more than five years were selected and the information on type and quantity of organics used by them in major cropping systems was collected.

3.1 LOCATION OF STUDY AREA

The agro-climatic zone-3 is mainly spread on the black soils of North Karnataka and it is the largest of all the zones in the state. It has a total geographical area of 48.74 lakh hectares. It is primarily agrarian in character with about 76.60 per cent of its geographical area under cultivation.

The zone lies between 14⁰39' to 17⁰24' N latitude and between 74⁰34' to 77⁰04' E longitude. It is characterized by the lowest rainfall in Karnataka state with an average annual rainfall of 585 mm. It has the most fertile soils and is predominated by medium black soils followed by deep and shallow black soils.

3.2 SOIL SAMPLING

Soil samples from the selected 16 organic farms under different crops/cropping systems spread out in different taluks of Northern Dry Zone of Karnataka were collected during summer season of 2006. Soil samples from the neighbouring conventional farms under the same crop/cropping system were also collected and treated as control to understand the changes in soil properties as influenced by organic farming. However, in case of vineyards, since most of the farmers were practicing organic farming soils from only one available conventional farm was collected and referred to as control for all the three organic farms studied. The details are given in Table 1.

3.3 PREPARATION AND STORING OF THE SOIL SAMPLES

The collected soil samples were air dried in shade. The air dried samples were ground with wooden pestle and mortar and passed through 2 mm sieve to separate the coarse fragments (>2 mm). The sieved soil samples were stored in separate clean and dry containers and used for various physical and chemical analysis.

3.3.1 Physical properties

3.3.1.1 Particle size analysis

Particle size analysis of the soil sample was carried out by International Pipette method using 1N sodium hydroxide as a dispersing agent as described by Piper (1966).

3.3.1.2 Bulk density

Bulk density of the soil sample was determined by clod method (Black, 1965).

3.3.1.3 Maximum water holding capacity

Maximum water holding capacity of soil was determined by using Keen-Raczkowaski brass cup as described by Piper (1966).

3.3.1.4 Water stable aggregates

Water stability of the soil aggregates was measured by wet sieving method as outlined by Yoder (1936).

3.3.2 Chemical properties of soil

3.3.2.1 Soil reaction

Soil pH was determined in 1:2.5 soil:water suspension as described by Jackson (1967) using systronic digital 331 pH meter.

Table 1. Particulars of farmers practicing organic farming in Northern Dry Zone of Karnataka

Sl. No.	Code	Name and address of the farmer	No. of year of Organic farming	Organics used	
				Type	Quantity (t/ha/yr)
Cotton based cropping system (rainfed)					
1.	C ₁	Krishi Vigyan Kendra, Kurthkoti, Gadag	5	Vermicompost	1.20
				FYM	10.00
2.	C ₂	Sharanayya Hiremath Kurthkoti, Gadag	5	Vermicompost	1.50
				FYM	10.00
3.	C ₃	G. N. Patil Kurthkoti, Gadag	5	Vermicompost	1.25
				FYM	12.00
4.	C ₄	R. S. Patil Kurthkoti, Gadag	7	Vermicompost	3.00
				FYM	12.00
Kharif jowar based cropping system (rainfed)					
5.	K ₁	Prakash Dhanreddy Mallapur, Ron	6	Vermicompost	1.00
				FYM	10.00
6.	K ₂	Shivanna S. Arehunasi Mallapur, Ron	5	Vermicompost	1.00
				FYM	8.00
Rabi jowar based cropping system (rainfed)					
7.	R ₁	Gurunath R. Odugoudar Hulkoti, Gadag	5	Vermicompost	1.50
				FYM	12.00
8.	R ₂	Udaya Desai Rudrapura, Saundatti	7	FYM	15.00
9.	R ₃	Krishi Vigyan Kendra, Kurthkoti, Gadag	5	Vermicompost	1.00
				FYM	10.00

Table 1 (Contd.....)

Sl. No.	Code	Name and address of the farmer	No. of year of Organic farming	Organics used	
				Type	Quantity (t/ha/yr)
Sugarcane based cropping system (irrigated)					
10.	S ₁	Vishwanath Kabbur Kalloli, Gokak	5	Vermicompost	1.50
				FYM	10.00
11.	S ₂	M. B. Savantri Yalangav, Athani	5	Vermicompost	2.00
				FYM	15.00
12.	S ₃	M. D. Patil Arabhavi, Gokak	10	Vermicompost	1.50
				FYM	15.00
13.	S ₄	Chandrashekar Nimbaragi Mahalingapur, Mudhol	5	FYM	20.00
Vineyard system (irrigated)					
14.	V ₁	B. D. Desai Raibag, Raibag	5	Vermicompost	1.50
				FYM	12.00
15.	V ₂	M. D. Desai Raibag, Raibag	5	Vermicompost	1.00
				FYM	8.00
16.	V ₃	K. M. Patil Devanakatti, Raibag	6	Vermicompost	2.00
				FYM	12.00

3.3.2.2 Electrical conductivity

Electrical conductivity of the soil was determined in the 1:2.5 soil to water extract ratio (Jackson, 1967) by using systronic digital conductivity meter 304 and expressed as dS per m.

3.3.2.3 Organic carbon

Organic carbon was estimated by Walkley and Black wet oxidation method where organic matter in finely ground soil is oxidized by chromic acid by making use of heat of dilution of sulphuric acid for reaction (Jackson, 1967).

3.3.2.4 Cation exchange capacity

Cation exchange capacity of soils was determined by sodium saturation method (Black, 1965). Five grams of soil was shaken for five minutes with 33 ml of 1N sodium acetate of pH 8.2 in a stoppered centrifuge tubes. The supernatant solution was decanted and extraction was repeated for two more times. Then, the soil was washed with isopropyl alcohol in the same manner to remove excess of sodium adsorbed on the soil exchange complex. The adsorbed sodium was later replaced by ammonium (NH_4^+) by treating the soil with neutral normal ammonium acetate (pH 7.0). The displaced sodium was determined by flame photometer.

3.3.2.5 Available nitrogen

Available nitrogen was estimated by alkaline KMnO_4 method where the organic matter in soil was oxidized with hot alkaline KMnO_4 solution. The ammonia (NH_3) evolved during oxidation was distilled and trapped in boric acid mixed indicator solution. The amount of NH_3 trapped was estimated by titrating with standard acid (Subbaiah and Asija, 1956).

3.3.2.6 Available phosphorus

Available phosphorus was extracted with sodium bicarbonate (0.5 M) at pH 8.5 (Olsen's reagent) and the amount of P in the extract was estimated by chlorostannous reduced phosphomolybdate blue colour method using spectrophotometer at wave length of 660 nm (Jackson, 1973).

3.3.2.7 Available potassium

Available potassium was extracted with neutral normal ammonium acetate and determined using flame photometer (Jackson, 1967).

3.3.2.8 Available sulphur

Available sulphur in CaCl_2 (0.15%) extract was reacted with barium chloride crystals and the intensity of turbidity formed was measured using spectrophotometer at a wave length of 420 nm (Jackson, 1973).

3.3.2.9 Available micronutrients

The available iron, zinc, copper and manganese were determined by atomic absorption flame photometer after extracting the soil with DTPA (Diethylene Triamine Penta Acetic acid) as described by Lindsay and Norvell (1978) and expressed in ppm.

3.3.3 Biological properties of soil

3.3.3.1 Dehydrogenase activity

Five grams of soil sample and 0.2 g of CaCO_3 were taken in the test tubes and treated with 2 ml of 2 per cent 2, 3, 5 triphenyl Tetrazolium Chloride (TTC) and 2 ml of distilled water was added to create anaerobic condition. Sample was mixed thoroughly using glass rod and incubated at 37°C for 24 hours. The amount of triphenyl formzone (TPF) formed in soil was extracted using methanol and filtered through a funnel plugged with cotton. The soil was repeatedly washed with methanol to remove all reddish colour and diluted to 100 ml. The intensity of reddish colour was measured at 485 nm by taking methanol as blank. The amount of TPF formed was calculated using calibration graph prepared from TPF standard (Casida *et al.*, 1964).

3.4 CHEMICAL ANALYSIS OF ORGANIC MANURES

Well decomposed farmyard manure and vermicompost samples collected from organic farms were air dried and sieved through 2 mm sieve and then oven dried at 65°C for 24 hrs. The nitrogen in the oven dried sample was determined by Kjeldhal's method using digestion mixture consisting of CuSO_4 , K_2SO_4 , selenium powder and H_2SO_4 . One gram of sample was digested in a block digestion unit. After complete digestion, the samples were distilled using microkjeldhal unit and the liberated ammonia was trapped in boric acid containing mixed indicator and titrated against 0.01 N H_2SO_4 (Jackson, 1973). For analysis of phosphorus and potassium, the samples were digested using diacid mixture. The phosphorus in the digest was determined by vanadomolybdate yellow colour method in nitric acid medium. The intensity of colour was read at 420 nm wavelength using spectrophotometer (Jackson, 1973). The potassium in the digest was estimated by atomizing the digest in the flame photometer as described by Jackson (1973). The nitrogen, phosphorus and potassium content in the organic manures were expressed in percentage. Organic carbon in the samples was estimated by dry combustion method as described by Jackson (1973).

IV. EXPERIMENTAL RESULTS

The results of the study on changes in soil properties as influenced by organic farming in some selected organic farms in Northern dry zone of Karnataka (Zone-3) are presented in this chapter under the following heads.

- 4.1 Organic manures as a source of plant nutrients
- 4.2 Effect of organic farming on soil physical properties
- 4.3 Effect of organic farming on soil chemical properties
- 4.4 Effect of organic farming on availability of plant nutrients
- 4.5 Effect of organic farming on soil biological properties

4.1 ORGANIC MANURES AS A SOURCE OF PLANT NUTRIENTS

4.1.1 Analysis of organic manures used by organic farmers

The analytical results of the representative samples of organic manures used by farmers are presented in Table 2.

Among different vermicompost samples used in organic farming, vermicomposts used by C₁ and R₃ farmer recorded highest organic carbon (42.46%) and lowest was recorded in the sample of K₁ farm (32.68%). Farmyard manure (FYM) sample collected from K₂ farmer recorded highest organic carbon (30.15%) and the lowest was noticed in the sample of V₁ farm (24.60%).

The total N content in vermicompost samples varied from a low 2.04 per cent (C₂) to a high of 3.10 per cent (C₃). In FYM samples the total N content was lower than its content in vermicomposts. It ranged from 0.68 per cent in the sample of K₁ farmer to 1.20 per cent in the sample of K₂ farmer.

The total P content in vermicompost was highest in the sample of K₁ farm (0.78%) and was lowest (0.52%) in the sample of C₁ farm. The total P content in FYM samples varied from a high of 0.54 per cent (V₂) to a low of 0.30 per cent (C₁).

The total K content in vermicompost samples was around 1.0 per cent in most of the samples, the highest (1.17%) being in the sample used by C₃ farmer and lowest (0.98%) in sample of V₁ farmer. In FYM, total K content varied from 0.64 (S₂) to 1.02 (K₂) per cent.

The C:N ratio was narrow in vermicompost samples (13:1 in C₃ to 20:1 in C₁ sample) compared to FYM samples (25:1 in K₂ to 38:1 in C₁ sample).

4.1.2 Quantity of nutrients added to soil through organics under different cropping systems

The Table 3 shows the total quantity of nutrients added to the soil through organics under different cropping systems. The addition of nitrogen through organics in cotton based cropping system varied from 95.56 (C₁) to 162.60 (C₄) kg per ha per year, phosphorus from 36.24 (C₁) to 79.90 (C₄) kg per ha per year and potassium from 99.15 (C₂) to 144.60 (C₄) kg per ha per year.

In case of *kharif* jowar based cropping system, nitrogen content added through organics ranged from 89.30 to 118.70 kg per ha per year, phosphorus content from 47.20 to 55.80 kg per ha per year and potassium content from 93.40 to 94.00 kg per ha per year. Under *rabi* jowar based cropping system, nitrogen content added through organics ranged from 95.60 (R₃) to 123.90 (R₁) kg per ha per year, phosphorus content from 41.20 (R₃) to 58.80 (R₁) kg per ha per year and potassium content from 96.20 (R₃) to 109.50 (R₁) kg per ha per year.

Table 2. Analysis of organic manures used by farmers

Code	Sample	Organic carbon (%)	Nitrogen (%)	Phosphorus (%)	Potassium (%)	C:N ratio
Cotton based cropping system						
C ₁	Vermicompost	42.46	2.13	0.52	1.06	20:1
	FYM	26.98	0.70	0.30	0.98	38:1
C ₂	Vermicompost	36.56	2.04	0.56	1.01	18:1
	FYM	27.14	0.73	0.36	0.84	37:1
C ₃	Vermicompost	39.23	3.10	0.75	1.17	13:1
	FYM	29.32	0.85	0.40	1.01	34:1
C ₄	Vermicompost	41.92	2.18	0.63	1.10	19:1
	FYM	28.82	0.81	0.51	0.93	29:1
Kharif jowar based cropping system						
K ₁	Vermicompost	32.68	2.13	0.78	1.14	15:1
	FYM	24.82	0.68	0.48	0.82	36:1
K ₂	Vermicompost	36.79	2.27	0.64	1.24	16:1
	FYM	30.15	1.20	0.51	1.02	25:1
Rabi jowar based cropping system						
R ₁	Vermicompost	40.08	2.42	0.72	1.06	17:1
	FYM	28.19	0.73	0.40	0.78	38:1
R ₂	FYM	26.69	0.71	0.32	0.72	37:1
R ₃	Vermicompost	42.46	2.56	0.72	1.12	17:1
	FYM	25.10	0.70	0.34	0.85	35:1
Sugarcane based cropping system						
S ₁	Vermicompost	40.02	2.40	0.69	1.02	17:1
	FYM	27.32	0.75	0.38	0.72	36:1
S ₂	Vermicompost	34.26	2.21	0.61	0.99	15:1
	FYM	26.80	0.72	0.34	0.64	37:1
S ₃	Vermicompost	38.76	2.06	0.72	1.04	19:1
	FYM	28.34	0.78	0.52	0.96	36:1
S ₄	FYM	25.69	0.71	0.38	0.65	36:1
Vineyard system						
V ₁	Vermicompost	34.56	2.20	0.64	1.12	16:1
	FYM	24.60	0.71	0.46	0.80	34:1
V ₂	Vermicompost	40.90	2.10	0.61	0.98	19:1
	FYM	30.08	0.85	0.54	0.76	35:1
V ₃	Vermicompost	42.08	2.50	0.71	1.08	17:1
	FYM	24.64	0.84	0.50	0.71	29:1

Table 3. Quantity of nutrients added to soil through organics

Sl. No.	Code	Type of organic used	Quantity of nutrients added to soil		
			N	P	K
			------(kg/ha/yr)-----		
Cotton based cropping system					
1.	C ₁	Vermicompost	25.56	6.24	12.72
		FYM	70.00	30.00	98.00
		Total	95.56	36.24	110.72
2.	C ₂	Vermicompost	30.60	8.40	15.15
		FYM	73.00	36.00	84.00
		Total	103.60	44.40	99.15
3.	C ₃	Vermicompost	26.25	9.37	14.62
		FYM	102.00	48.00	121.20
		Total	128.25	57.37	135.82
4.	C ₄	Vermicompost	65.40	18.90	33.00
		FYM	97.20	61.20	111.60
		Total	162.60	79.90	144.60
Kharif jowar based cropping system					
5.	K ₁	Vermicompost	21.30	7.80	11.40
		FYM	68.00	48.00	82.40
		Total	89.30	55.80	93.40
6.	K ₂	Vermicompost	22.70	6.40	12.40
		FYM	96.00	40.80	81.60
		Total	118.70	47.20	94.00
Rabi jowar based cropping system					
7.	R ₁	Vermicompost	36.30	10.80	15.90
		FYM	87.60	48.00	93.60
		Total	123.90	58.80	109.50
8.	R₂	FYM	106.50	48.00	108.00
9.	R ₃	Vermicompost	25.60	7.20	11.20
		FYM	70.00	34.00	85.00
		Total	95.60	41.20	96.20

Table 3 (Contd....)

Sl. No.	Code	Type of organic used	Quantity of nutrients added to soil		
			N	P	K
			------(kg/ha/yr)-----		
Sugarcane based cropping system					
10.	S ₁	Vermicompost	36.00	10.35	15.30
		FYM	75.00	38.00	72.00
		Total	111.00	48.35	87.30
11.	S ₂	Vermicompost	44.20	12.20	19.80
		FYM	108.00	51.00	96.00
		Total	152.20	63.20	115.80
12.	S ₃	Vermicompost	30.90	10.80	15.60
		FYM	117.00	78.00	144.00
		Total	147.90	88.80	159.60
13.	S₄	FYM	142.00	76.00	130.00
Vineyard based cropping system					
14.	V ₁	Vermicompost	33.00	9.60	16.80
		FYM	85.20	55.20	96.04
		Total	118.20	64.80	112.80
15.	V ₂	Vermicompost	21.00	6.10	9.80
		FYM	68.00	43.20	60.80
		Total	89.00	49.30	70.60
16.	V ₃	Vermicompost	50.00	14.20	21.60
		FYM	100.80	60.00	85.20
		Total	150.80	74.20	106.80

Under sugarcane based cropping system, the nitrogen content added to soil through organics varied from 111.00 (S₁) to 152.20 (S₂) kg per ha per year and phosphorus content from 48.35 (S₁) to 88.80 (S₃) kg per ha per year and potassium content from 87.30 to 159.60 (S₃) kg per ha per year.

In case of vine yard system, addition of nitrogen through organics ranged from 89.00 (V₂) to 150.80 (V₃) kg per ha per year, phosphorus content varied from 49.30 (V₂) to 74.20 (V₃) kg per ha per year and potassium content ranged from 70.60 (V₂) to 112.80 (V₁) kg per ha per year.

4.2 EFFECT OF ORGANIC FARMING ON SOIL PHYSICAL PROPERTIES

4.2.1 Soil texture (Table 4)

Particle size distribution of cotton based cropping system of four organic farming soil samples revealed that the average sand, silt and clay content were 12.14, 22.50 and 63.33 per cent, respectively. While in the conventional farming, they were 12.32, 23.78 and 62.35 per cent, respectively.

In *kharif* jowar cropping system, soils of two organic farms on an average, recorded sand, silt and clay content of 12.61, 23.16 and 63.67 per cent, respectively, while in the conventional farming, they were 13.17, 24.45 and 62.39 per cent, respectively.

An average of 13.29, 22.76 and 61.60 per cent of sand, silt clay contents were observed in soils of *rabi* jowar cropping system under organic farming. Soils of conventional farming under same cropping system contained 12.70, 24.20 and 60.37 per cent of sand, silt clay, respectively.

In sugarcane based cropping system, the average of four organic farm soils accounted for sand, silt and clay content of 11.57, 23.51 and 63.66 per cent, respectively as compared to 11.60, 24.79 and 61.84 per cent, respectively in soils of conventional farms.

In vineyard system, the average of sand, silt and clay content of soils of organic farms was 10.15, 20.23 and 68.70 per cent, respectively. While in the conventional farming, they were 11.96, 20.63 and 66.72 per cent, respectively.

All the soils under both organic and conventional farming were clay in texture, irrespective of cropping system followed.

4.2.2 Bulk density

The data on the effect of organic farming on bulk density of soils under different cropping systems is given in Table 5, 6, 7 and 8.

Under cotton based cropping system (Table 5), on an average, the soils of four farms showed a reduction in bulk density of surface soil from 1.42 Mg m⁻³ in conventional farms to 1.31 Mg m⁻³ in organic farms and from 1.44 to 1.35 Mg m⁻³ in subsurface soil. The average decrease in bulk density was to the extent of 7.75 per cent and 6.25 per cent in surface and subsurface soil, respectively. Among the soils of four organic farms, the highest decrease in bulk density was observed in soils of C₄ farmer (9.40%) followed by C₂ farmer (7.30%) and lowest reduction was observed in soils of C₁ farmer (3.60%).

In *kharif* jowar based cropping system (Table 6), the average of two soils indicated a reduction in bulk density from 1.40 to 1.25 Mg m⁻³ and 1.44 to 1.30 Mg m⁻³ in surface and subsurface soils, respectively. The overall reduction in bulk density of soil due to organic farming worked to 10.7 per cent in surface soil and 9.72 per cent in subsurface soil. The highest decrease in bulk density of soil was observed in soils of K₁ farmer (10.65%).

In *rabi* jowar based cropping system (Table 6), the average of three soils indicated a decrease in bulk density in both surface and subsurface soils (1.44 to 1.32 Mg m⁻³ and 1.48 to 1.34 Mg m⁻³, respectively). Among three organic farms, soils of R₁ farm showed a highest reduction in bulk density (12.00%).

Table 4. Particle size distribution and texture of soils

Code	Depth (cm)	Organic farming				Conventional farming			
		Sand (%)	Silt (%)	Clay (%)	Textural class	Sand (%)	Silt (%)	Clay (%)	Textural class
Cotton based cropping system									
C ₁	0-15	12.79	23.03	63.30	Clay	13.70	21.40	61.42	Clay
	15-30	9.89	22.81	65.21	Clay	15.01	21.05	63.21	Clay
Mean		11.34	22.92	64.25		14.35	21.22	62.31	
C ₂	0-15	10.54	29.01	59.12	Clay	10.59	30.15	58.06	Clay
	15-30	13.72	23.19	61.36	Clay	12.68	26.28	59.95	Clay
Mean		12.13	26.10	60.24		11.63	28.21	59.00	
C ₃	0-15	11.24	21.01	64.28	Clay	12.12	23.04	62.18	Clay
	15-30	10.18	20.64	67.05	Clay	11.06	22.61	64.13	Clay
Mean		10.21	20.82	65.66		11.59	22.82	63.15	
C ₄	0-15	13.92	20.40	61.48	Clay	11.98	24.04	63.92	Clay
	15-30	14.86	19.92	64.89	Clay	11.46	21.68	65.84	Clay
Mean		14.39	20.16	63.18		11.72	22.86	64.88	
Average mean		12.14	22.50	63.33		12.32	23.78	62.35	
Kharif jowar based cropping system									
K ₁	0-15	13.33	24.10	62.10	Clay	13.40	25.39	61.05	Clay
	15-30	12.12	22.35	65.18	Clay	12.72	23.03	63.13	Clay
Mean		12.72	23.22	63.64		13.06	24.21	62.09	
K ₂	0-15	13.30	24.15	62.16	Clay	13.40	25.64	62.05	Clay
	15-30	11.71	22.05	65.24	Clay	12.76	23.73	63.34	Clay
Mean		12.50	23.10	63.70		13.08	24.68	62.69	
Average mean		12.61	23.16	63.67		13.17	24.45	62.39	

Table 4 (Contd.....)

Code	Depth (cm)	Organic farming				Conventional farming			
		Sand (%)	Silt (%)	Clay (%)	Textural class	Sand (%)	Silt (%)	Clay (%)	Textural class
Rabi jowar based cropping system									
R ₁	0-15	10.62	26.85	58.40	Clay	10.69	27.96	57.26	Clay
	15-30	13.86	21.05	62.91	Clay	14.82	23.07	60.09	Clay
Mean		12.24	23.95	60.65		12.75	25.51	58.67	
R ₂	0-15	13.71	21.40	61.42	Clay	12.14	26.82	60.3	Clay
	15-30	15.01	21.05	62.21	Clay	10.89	24.60	62.30	Clay
Mean		14.36	21.22	61.81		11.51	25.71	61.30	
R ₃	0-15	13.72	23.19	61.36	Clay	13.65	22.62	60.32	Clay
	15-30	12.79	23.03	63.30	Clay	14.01	20.09	61.98	Clay
Mean		13.25	23.11	62.33		13.83	21.35	61.15	
Average mean		13.29	22.76	61.60		12.70	24.20	60.37	
Sugarcane based cropping system									
S ₁	0-15	11.21	24.14	61.63	Clay	11.05	24.62	61.18	Clay
	15-30	11.47	22.91	65.21	Clay	12.13	24.30	62.96	Clay
Mean		11.34	23.52	63.42		11.59	24.46	62.07	
S ₂	0-15	11.34	23.04	64.42	Clay	11.64	24.96	62.10	Clay
	15-30	11.20	18.61	69.81	Clay	11.36	20.19	64.61	Clay
Mean		11.27	20.82	67.11		11.50	22.57	63.35	
S ₃	0-15	10.35	28.50	59.31	Clay	10.68	29.10	59.01	Clay
	15-30	11.85	24.62	62.30	Clay	11.92	26.32	61.12	Clay
Mean		11.10	26.56	60.80		11.30	27.71	60.06	
S ₄	0-15	12.33	24.30	62.40	Clay	12.34	24.68	60.72	Clay
	15-30	12.79	22.00	64.18	Clay	11.68	24.13	63.06	Clay
Mean		12.56	23.15	63.29		12.01	24.40	61.89	
Average mean		11.57	23.51	63.66		11.60	24.79	61.84	

Table 4 (Contd.....)

Code	Depth (cm)	Organic farming				Conventional farming			
		Sand (%)	Silt (%)	Clay (%)	Textural class	Sand (%)	Silt (%)	Clay (%)	Textural class
Vineyard system									
V ₁	0-15	10.17	22.61	65.41	Clay	12.12	22.35	65.18	Clay
	15-30	10.93	21.46	67.16	Clay	11.80	18.91	68.26	Clay
Mean		10.55	22.03	66.28		11.96	20.63	66.72	
V ₂	0-15	9.90	18.44	70.91	Clay	12.12	22.35	65.18	Clay
	15-30	8.96	18.13	72.15	Clay	11.80	18.91	68.26	Clay
Mean		9.43	18.28	71.53		11.96	20.63	66.72	
V ₃	0-15	11.77	22.36	65.41	Clay	12.12	22.35	65.18	Clay
	15-30	9.15	18.40	71.20	Clay	11.80	18.91	68.26	Clay
Mean		10.46	20.38	68.30		11.96	20.63	66.72	
Average mean		10.15	20.23	68.70		11.96	20.63	66.72	

Table 5. Physical properties of soils under cotton based cropping system

Code	Depth (cm)	Bulk density (Mg/m ³)			Maximum water holding capacity (%)			Water stable aggregates (%) (>0.25 mm)		
		Organic farming	Conventional farming	% decrease over conventional farming	Organic farming	Conventional farming	% increase over conventional farming	Organic farming	Conventional farming	% increase over conventional farming
C ₁	0-15	1.34	1.40	4.30	62.44	60.64	2.97	78.50	76.10	3.15
	15-30	1.36	1.41	3.55	69.40	64.40	7.80	78.40	75.80	3.34
	Mean	1.35	1.40	3.60	65.92	62.52	5.44	78.45	75.95	3.30
C ₂	0-15	1.38	1.50	8.00	63.90	61.80	3.44	82.20	79.10	3.92
	15-30	1.42	1.52	6.60	67.23	64.91	3.60	79.90	76.70	4.20
	Mean	1.40	1.51	7.30	65.56	63.35	3.50	81.05	77.90	4.04
C ₃	0-15	1.31	1.40	6.43	70.06	64.40	8.80	77.94	75.40	3.40
	15-30	1.34	1.43	6.30	75.95	69.75	8.90	75.04	72.20	3.93
	Mean	1.33	1.42	6.40	73.00	67.07	8.84	76.49	73.60	3.64
C ₄	0-15	1.23	1.37	10.20	69.22	66.12	4.70	85.80	81.20	5.66
	15-30	1.28	1.40	8.60	70.01	66.81	4.80	82.70	78.00	6.02
	Mean	1.26	1.39	9.40	69.61	66.46	4.74	84.25	79.60	5.84
Average of C ₁ – C ₄	0-15	1.31	1.42	7.75	66.40	63.24	5.00	81.11	77.95	4.05
	15-30	1.35	1.44	6.25	70.64	66.46	6.30	79.01	75.67	4.41
	Mean	1.33	1.43	7.00	68.52	64.85	5.65	80.06	76.81	4.23

Table 6. Physical properties of soils under jowar based cropping system

Code	Depth (cm)	Bulk density (Mg/m ³)			Maximum water holding capacity (%)			Water stable aggregates (%) (>0.25 mm)		
		Organic farming	Conventional farming	% decrease over conventional farming	Organic farming	Conventional farming	% increase over conventional farming	Organic farming	Conventional farming	% increase over conventional farming
<i>Kharif jowar based cropping system</i>										
K ₁	0-15	1.23	1.39	11.51	69.92	64.82	7.87	86.60	82.60	4.59
	15-30	1.29	1.43	9.79	70.13	65.50	7.06	84.20	80.30	8.86
	Mean	1.26	1.41	10.65	70.02	65.16	7.45	84.40	81.50	4.72
K ₂	0-15	1.28	1.42	9.86	70.13	65.35	7.31	81.70	78.30	4.34
	15-30	1.32	1.46	9.59	70.91	69.15	6.88	81.00	77.40	4.65
	Mean	1.30	1.44	9.72	70.02	67.25	7.09	81.40	77.80	4.50
Average of K ₁ – K ₂	0-15	1.25	1.40	10.70	70.02	65.08	7.60	84.10	80.50	4.47
	15-30	1.30	1.44	9.72	70.52	67.32	4.75	82.60	78.80	4.82
	Mean	1.27	1.42	10.60	70.27	66.20	6.10	83.35	79.65	4.64
<i>Rabi jowar based cropping system</i>										
R ₁	0-15	1.24	1.41	12.05	69.65	67.05	3.88	79.10	76.80	2.99
	15-30	1.26	1.44	12.50	71.91	69.71	3.16	76.70	74.90	2.40
	Mean	1.25	1.43	12.00	70.76	68.38	3.51	77.90	75.85	2.70
R ₂	0-15	1.36	1.48	8.11	66.89	64.39	3.88	79.30	76.10	4.20
	15-30	1.38	1.52	9.20	69.86	67.46	3.56	78.00	75.80	2.90
	Mean	1.37	1.50	8.7	68.37	65.92	3.72	78.65	75.95	3.55
R ₃	0-15	1.36	1.44	5.58	65.78	62.18	3.79	75.40	73.10	3.15
	15-30	1.39	1.50	7.33	68.38	64.48	6.05	74.80	72.70	2.89
	Mean	1.37	1.47	6.50	67.08	63.33	5.92	75.10	72.90	3.01
Average of R ₁ – R ₃	0-15	1.32	1.44	8.33	67.30	64.54	4.30	77.93	75.33	3.45
	15-30	1.34	1.48	9.45	70.05	67.21	4.22	76.50	74.46	2.74
	Mean	1.33	1.46	8.90	68.67	65.87	4.25	77.21	74.89	3.10

In sugarcane based cropping system (Table 7), the average decrease in bulk density due to organic farming was from 1.34 to 1.27 Mg m⁻³ in surface and 1.42 to 1.32 Mg m⁻³ in subsurface soils. The highest decrease in bulk density was observed in soils of S₃ farmer (9.22%) followed by S₁ farmer (6.70%) and lowest was noticed in soils of S₂ farmer (3.10%). The overall reduction in bulk density of sugar cane soils under organic farming worked out to 6.52 per cent over conventional farming.

In Vineyard system (Table 8), the average of three organic farms indicated a reduction in bulk density of soil from 1.48 to 1.39 Mg m⁻³ and 1.59 to 1.42 Mg m⁻³ in surface and subsurface soils, respectively. The highest and lowest reduction in bulk density of soil was recorded in soils of V₃ farmer (10.45%) and V₁ farmer (6.20%), respectively. The average reduction in bulk density was more in subsurface soil (9.40%) than in surface soil (6.10%).

4.2.3 Maximum water holding capacity

The results on maximum water holding capacity (MWHC) of soils as influenced by organic farming are presented in Table 5, 6, 7 and 8.

The results from cotton based cropping system (Table 5) showed that there was an increase in MWHC due to organic farming. The soils of C₃ farmer showed highest increase in MWHC (8.84%), followed by soils of C₁ farmer (5.44%) and lowest increase was observed in soils of C₂ farmer (3.50%). On an average, MWHC increased from 64.85 per cent in conventional farming to 68.52 per cent in organic farming, accounting for an increase by 5.65 per cent.

In *kharif* jowar based cropping system (Table 6), the average of two soils indicated an increase in MWHC from 65.08 to 70.02 per cent and 67.32 to 70.52 per cent in surface and subsurface soils, respectively. The average increase in MWHC due to organic farming was 7.60 per cent in surface soil and 4.75 per cent in subsurface soil. The highest increase in MWHC was observed in soils of K₁ farmer (7.45%).

In *rabi* jowar cropping system, the average of three soils showed an increase in MWHC of surface soil from 64.54 per cent in conventional farm to 67.30 per cent in organic farm and from 67.21 to 70.05 per cent in subsurface soil. Among three soils, the highest increase in MWHC over conventional farming was observed in the soils of R₃ farmer (5.92%) and lowest increase was in the soils of R₁ farmer (3.51%).

In sugarcane based cropping system (Table 7), an increase in MWHC due to organic farming practice was observed in all the farms. The average increase in MWHC of soils of organic farms over conventional farms was 4.70 and 3.50 per cent in surface and subsurface soils, respectively. The highest increase in MWHC was noticed in the soils of S₂ farmer (6.50%) and lowest was in soils of S₁ farmer (2.28%). Surface soils showed higher increase in MWHC due to organic farming than subsurface soils.

In vineyard system (Table 8) the MWHC of soils on an average, was 69.89 per cent and 71.30 per cent in surface and subsurface soils, respectively under organic farming compared to 66.94 and 66.73 per cent in conventional farming. The average increase in MWHC worked out to 7.62 per cent in surface soil and 6.84 per cent in subsurface soil. The soils from V₂ farmer recorded highest increase in MWHC (10.50%) while the lowest increase was in soils of V₃ farmer (3.45%).

4.2.4 Water stable aggregates

The results on water stable aggregates (>0.25 mm) are presented in Table 5, 6, 7 and 8.

In cotton based cropping system (Table 5), water stable aggregates, on an average increased from 77.95 to 81.11 per cent and 75.67 to 79.01 per cent in conventional farm to organic farms in surface and subsurface soils, respectively. Among the soils of four organic farms, the highest increase in water stable aggregates was observed in soils of C₄ farmer (5.84%) followed by C₂ farmer (4.04%) and lowest increase was observed in soils of C₁ farmer (3.30%). The water stable aggregates were more in surface soils than in subsurface soil. However, their per cent increase due to organic farming was more in subsurface soil (4.41%) than surface soil (4.05%).

Table 7. Physical properties of soils under sugarcane based cropping system

Code	Depth (cm)	Bulk density (Mg/m ³)			Maximum water holding capacity (%)			Water stable aggregates (%) (>0.25 mm)		
		Organic farming	Conventional farming	% decrease over conventional farming	Organic farming	Conventional farming	% increase over conventional farming	Organic farming	Conventional farming	% increase over conventional farming
S ₁	0-15	1.23	1.27	3.15	71.61	69.81	2.58	75.40	73.20	3.01
	15-30	1.30	1.43	9.10	71.68	70.28	1.99	73.60	72.10	2.70
	Mean	1.26	1.35	6.70	71.64	70.04	2.28	74.50	72.65	2.54
S ₂	0-15	1.24	1.27	2.36	66.90	64.62	8.20	86.70	84.30	2.85
	15-30	1.27	1.33	4.51	70.10	66.93	4.78	84.00	81.40	3.20
	Mean	1.26	1.30	3.10	70.02	65.77	6.50	85.30	82.85	3.00
S ₃	0-15	1.26	1.38	8.70	72.90	69.90	4.29	91.70	88.90	3.15
	15-30	1.30	1.43	9.09	68.20	66.30	2.87	89.80	87.30	2.98
	Mean	1.28	1.41	9.22	70.50	68.10	3.60	90.80	88.10	3.10
S ₄	0-15	1.33	1.43	6.99	69.59	64.10	8.56	78.10	75.90	2.90
	15-30	1.41	1.48	4.73	70.13	67.12	4.48	76.90	74.80	2.81
	Mean	1.37	1.46	6.16	69.86	65.61	4.43	77.50	75.33	2.85
Average of S ₁ - S ₄	0-15	1.27	1.34	6.00	70.25	67.10	4.7	82.90	80.60	2.85
	15-30	1.32	1.42	7.04	70.02	67.65	3.5	81.10	78.90	2.80
	Mean	1.29	1.38	6.52	70.13	67.37	4.1	82.00	79.70	2.90

Table 8. Physical properties of soils under vineyard system

Code	Depth (cm)	Bulk density (Mg/m ³)			Maximum water holding capacity (%)			Water stable aggregates (>0.25 mm) (%)		
		Organic farming	Conventional farming	% decrease over conventional farming	Organic farming	Conventional farming	% increase over conventional farming	Organic farming	Conventional farming	% increase over conventional farming
V ₁	0-15	1.42	1.48	4.05	69.92	64.94	7.67	81.70	80.00	2.13
	15-30	1.46	1.59	8.17	70.28	66.53	5.64	78.80	77.30	1.94
	Mean	1.44	1.53	6.20	70.10	65.73	6.64	80.25	78.65	2.03
V ₂	0-15	1.38	1.48	6.75	71.48	64.94	10.07	84.20	80.00	5.25
	15-30	1.42	1.59	10.69	73.91	66.53	11.09	81.40	77.30	5.30
	Mean	1.40	1.53	8.72	72.69	65.73	10.50	82.80	78.65	5.28
V ₃	0-15	1.36	1.48	8.10	68.28	64.94	5.14	85.10	80.00	6.37
	15-30	1.39	1.59	12.57	69.72	66.53	4.79	82.40	77.30	6.59
	Mean	1.37	1.53	10.45	68.00	65.73	3.45	83.75	78.65	6.48
Average of V ₁ - V ₃	0-15	1.39	1.48	6.10	69.89	64.94	7.62	83.70	80.70	4.60
	15-30	1.42	1.59	9.40	71.30	66.73	6.84	80.86	77.30	4.70
	Mean	1.41	1.53	7.80	70.59	65.73	7.40	82.3	78.65	4.60

In *kharif* jowar based cropping system (Table 6), the average of two soils indicated increase in water stable aggregates from 80.50 per cent in conventional farm to 84.10 per cent in organic farm in surface soil and from 78.80 to 82.60 per cent in subsurface soils. The overall increase in water stable aggregates due to organic farming was 4.64 per cent.

The soils from *rabi* jowar based cropping system (Table 6) also showed an increase in water stable aggregates due to organic farming (75.33 to 77.93% and 74.46 to 76.50% in surface and subsurface soils, respectively). Among the three soils, the highest increase in water stable aggregates was observed in soil of R₂ farmer (3.55%) and lowest was in soils of R₁ farmer (2.70%).

The average increase in water stable aggregates due to organic farming in sugarcane based cropping system (Table 7) was 2.85 and 2.80 per cent in surface and subsurface soils, respectively. The highest increase in water stable aggregates was recorded in soils of S₃ farmer (3.10%) and lowest was in soils of S₁ farmer (2.54%). The mean of four soils showed an increase in water stable aggregates from 79.7 per cent in conventional farming to 82.0 per cent in organic farming.

Water stable aggregates of vine yards (Table 8), on an average increased from 80.70 to 83.70 per cent and 77.30 to 80.86 per cent in surface and subsurface soils, respectively due to organic farming. The highest and lowest increase in water stable aggregates due to organic farming was recorded in soils of V₃ farmer (6.48%) and V₁ farmer (2.03%), respectively. The per cent increase in water stable aggregates in soil of each farm was almost same in surface and subsurface soil.

4.3 EFFECT OF ORGANIC FARMING ON SOIL CHEMICAL PROPERTIES

4.3.1 Soil reaction (pH) and electrical conductivity (EC)

The data on soil pH and EC in different cropping systems is presented in Table 9. All the soils of both conventional and organic farms were alkaline in reaction and non-saline. The results revealed that there was a slight decrease in both soil pH and EC due to organic farming practice. The overall mean of the soils showed that the soil pH decreased from 8.50 to 8.43 in cotton based cropping system 8.31 to 8.21 in *kharif* jowar based cropping system, 8.35 to 8.28 in *rabi* jowar based cropping system, 8.48 to 8.37 in sugarcane based cropping system and 8.65 to 8.33 in vine yard system.

The EC of soils decreased slightly by 0.04 dS m⁻¹ in cotton based cropping system, 0.07 dS m⁻¹ in *rabi* jowar based cropping system, 0.08 dS m⁻¹ in sugarcane based cropping system and by 0.12 dS m⁻¹ in vineyard system.

In cotton based cropping system the mean soil pH and EC values ranged from 8.34 to 8.60 and 0.22 to 0.28 dS m⁻¹ respectively under conventional farming and 8.28 to 8.60 and 0.19 to 0.24 dS m⁻¹, respectively under organic farming. The corresponding values for soils of jowar based cropping systems were 8.29 to 8.48 and 0.20 to 0.35 dS m⁻¹ in conventional and 8.17 to 8.38 and 0.15 to 0.27 dS m⁻¹ in organic farming.

In soils of sugarcane cropping system, the mean soil pH varied from 8.27 to 8.58 and from 8.14 to 8.47 under conventional and organic farms, respectively. The mean EC values of soils varied from 0.28 to 0.44 dS m⁻¹ in conventional farms and 0.18 to 0.31 dS m⁻¹ in organic farms. In the soils of vine yard, conventional and organic farms recorded overall mean soil pH values of 8.65 and 8.33, respectively. The corresponding soil EC values were 0.38 and 0.26 dS m⁻¹.

4.3.2 Organic carbon

The organic carbon content of soils under different cropping systems is presented in Tables 10, 11, 12 and 13.

Table 9. Soil pH and EC values in different cropping systems

Code	Depth (cm)	pH		Electrical conductivity (dS/m)	
		Organic farming	Conventional farming	Organic farming	Conventional farming
Cotton based cropping system					
C ₁	0-15	8.24	8.31	0.18	0.22
	15-30	8.32	8.38	0.21	0.23
	Mean	8.28	8.34	0.19	0.23
C ₂	0-15	8.32	8.39	0.21	0.22
	15-30	8.35	8.44	0.17	0.23
	Mean	8.33	8.41	0.19	0.23
C ₃	0-15	8.56	8.60	0.18	0.21
	15-30	8.64	8.67	0.21	0.22
	Mean	8.60	8.63	0.20	0.22
C ₄	0-15	8.47	8.58	0.29	0.28
	15-30	8.56	8.63	0.19	0.29
	Mean	8.51	8.60	0.24	0.28
Average of C ₁ – C ₄	0-15	8.40	8.47	0.21	0.23
	15-30	8.46	8.53	0.19	0.24
	Mean	8.43	8.50	0.20	0.24
Kharif jowar based cropping system					
K ₁	0-15	8.08	8.19	0.28	0.29
	15-30	8.38	8.47	0.21	0.24
	Mean	8.23	8.33	0.25	0.27
K ₂	0-15	8.15	8.27	0.19	0.21
	15-30	8.20	8.32	0.22	0.24
	Mean	8.17	8.29	0.21	0.23
Average of K ₁ – K ₂	0-15	8.11	8.23	0.23	0.25
	15-30	8.31	8.40	0.21	0.24
	Mean	8.21	8.31	0.22	0.25

Table 9 (Contd.....)

Code	Depth (cm)	pH		Electrical conductivity (dS/m)	
		Organic farming	Conventional farming	Organic farming	Conventional farming
Rabi-jowar based cropping system					
R ₁	0-15	8.12	8.15	0.28	0.31
	15-30	8.25	8.29	0.26	0.39
	Mean	8.18	8.22	0.27	0.35
R ₂	0-15	8.34	8.40	0.12	0.18
	15-30	8.42	8.32	0.17	0.21
	Mean	8.38	8.36	0.15	0.20
R ₃	0-15	8.22	8.44	0.28	0.33
	15-30	8.34	8.52	0.24	0.36
	Mean	8.28	8.48	0.26	0.35
Average of R ₁ – R ₃	0-15	8.22	8.33	0.22	0.27
	15-30	8.34	8.38	0.23	0.32
	Mean	8.28	8.35	0.22	0.29
Sugarcane based cropping system					
S ₁	0-15	8.37	8.43	0.30	0.31
	15-30	8.51	8.58	0.32	0.34
	Mean	8.44	8.50	0.31	0.32
S ₂	0-15	8.03	8.16	0.12	0.26
	15-30	8.25	8.38	0.23	0.31
	Mean	8.14	8.27	0.18	0.29
S ₃	0-15	8.35	8.51	0.25	0.33
	15-30	8.54	8.62	0.39	0.54
	Mean	8.44	8.56	0.32	0.44
S ₄	0-15	8.42	8.54	0.21	0.26
	15-30	8.53	8.62	0.24	0.30
	Mean	8.47	8.58	0.23	0.28
Average of S ₁ – S ₄	0-15	8.29	8.41	0.22	0.29
	15-30	8.45	8.55	0.29	0.37
	Mean	8.37	8.48	0.25	0.33

Table 9 (Contd.....)

Code	Depth (cm)	pH		Electrical conductivity (dS/m)	
		Organic farming	Conventional farming	Organic farming	Conventional farming
Vineyard system					
V ₁	0-15	8.09	8.42	0.26	0.28
	15-30	8.31	8.88	0.22	0.49
	Mean	8.20	8.65	0.24	0.38
V ₂	0-15	8.45	8.42	0.27	0.28
	15-30	8.58	8.88	0.34	0.49
	Mean	8.52	8.65	0.30	0.38
V ₃	0-15	8.26	8.42	0.26	0.28
	15-30	8.34	8.88	0.32	0.49
	Mean	8.30	8.65	0.29	0.38
Average of V ₁ – V ₃	0-15	8.26	8.42	0.26	0.28
	15-30	8.41	8.88	0.29	0.49
	Mean	8.33	8.65	0.26	0.38

Table 10. Organic carbon and cation exchange capacity of soils under cotton based cropping system

Code	Depth (cm)	Organic carbon (%)			Cation exchange capacity (cmol (p+)/kg)		
		Organic farming	Conventional farming	% increase over conventional farming	Organic farming	Conventional farming	% increase over conventional farming
C ₁	0-15	0.71	0.59	20.34	56.51	53.16	6.30
	15-30	0.63	0.52	21.15	54.77	52.40	4.50
	Mean	0.67	0.55	20.72	55.64	52.78	5.40
C ₂	0-15	0.76	0.65	16.92	71.73	66.16	8.40
	15-30	0.70	0.62	12.90	69.56	65.38	6.41
	Mean	0.73	0.64	14.10	70.64	65.77	7.40
C ₃	0-15	0.64	0.53	20.75	63.03	58.77	7.24
	15-30	0.58	0.42	38.10	60.08	55.38	8.50
	Mean	0.61	0.48	27.10	61.55	57.07	7.80
C ₄	0-15	0.83	0.59	40.67	58.25	53.03	9.84
	15-30	0.79	0.52	51.92	58.25	52.17	10.65
	Mean	0.81	0.55	47.30	57.99	52.6	10.20
Average of C ₁ – C ₄	0-15	0.73	0.59	23.72	62.38	57.88	7.80
	15-30	0.67	0.52	28.84	60.53	56.33	7.45
	Mean	0.70	0.55	27.30	61.45	57.10	7.61

Table 11. Organic carbon and cation exchange capacity of soils under jowar based cropping system

Code	Depth (cm)	Organic carbon (%)			Cation exchange capacity (cmol (p+)/kg)		
		Organic farming	Conventional farming	% increase over conventional farming	Organic farming	Conventional farming	% increase over conventional farming
<i>Kharif-jowar based cropping system</i>							
K ₁	0-15	0.80	0.48	66.67	65.29	58.86	10.90
	15-30	0.69	0.39	76.92	64.08	57.82	10.80
	Mean	0.75	0.44	70.45	64.68	58.34	10.90
K ₂	0-15	0.72	0.51	71.18	65.73	59.64	10.20
	15-30	0.60	0.42	42.86	63.73	58.34	9.20
	Mean	0.66	0.47	40.42	64.73	58.99	9.70
Average of K ₁ – K ₂	0-15	0.76	0.49	55.10	65.51	59.25	10.60
	15-30	0.64	0.40	60.00	63.90	58.08	10.00
	Mean	0.70	0.44	59.10	64.70	58.66	10.30
<i>Rabi-jowar based cropping system</i>							
R ₁	0-15	0.76	0.40	90.00	63.47	59.12	7.35
	15-30	0.68	0.34	100.00	61.21	57.38	6.70
	Mean	0.72	0.37	94.60	62.34	58.25	7.02
R ₂	0-15	0.72	0.35	105.71	63.21	57.64	9.70
	15-30	0.66	0.33	102.74	62.08	56.08	10.70
	Mean	0.69	0.34	102.94	62.64	56.86	10.20
R ₃	0-15	0.68	0.46	47.82	62.16	58.60	6.10
	15-30	0.67	0.41	63.41	60.86	57.21	6.40
	Mean	0.68	0.44	55.61	61.51	57.90	6.23
Average of R ₁ – R ₃	0-15	0.72	0.40	80.00	62.94	58.45	7.70
	15-30	0.67	0.36	86.10	61.38	56.89	7.90
	Mean	0.69	0.38	81.60	62.16	57.67	7.80

Table 12. Organic carbon and cation exchange capacity of soils under sugarcane based cropping system

Code	Depth (cm)	Organic carbon (%)			Cation exchange capacity (cmol (p+)/kg)		
		Organic farming	Conventional farming	% increase over conventional farming	Organic farming	Conventional farming	% increase over conventional farming
S ₁	0-15	0.83	0.66	25.75	74.08	66.34	11.70
	15-30	0.79	0.60	31.66	72.42	65.90	9.90
	Mean	0.81	0.63	28.70	73.25	66.12	10.80
S ₂	0-15	0.75	0.54	38.88	66.77	63.56	5.05
	15-30	0.71	0.52	36.54	65.99	62.16	5.20
	Mean	0.73	0.53	37.71	66.38	62.86	5.60
S ₃	0-15	0.82	0.56	46.43	68.86	61.73	11.50
	15-30	0.74	0.51	45.09	68.08	60.86	11.90
	Mean	0.78	0.54	45.76	68.47	61.29	11.70
S ₄	0-15	0.69	0.55	25.45	66.69	60.86	9.80
	15-30	0.65	0.53	22.64	65.03	59.12	10.00
	Mean	0.67	0.54	24.05	65.86	59.99	9.90
Average of S ₁ – S ₄	0-15	0.77	0.58	32.75	69.10	63.12	9.50
	15-30	0.72	0.54	33.30	67.88	62.01	9.40
	Mean	0.74	0.56	33.00	68.49	62.56	9.50

Table 13. Organic carbon and cation exchange capacity of soils under vineyard system

Code	Depth (cm)	Organic carbon (%)			Cation exchange capacity (cmol (p+)/kg)		
		Organic farming	Conventional farming	% increase over conventional farming	Organic farming	Conventional farming	% increase over conventional farming
V ₁	0-15	0.96	0.79	21.52	60.43	53.73	12.50
	15-30	0.88	0.75	17.33	59.21	53.03	11.60
	Mean	0.92	0.77	19.42	59.82	53.38	12.10
V ₂	0-15	0.97	0.79	22.78	59.47	53.73	10.70
	15-30	0.91	0.75	21.33	58.43	53.03	10.20
	Mean	0.94	0.77	22.08	58.95	53.38	10.40
V ₃	0-15	1.12	0.79	41.77	63.47	53.73	18.10
	15-30	0.95	0.75	26.67	61.03	53.03	15.10
	Mean	1.03	0.77	33.80	62.25	53.38	16.60
Average of V ₁ – V ₃	0-15	1.02	0.79	29.10	61.12	53.73	5.90
	15-30	0.91	0.75	21.30	59.55	53.03	12.30
	Mean	0.96	0.77	24.70	60.33	55.38	8.90

In cotton based cropping system (Table 10), on an average, the organic carbon content increased from 0.59 per cent in conventional farm to 0.73 per cent in organic farm in surface soil and from 0.52 to 0.67 per cent in subsurface soil accounting for an increase of 23.72 per cent in surface soil and 28.84 per cent in subsurface soil. Among the soils of four organic farms, the highest increase in organic carbon content was observed in soils of C₄ farmer (47.30%), followed by C₃ farmer (27.10%) and lowest increase was observed in soils of C₂ farmer (14.10%).

In *kharif* jowar based cropping system (Table 11), the average of two farms indicated an increase of organic carbon of soil due to organic farming from 0.49 to 0.76 per cent and 0.40 to 0.64 per cent in surface and subsurface soils, respectively. The average increase in surface soil was 55.10 per cent and subsurface was 60.00 per cent. The soils of K₁ recorded higher increase in organic carbon (70.45%) than K₂ farmer (40.42%).

In *rabi* jowar based cropping system (Table 11), the average of three soils showed an increase in organic carbon content in both surface and subsurface soils (0.40 to 0.72% and 0.36 to 0.67%, respectively). The surface soils contained higher amount of organic carbon than subsurface soil. But, however, the average increase in organic carbon content due to organic farming was more in subsurface soil (86.10%) than in surface soil (80.0%). Among the three organic farms the highest mean organic carbon content was observed in soils of R₁ farmer (0.72) and lowest was in soils of R₃ farmer (0.68%).

In sugarcane based cropping system (Table 12), the highest increase in organic carbon due to organic farming practice was recorded in S₃ farmer (45.76%), followed by S₂ (37.71%) and lowest increase was in S₄ (24.04%). The mean organic carbon content of soils of organic farms ranged from 0.67 per cent (S₄) to 0.81 per cent (S₁). The average of four soils showed an increase of organic carbon from 0.58 to 0.77 per cent and 0.54 to 0.72 per cent in surface and subsurface soils, respectively due to organic farming practice. The overall increase in organic carbon content was 33.00 per cent.

In vine yard system (Table 13), the average of three soils indicated an increase in organic carbon due to organic farming from 0.79 to 1.02 per cent and 0.75 to 0.91 per cent in surface and subsurface soils, respectively. The average increase in organic carbon in surface soil was 29.10 per cent and subsurface was 21.3 per cent. The highest and lowest increase in organic carbon was recorded in soils of V₃ farmer (33.80%) and V₁ farmer (19.42%), respectively.

4.3.3 Cation exchange capacity

The data on cation exchange capacity (CEC) of soils under different cropping systems is given in Table 10, 11, 12 and 13.

Under cotton based cropping system (Table 10), the average CEC of four soils showed an increase in surface soil from 57.88 cmol (p+) per kg in conventional farms to 62.38 cmol (p+) per kg in organic farms. It increased from 56.33 to 60.53 cmol (p+) per kg in subsurface soil. The average increase in CEC was to the extent of 7.80 per cent and 7.45 per cent in surface and subsurface soils, respectively. Among the soils of four organic farms, the highest increase in CEC was observed in soil C₄ farmer (10.20%), followed by C₃ farmer (7.80%) and lowest was noticed in soils of C₁ farmer (5.40%).

In *kharif* jowar based cropping system (Table 11), the average of two soils indicated an increase of CEC due to organic farming from 59.25 to 65.51 cmol (p+) per kg and 58.08 to 63.90 cmol (p+) per kg in surface and subsurface soils, respectively accounting for an increase of 10.60 per cent in surface soil and 10.00 per cent in subsurface soil.

The average of three soils showed under *rabi* jowar cropping system (Table 11) indicated an increase of CEC in both surface and subsurface soils (58.45 to 62.94 cmol (p+)/kg and 56.89 to 61.38 cmol (p+)/kg, respectively). The average increase in CEC due to organic farming worked to 7.7 per cent in surface and 7.9 per cent in subsurface soil. Among the three organic farms, soils of R₂ farm recorded a highest CEC (62.64 cmol (p+)/kg).

In sugarcane based cropping system (Table 12), all the four organic farms showed an increase in CEC due to organic farming practice. The average increase in CEC of soils of organic farms over conventional farms was 9.50 and 9.40 per cent in surface and subsurface

soils, respectively. The highest increase of 11.70 per cent in CEC was noticed in soils of S₃ farmer (61.29 to 68.47 cmol (p+)/kg).

In vine yard system (Table 13), the average of three organic farms indicated an increase of CEC from 53.73 to 61.12 cmol (p-) per kg and 53.03 to 59.55 cmol (p+) per kg in surface and subsurface soils, respectively. The highest and lowest increase in CEC was recorded in soils of V₃ farmer (16.60%) and V₂ farmer (10.40%) respectively. The increase in CEC was more in surface soil (13.80%) than in subsurface soil (12.30%).

4.4 EFFECT OF ORGANIC FARMING ON AVAILABILITY OF PLANT NUTRIENTS

4.4.1 Available soil nitrogen

The data presented in Table 14 shows the effect of organic farming on available nitrogen (N) content of soils. All the soils were low in available N status irrespective of type of farming and cropping system. In cotton based cropping system, the available nitrogen content on an average, increased from 135.71 to 154.18 kg per ha and 123.73 to 140.53 kg per ha in surface and subsurface soils, respectively. The available N content was more in surface soils than in subsurface soils in all the farms. Among the soils of four organic farms, the highest increase of 21.90 per cent in available nitrogen content was observed in soils of C₄ farmer (125.45 to 152.88 kg/ha) and lowest increase (4.10%) was observed in soils of C₁ farmer *i.e.*, from 124.38 to 129.44 kg per ha.

In *kharif* jowar based cropping system, the average of two soils indicated an increase in available nitrogen content from 159.50 kg per ha in conventional farm to 168.62 kg per ha in organic farm in surface soil and 150.60 to 162.85 kg per ha in subsurface soils. The overall increase in nitrogen content due to organic farming was 7.27 per cent. The highest increase in nitrogen content was observed in soils of K₁ farmer (8.34%). The surface soils accounted for higher N content than subsurface soils.

The soils from *rabi* jowar based cropping system also showed an increase in nitrogen content due to organic farming (169.57 kg/ha in conventional farm to 188.67 kg per ha in organic farm in surface soil and 159.41 to 182.30 kg per ha in subsurface soils, respectively). Among the three farms, the highest increase in nitrogen content was observed in soils of R₁ farmer (15.12%) and the lowest increase was in soils of R₃ farmer (9.20%). Although, the available N content was more in surface soils, the per cent increase in it due to organic farming practice was more in subsurface (14.35%) than in surface soils (11.30%).

The increase in nitrogen content due to organic farming in sugarcane based cropping system on an average was 17.22 per cent in surface soils (189.73 to 222.41 kg/ha) and 13.10 per cent in subsurface soils (180.84 to 204.49 kg/ha), respectively. The highest increase in nitrogen content was recorded in soils of S₃ farmer (19.82%) and lowest increase was noticed in soil of S₁ farmer (10.0%). The surface soils recorded higher available N content than surface soils in all the farms. The per cent increase in available nitrogen due to organic farming was also more in surface soils than in subsurface soils.

In vineyard system, the average of three soils indicated that nitrogen content increased due to organic farming from 216.76 to 236.56 kg per ha and 207.30 to 226.50 kg per ha in surface and subsurface soils, respectively. The available N content was more in surface soil than subsurface soil in both conventional and organic farms. The highest and lowest increase in nitrogen content due to organic farming was recorded in soils of V₃ farmer (12.95%) and V₂ farmer (7.60%), respectively.

4.4.2 Available phosphorus in soil

The results on influence of organic farming on available phosphorus content of soils are presented in Table 15. The available phosphorus status was low to medium in all the soils. However, the soils under organic farming accounted for higher amounts than those under conventional farming.

Table 14. Available nitrogen (kg N/ha) in soils under different cropping systems

Code	Depth (cm)	Organic farming	Conventional farming	% increase over conventional farming
C ₁	0-15	133.28	131.17	1.60
	15-30	125.60	117.60	6.80
	Mean	129.44	124.38	4.10
C ₂	0-15	145.82	130.14	12.04
	15-30	138.60	125.44	10.49
	Mean	142.21	127.79	11.30
C ₃	0-15	180.82	151.36	19.13
	15-30	148.96	131.17	13.60
	Mean	164.64	141.26	16.55
C ₄	0-15	156.80	130.17	20.46
	15-30	148.96	120.73	23.40
	Mean	152.88	125.45	21.90
Average of C ₁ – C ₄	0-15	154.18	135.71	13.60
	15-30	140.53	123.73	13.50
	Mean	147.35	129.72	13.60
Kharif jowar based cropping system				
K ₁	0-15	164.64	156.80	5.00
	15-30	161.50	144.25	11.95
	Mean	163.07	150.52	8.34
K ₂	0-15	172.60	160.20	7.74
	15-30	164.20	156.9	4.65
	Mean	168.40	158.50	6.25
Average of K ₁ – K ₂	0-15	168.62	159.50	6.40
	15-30	162.85	150.60	8.13
	Mean	165.73	154.50	7.27
Rabi jowar based cropping system				
R ₁	0-15	172.48	150.80	14.40
	15-30	163.58	141.12	15.91
	Mean	168.03	145.96	15.12
R ₂	0-15	183.45	165.12	11.10
	15-30	180.20	151.52	18.92
	Mean	181.82	158.32	14.84
R ₃	0-15	210.10	192.80	9.00
	15-30	203.10	185.60	9.42
	Mean	206.60	189.20	9.20
Average of R ₁ – R ₃	0-15	188.67	169.57	11.30
	15-30	182.30	159.41	14.35
	Mean	185.48	164.49	12.80

Table 14 (Contd.....)

Code	Depth (cm)	Organic farming	Conventional farming	% increase over conventional farming
Sugarcane based cropping system				
S ₁	0-15	229.80	208.60	10.20
	15-30	226.80	205.00	10.63
	Mean	228.30	206.80	10.00
S ₂	0-15	156.80	130.14	20.50
	15-30	148.96	125.73	18.47
	Mean	152.88	127.93	19.50
S ₃	0-15	280.40	227.36	23.32
	15-30	255.84	220.16	16.20
	Mean	268.12	223.76	19.82
S ₄	0-15	222.65	192.86	15.44
	15-30	188.16	172.48	9.10
	Mean	205.40	182.67	12.44
Average of S ₁ – S ₄	0-15	222.41	189.73	17.22
	15-30	204.49	180.84	13.10
	Mean	213.45	185.28	15.20
Vineyard system				
V ₁	0-15	228.33	216.76	9.95
	15-30	225.50	207.30	8.80
	Mean	231.91	212.03	9.40
V ₂	0-15	236.76	216.76	9.22
	15-30	219.52	207.30	5.90
	Mean	228.14	212.03	7.60
V ₃	0-15	244.60	216.76	12.84
	15-30	234.50	207.30	13.12
	Mean	239.50	212.03	12.95
Average of V ₁ – V ₃	0-15	236.56	216.76	9.13
	15-30	226.50	207.30	9.30
	Mean	231.53	212.03	9.20

Table 15. Available phosphorus (kg P₂O₅/ha) in soils under different cropping systems

Code	Depth (cm)	Organic farming	Conventional farming	% increase over conventional farming
Cotton based cropping system				
C ₁	0-15	18.60	17.20	8.14
	15-30	17.80	16.40	8.84
	Mean	18.20	16.80	8.33
C ₂	0-15	20.00	18.70	7.10
	15-30	19.60	17.70	11.11
	Mean	19.80	18.20	8.80
C ₃	0-15	28.80	24.60	17.10
	15-30	24.80	22.40	10.70
	Mean	26.80	23.50	14.00
C ₄	0-15	24.80	20.50	20.80
	15-30	22.80	19.30	18.10
	Mean	23.80	19.90	19.60
Average of C ₁ – C ₄	0-15	23.05	20.20	13.90
	15-30	21.20	18.90	12.20
	Mean	22.10	19.50	13.30
Kharif jowar based cropping system				
K ₁	0-15	26.80	24.91	7.60
	15-30	24.81	22.83	8.62
	Mean	25.80	23.87	8.10
K ₂	0-15	20.52	19.72	4.05
	15-30	20.12	18.89	6.51
	Mean	20.32	19.30	5.30
Average of K ₁ – K ₂	0-15	23.66	22.31	6.05
	15-30	22.46	20.86	7.70
	Mean	23.06	21.58	6.85
Rabi jowar based cropping system				
R ₁	0-15	28.00	22.80	22.80
	15-30	27.20	20.34	33.72
	Mean	27.60	21.57	27.90
R ₂	0-15	28.80	24.91	15.61
	15-30	28.40	22.83	24.40
	Mean	28.60	23.87	19.81
R ₃	0-15	30.00	26.98	11.20
	15-30	29.20	25.95	12.52
	Mean	29.60	26.46	11.90
Average of R ₁ – R ₃	0-15	28.93	24.89	16.23
	15-30	28.26	23.04	22.65
	Mean	28.59	23.96	19.32

Table 15 (Contd.....)

Code	Depth (cm)	Organic farming	Conventional farming	% increase over conventional farming
Sugarcane based cropping system				
S ₁	0-15	35.20	31.14	13.03
	15-30	34.00	26.98	26.01
	Mean	34.60	29.06	19.10
S ₂	0-15	30.40	26.98	12.70
	15-30	30.00	22.83	31.40
	Mean	30.20	24.90	21.30
S ₃	0-15	28.80	22.80	22.80
	15-30	27.20	18.68	45.60
	Mean	27.60	20.74	33.10
S ₄	0-15	30.10	24.80	21.40
	15-30	26.40	22.50	17.33
	Mean	28.20	23.60	19.50
Average of S ₁ - S ₄	0-15	30.92	26.43	17.00
	15-30	29.40	22.74	29.30
	Mean	30.16	24.58	22.70
Vineyard system				
V ₁	0-15	37.20	31.14	19.50
	15-30	36.00	29.06	23.90
	Mean	36.50	30.10	21.60
V ₂	0-15	36.40	31.14	16.90
	15-30	35.60	29.06	22.50
	Mean	36.00	30.10	20.00
V ₃	0-15	39.60	31.14	27.20
	15-30	38.80	29.06	33.50
	Mean	39.20	30.10	30.23
Average of V ₁ - V ₃	0-15	37.73	31.14	21.20
	15-30	36.80	29.06	26.63
	Mean	37.26	30.10	23.80

In cotton based cropping system, the mean available P content in soils ranged from 18.20 (C₁) to 26.80 (C₃) kg per ha in organic farms and 16.80 (C₁) to 23.50 (C₃) kg per ha in conventional farms. On an average, the available phosphorus content increased from 20.20 kg per ha in conventional farm to 23.05 kg per ha in organic farms in surface soil and from 18.90 to 21.20 kg per ha in subsurface soil accounting for an increase of 13.90 and 12.20 per cent respectively. The available P content in surface soil was slightly higher than subsurface soil in all the farms. Among the soils of four organic farms, the highest increase of 19.60 per cent in available phosphorus content was recorded in soils of C₄ farmer followed by C₃ farmer (14.00%) and lowest increase was observed in soils of C₁ farmer (8.33%).

In *kharif* jowar based cropping system, the average of two soils indicated an increase of available phosphorus content due to organic farming from 22.31 to 23.66 kg per ha and 20.86 to 22.46 kg per ha in surface and subsurface soils, respectively. The average increase in surface soil was 6.05 per cent and subsurface was 7.70 per cent. The soils of K₁ farmer recorded highest increase in available phosphorus content (8.10%) than K₂ farmer (5.30%).

In *rabi* jowar based cropping system, the average of three soils showed an increase in available phosphorus content from 24.89 kg per ha in conventional farm to 28.93 kg per ha in organic farm in surface soil and from 23.04 to 28.26 kg per ha in subsurface soils. The surface soils contained more available P than subsurface soil in all the farms. But, however, the per cent increase in its availability was more in subsurface soil (22.65%) than in surface soil (16.23%). Among three organic farms, the highest increase in available phosphorus content over conventional farming was observed in soils of R₁ farmer (27.90%) and lowest was in soils of R₃ farmer (11.90%).

In sugarcane based cropping system, the highest increase in available phosphorus content due to organic farming was recorded in soils of S₃ farmer (33.10%), followed by S₂ farmer (21.30%) and lowest increase was in soils of S₁ farmer (19.10%). The available P status was high in all the soils under organic farming and it ranged from 27.60 kg per ha (S₃) to 34.60 kg per ha (S₁). The average of four farms showed an increase of soil phosphorus content due to organic farming from 26.43 to 30.92 kg per ha and 22.74 to 29.40 kg per ha in surface and subsurface soils, respectively. The overall increase in phosphorus content due to organic farming was 22.70 per cent.

In vineyards, the average of three farms indicated an average increase in available phosphorus content due to organic farming from 31.14 to 37.73 kg per ha and 29.06 to 36.80 kg per ha in surface and subsurface soils, respectively. The available P status was high in soils of organic farms. The surface soils contained more available P than subsurface soils in all farms. But, the average increase in phosphorus content due to organic farming was more in subsurface (26.63%) than in surface soil (21.20%). The highest and lowest increase in available phosphorus content due to organic farming was recorded in soils of V₃ farmer (30.23%) and V₂ farmer (20.00%), respectively.

4.4.3 Available potassium in soil

The data on the effect of organic farming on available potassium content of soils under different cropping systems is given in Table 16. The status of available potassium was high in both conventional and organic farms in all the cropping systems studied.

Under cotton based cropping system, the mean available K₂O content varied from 514 kg per ha (C₂) to 574 kg per ha (C₁) in organic farms and 492 kg per ha (C₂) 554.00 kg per ha (C₁) in conventional farms. On an average, available potassium content of four soils showed an increase of potassium content of surface soil from 524.00 kg per ha under conventional farming to 548.00 kg per ha under organic farming and from 512 to 535 kg per ha in subsurface soil accounting for an increase of 4.60 per cent and 4.50 per cent in surface and subsurface soil, respectively. Among the soils of four organic farms, the highest increase in potassium was recorded in soils of C₄ farmer (5.23%) and lowest increase was noticed in soils of C₁ farmer (3.61%).

Table 16. Available potassium (kg K₂O/ha) in soils under different cropping systems

Code	Depth (cm)	Organic farming	Conventional farming	% increase over conventional farming
Cotton based cropping system				
C ₁	0-15	580	565	2.65
	15-30	568	543	4.60
	Mean	574	554	3.61
C ₂	0-15	520	498	4.41
	15-30	508	486	4.52
	Mean	514	492	4.50
C ₃	0-15	562	528	6.43
	15-30	548	531	3.20
	Mean	555	529	4.91
C ₄	0-15	530	504	5.15
	15-30	516	490	5.30
	Mean	523	497	5.23
Average of C ₁ – C ₄	0-15	548	524	4.60
	15-30	535	512	4.50
	Mean	541	518	4.44
Kharif jowar based cropping system				
K ₁	0-15	620	590	5.10
	15-30	584	564	3.54
	Mean	602	577	4.33
K ₂	0-15	592	568	4.22
	15-30	576	556	3.60
	Mean	584	562	3.91
Average of K ₁ – K ₂	0-15	606	579	4.70
	15-30	580	560	3.60
	Mean	593	569	4.21
Rabi jowar based cropping system				
R ₁	0-15	550	528	4.20
	15-30	534	516	3.50
	Mean	542	522	3.83
R ₂	0-15	520	503	3.40
	15-30	510	492	3.70
	Mean	515	497	3.62
R ₃	0-15	610	596	2.34
	15-30	590	580	1.72
	Mean	600	586	2.40
Average of R ₁ – R ₃	0-15	560	542	3.32
	15-30	544	529	2.83
	Mean	552	535	3.20

Table 16 (Contd.....)

Code	Depth (cm)	Organic farming	Conventional farming	% increase over conventional farming
Sugarcane based cropping system				
S ₁	0-15	605	592	2.20
	15-30	588	570	3.10
	Mean	596	581	2.70
S ₂	0-15	612	592	3.40
	15-30	556	530	4.90
	Mean	584	561	4.10
S ₃	0-15	624	578	7.95
	15-30	592	570	3.85
	Mean	608	574	5.92
S ₄	0-15	613	598	2.00
	15-30	590	559	5.54
	Mean	600	578	3.72
Average of S ₁ – S ₄	0-15	613	590	3.90
	15-30	581	557	4.31
	Mean	597	573	4.10
Vineyard system				
V ₁	0-15	620	598	3.70
	15-30	586	575	1.91
	Mean	603	586.5	2.81
V ₂	0-15	605	598	1.20
	15-30	585	575	1.73
	Mean	595	586.5	1.44
V ₃	0-15	620	598	3.70
	15-30	596	575	3.65
	Mean	608	586.5	3.70
Average of V ₁ – V ₃	0-15	615	598	2.84
	15-30	589	575	2.43
	Mean	602	586.5	2.64

Table 17. Available sulphur (kg S/ha) in soils under different cropping systems

Code	Depth (cm)	Organic farming	Conventional farming	% increase over conventional farming
C ₁	0-15	29.25	27.00	8.33
	15-30	26.25	24.75	6.10
	Mean	27.75	24.87	11.60
C ₂	0-15	30.50	27.75	9.91
	15-30	27.00	24.75	9.10
	Mean	28.75	26.25	9.52
C ₃	0-15	29.25	27.00	8.33
	15-30	27.75	24.75	12.12
	Mean	28.50	25.87	10.20
C ₄	0-15	33.00	28.98	13.90
	15-30	30.75	26.80	14.74
	Mean	31.87	27.89	14.30
Average of C ₁ – C ₄	0-15	30.50	27.68	10.20
	15-30	27.94	25.26	10.60
	Mean	29.22	26.47	10.40
Kharif jowar based cropping system				
K ₁	0-15	36.75	35.25	4.25
	15-30	33.00	32.25	2.32
	Mean	34.87	33.75	3.32
K ₂	0-15	34.50	33.00	4.54
	15-30	32.50	31.50	3.17
	Mean	33.5	32.25	3.90
Average of K ₁ – K ₂	0-15	35.62	34.12	4.40
	15-30	32.75	31.87	2.80
	Mean	34.18	32.99	3.60
Rabi jowar based cropping system				
R ₁	0-15	25.50	24.00	6.25
	15-30	23.25	21.75	6.90
	Mean	24.37	22.87	6.50
R ₂	0-15	25.30	23.60	7.20
	15-30	23.50	22.40	4.91
	Mean	24.40	23.00	6.10
R ₃	0-15	28.75	27.75	3.60
	15-30	27.00	25.50	5.90
	Mean	27.87	26.62	4.70
Average of R ₁ – R ₃	0-15	26.51	25.11	5.60
	15-30	24.58	23.21	5.90
	Mean	25.54	24.16	5.71

Table 17 (Contd.....)

Code	Depth (cm)	Organic farming	Conventional farming	% increase over conventional farming
Sugarcane based cropping system				
S ₁	0-15	33.70	31.50	7.14
	15-30	29.25	26.25	11.42
	Mean	31.47	28.87	9.00
S ₂	0-15	31.50	28.50	10.52
	15-30	29.25	27.75	5.40
	Mean	30.37	28.12	8.00
S ₃	0-15	25.50	23.25	9.70
	15-30	24.00	21.75	1.34
	Mean	24.75	22.50	10.00
S ₄	0-15	24.75	23.25	6.45
	15-30	21.75	20.25	7.40
	Mean	23.25	21.75	6.90
Average of S ₁ – S ₄	0-15	28.86	26.62	8.41
	15-30	26.06	24.00	8.60
	Mean	27.46	25.31	8.50
Vineyard system				
V ₁	0-15	36.00	34.42	4.60
	15-30	33.75	32.86	2.70
	Mean	34.87	33.64	3.65
V ₂	0-15	36.75	34.42	6.80
	15-30	34.00	32.86	3.50
	Mean	35.00	33.64	4.00
V ₃	0-15	36.50	34.42	6.04
	15-30	34.30	32.86	4.40
	Mean	35.40	33.64	5.23
Average of V ₁ – V ₃	0-15	36.41	34.42	5.80
	15-30	33.68	32.86	2.50
	Mean	35.04	33.64	4.20

In *kharif* jowar based cropping system, the average of two soils indicated increase of available potassium content from 579 to 606 kg per ha and 560 to 580 kg per ha in surface and subsurface soils, respectively. The average increase in potassium due to organic farming worked to 4.70 per cent in surface soil and 3.60 per cent in subsurface soil. The highest increase in potassium content was observed in K₁ farmer (4.33%).

The average of three soils under *rabi* jowar based cropping system indicated an increase of potassium in both surface and subsurface soils (542 to 560 kg/ha and 529 to 544 kg/ha, respectively). The average increase in potassium in surface and subsurface soil was 3.32 per cent and 2.83 per cent, respectively. Among three soils, soils of R₁ farmer showed a highest increase in potassium (3.83%) due to organic farming.

In sugarcane based cropping system, available K₂O content in soils under organic farms ranged from 584 (S₂) to 608 (S₃) kg per ha, while it ranged from 561 (S₂) to 581 (S₁) kg per ha in conventional farms. On an average, the available potassium content in soils due to organic farming increased from 590 to 613 kg per ha in surface and 557 to 581 kg per ha in subsurface soils. The highest increase in potassium content was in soils of S₃ farmer (5.92%), followed by S₂ farmer (4.10%) and lowest increase was noticed in soils of S₁ farmer (2.70%). All the soils contained more available K in surface than in subsurface soil.

In vineyards, the average of three organic farms indicated an increase of available potassium content from 598 to 615 kg per ha and 575 to 589 kg per ha in surface and subsurface soils, respectively. The highest and lowest increase in potassium was recorded in soils of V₃ (3.70%) and V₂ farmer (1.44%), respectively.

4.4.4 Available sulphur in soil

The results on available sulphur content of soils as influenced by organic farming are presented in Table 17. The available S content in all the soils was above critical limit irrespective of type of farming and cropping system followed.

The results from cotton based cropping system showed that there was increase in available sulphur content due to organic farming. In organic farms, mean available sulphur ranged from 27.75 kg per ha (C₁) to 31.87 kg per ha (C₄). The soils of C₄ farmer showed greater increase in sulphur (14.30%), followed by C₁ farmer (11.60%) and lowest increase was observed in soils of C₂ farmer (9.52%). On an average, sulphur content in surface soil increased from 27.68 kg per ha in conventional farms to 30.50 kg per ha in organic farms, accounting for an increase of 10.20 per cent. Whereas, in subsurface soil, available S increased from 25.26 kg per ha under conventional farming to 27.94 kg per ha under organic farming, accounting for an increase of 10.60 per cent.

In *kharif* jowar based cropping system, the average of two soils indicated an increase in sulphur content from 34.12 to 35.62 kg per ha and 31.87 to 32.75 kg per ha in surface and subsurface soils, respectively. The average increase in sulphur content due to organic farming worked to 4.40 per cent in surface soil and 2.80 per cent in subsurface soil. The highest increase in sulphur content was observed in soils of K₂ farmer (3.90%).

In *rabi* jowar based cropping system, the average of three soils showed an increase in available sulphur content of surface soil from 25.11 kg per ha in conventional farm to 26.51 kg per ha in organic farm and in the subsurface it increased from 23.21 to 24.58 kg per ha. Among the three organic farms, the highest increase in available sulphur content over conventional farming was observed in soils R₁ farmer (6.50%) and lowest increase was in soils of R₃ farmer (4.70%).

The soils of sugarcane based cropping system showed an increase in available sulphur due to organic farming practice. The average increase in available sulphur over conventional farming was 8.41 per cent and 8.60 per cent in surface and subsurface soils, respectively. The mean available sulphur in soils of organic farms ranged from 23.25 kg per ha (S₄) to 31.47 kg per ha (S₁). While, in conventional farms it ranged from 21.75 kg per ha (S₄) to 28.87 kg per ha (S₁). The highest increase in available sulphur content due to organic farming was noticed in soils of S₁ farmer (10.00%) and lowest increase was in soils of S₄ (6.90%).

The available sulphur content of three soils under vineyards recorded an average of 36.41 and 33.68 kg per ha in surface and subsurface soils, respectively under organic farming

compared to 34.42 and 32.86 kg per ha in conventional farms. The average increase in available sulphur content in surface soil was 5.80 per cent and 2.50 per cent in subsurface soil. The soils from V₃ farmer recorded highest increase in sulphur content (5.23%), while the lowest increase was in soils of V₁ farmer (3.65%).

4.4.5 DTPA extractable micronutrients in soil

4.4.5.1 Zinc

The data on DTPA extractable zinc content of soils under different cropping systems is given in Table 18, 19, 20 and 21.

The Zn content in all the soils was above critical concentration irrespective of type of farming and cropping system.

Under cotton based cropping system (Table 18), the mean zinc content in soil varied from 1.37 ppm (C₁) to 1.63 ppm (C₃) in organic farms as against 0.99 ppm (c₁) to 1.10 ppm (C₃) conventional farms. On an average, zinc content of four soils showed an increase from 1.17 ppm under conventional farming to 1.64 ppm under organic farming in surface soil and from 0.90 to 1.32 ppm in subsurface soil. The average increase in zinc content was to the extent of 40.20 per cent and 46.70 per cent in surface and subsurface soils, respectively. Among the soils of four organic farms, the highest increase in zinc was recorded in soils of C₄ farmer (49.40%) followed by C₃ farmer (47.50%) and lowest increase was observed in soils of C₁ farmer (38.40%).

In *kharif* jowar based cropping system (Table 19), the average of two soils indicated an increase of zinc content due to organic farming from 1.26 to 1.84 ppm and 1.01 to 1.51 ppm in surface and subsurface soils, respectively. The average increase in zinc due to organic farming worked to 46.03 per cent in surface soil and 49.50 per cent in subsurface soil. The highest increase in zinc content was observed in soils of K₁ farmer (54.54%).

The average Zn content of three soils under *rabi* jowar based cropping system (Table 19) indicated increase of zinc due to organic farming in both surface and subsurface soils (1.14 to 1.60 ppm and 0.85 to 1.27 ppm, respectively). The average increase in zinc content in surface and subsurface soil was 40.35 per cent and 49.41 per cent, respectively. Among three farms, soils of R₁ farmer showed a highest increase in zinc content (53.85%) due to organic farming and lowest increase was recorded in soils of R₃ farmer (37.14%).

In sugarcane based cropping system (Table 20), the mean soil zinc content in organic farms varied from 1.40 ppm (S₄) to 1.69 ppm (S₁), while, it ranged from 0.92 ppm (S₃) to 1.18 ppm (S₁) in conventional farms. The average increase in zinc due to organic farming was from 1.18 to 1.65 ppm and 0.86 to 1.34 ppm in surface and subsurface soils, respectively. The highest increase in zinc content was observed in soils of S₃ farmer (56.52%) and lowest increase was noticed in soils of S₁ farmer (43.22%).

In vineyard system (Table 21), the average of three organic farms indicated increase of zinc content from 1.37 to 1.80 ppm in surface soils and 1.12 to 1.47 ppm in subsurface soils. The highest and lowest increase in zinc content was recorded in soils of V₃ farmer (41.93%) and V₂ farmer (25.80%), respectively.

In all the soils, DTPA-zinc was more in surface than in subsurface irrespective of type of farming and cropping system followed by the farmers.

4.4.5.2 Iron

The results on DTPA extractable iron content (DTPA-Fe) of soil as influenced by organic farming are presented in Table 18, 19, 20 and 21.

The results from cotton based cropping system (Table 18) showed that there was increase in DTPA-Fe content in soil due to organic farming. It ranged from 4.09 ppm (C₄) to 5.40 ppm (C₃) in organic farms and from 2.71 ppm (C₄) to 3.85 ppm (C₃) in conventional farms. The soils of C₄ farmer recorded highest increase in iron content (50.92%), followed by C₃ (40.30%) and lowest increase was observed in soils of C₁ farmer (34.15%). On an average, iron content of soils increased from 3.50 ppm under conventional farming to 4.89 ppm under organic farming, accounting for an increase by 39.71 per cent.

Table 18. DTPA-extractable zinc and iron in soils under cotton based cropping system

Code	Depth (cm)	Zinc (ppm)			Iron (ppm)		
		Organic farming	Conventional farming	% increase over conventional farming	Organic farming	Conventional farming	% increase over conventional farming
C ₁	0-15	1.55	1.09	42.20	5.72	4.32	32.40
	15-30	1.19	0.89	33.70	4.19	3.06	36.92
	Mean	1.37	0.99	38.40	4.95	3.69	34.15
C ₂	0-15	1.62	1.21	33.88	5.98	4.41	35.60
	15-30	1.23	0.84	46.42	4.40	3.05	44.26
	Mean	1.43	1.02	40.15	5.19	3.73	39.14
C ₃	0-15	1.74	1.18	47.45	6.16	4.62	33.33
	15-30	1.52	1.03	47.60	4.57	3.09	47.89
	Mean	1.63	1.10	47.50	5.40	3.85	40.30
C ₄	0-15	1.67	1.21	38.01	4.28	2.88	48.61
	15-30	1.35	0.84	60.71	3.90	2.55	52.94
	Mean	1.51	1.02	49.40	4.09	2.71	50.92
Average of C ₁ – C ₄	0-15	1.64	1.17	40.20	5.53	4.06	36.20
	15-30	1.32	0.90	46.70	4.26	2.94	44.90
	Mean	1.48	1.03	43.70	4.89	3.50	39.71

Table 19. DTPA-extractable zinc and iron in soils under jowar based cropping system

Code	Depth (cm)	Zinc (ppm)			Iron (ppm)		
		Organic farming	Conventional farming	% increase over conventional farming	Organic farming	Conventional farming	% increase over conventional farming
<i>Kharif jowar based cropping system</i>							
K ₁	0-15	1.72	1.13	52.21	5.91	4.39	34.62
	15-30	1.34	0.86	55.81	4.06	2.64	53.78
	Mean	1.53	0.99	54.54	4.60	3.20	43.75
K ₂	0-15	1.97	1.39	41.72	5.96	4.45	33.93
	15-30	1.68	1.16	44.82	4.28	2.98	43.62
	Mean	1.82	1.27	43.30	5.12	3.71	38.00
Average of K ₁ – K ₂	0-15	1.84	1.26	46.03	5.93	4.42	34.20
	15-30	1.51	1.01	49.50	4.17	2.81	48.40
	Mean	1.67	1.13	47.80	5.05	3.61	39.88
<i>Rabi jowar based cropping system</i>							
R ₁	0-15	1.57	1.05	49.52	5.62	4.12	36.41
	15-30	1.24	0.78	58.97	4.32	2.78	55.40
	Mean	1.40	0.91	53.85	4.97	3.45	44.05
R ₂	0-15	1.60	1.14	40.35	5.98	4.42	35.29
	15-30	1.31	0.89	47.19	4.53	3.29	37.69
	Mean	1.45	1.01	43.60	5.25	3.85	36.40
R ₃	0-15	1.64	1.24	32.25	6.13	4.59	33.55
	15-30	1.25	0.87	43.67	4.86	3.49	39.26
	Mean	1.44	1.05	37.14	5.49	4.04	35.90
Average of R ₁ – R ₃	0-15	1.60	1.14	40.35	5.91	4.38	34.93
	15-30	1.27	0.85	49.41	4.57	3.19	43.30
	Mean	1.43	1.00	43.00	5.24	3.78	38.62

Table 20. DTPA-extractable zinc and iron in soils under sugarcane based cropping system

Code	Depth (cm)	Zinc (ppm)			Iron (ppm)		
		Organic farming	Conventional farming	% increase over conventional farming	Organic farming	Conventional farming	% increase over conventional farming
S ₁	0-15	1.81	1.26	43.65	6.35	4.74	33.96
	15-30	1.58	1.10	43.63	4.96	3.68	34.78
	Mean	1.69	1.18	43.22	5.65	4.21	34.20
S ₂	0-15	1.68	1.24	35.48	6.54	4.86	34.56
	15-30	1.22	0.76	60.52	5.24	3.62	44.75
	Mean	1.45	1.00	45.00	5.89	4.24	38.91
S ₃	0-15	1.55	1.09	42.20	6.31	4.51	39.91
	15-30	1.33	0.76	75.00	4.91	3.43	43.14
	Mean	1.44	0.92	56.52	5.61	3.97	41.30
S ₄	0-15	1.58	1.12	41.10	6.16	4.62	33.33
	15-30	1.23	0.83	48.20	4.96	3.58	38.54
	Mean	1.40	0.97	44.33	5.56	4.10	35.60
Average of S ₁ – S ₄	0-15	1.65	1.18	39.83	6.34	4.68	35.50
	15-30	1.34	0.86	55.81	5.01	3.58	39.94
	Mean	1.49	1.02	40.10	5.67	4.13	37.30

Table 21. DTPA-extractable zinc and iron in soils under vineyard system

Code	Depth (cm)	Zinc (ppm)			Iron (ppm)		
		Organic farming	Conventional farming	% increase over conventional farming	Organic farming	Conventional farming	% increase over conventional farming
V ₁	0-15	1.72	1.37	25.54	6.16	4.72	30.50
	15-30	1.47	1.12	31.25	5.02	3.65	37.53
	Mean	1.59	1.24	28.22	5.59	4.19	33.41
V ₂	0-15	1.74	1.37	27.00	5.91	4.72	25.21
	15-30	1.38	1.12	23.21	4.80	3.65	31.50
	Mean	1.56	1.24	25.80	5.35	4.19	27.68
V ₃	0-15	1.95	1.37	42.33	6.35	4.72	34.53
	15-30	1.57	1.12	40.20	5.06	3.65	38.63
	Mean	1.76	1.24	41.93	5.70	4.19	36.03
Average of V ₁ – V ₃	0-15	1.80	1.37	31.40	6.14	4.72	30.08
	15-30	1.47	1.12	31.25	4.96	3.65	35.89
	Mean	1.63	1.24	31.45	5.55	4.19	32.45

In *kharif* jowar based cropping system (Table 19), the average of two soils indicated an increase in iron content due to organic farming from 4.42 to 5.93 ppm and 2.81 to 4.17 ppm in surface and subsurface soils, respectively, accounting for an increase of 34.20 per cent in surface soil and 48.40 per cent in subsurface soils. The highest increase in iron content was observed in soils of K₁ farmer (43.75%) than K₂ farmer (38.00%).

In *rabi* jowar based cropping system (Table 19) also there was an increase in average iron content of soils from 4.38 ppm in conventional farm to 5.91 ppm in organic farm in the surface soils and from 3.19 to 4.57 ppm in the subsurface soil. Among three organic farms, the highest increase in iron content of organic farm, over conventional farms was observed in soils of R₁ farmer (44.05%) and lowest increase was in soils of R₃ farmer (35.90%).

All the four soils under sugarcane based cropping system (Table 20) showed an increase in iron content due to organic farming practice. The DTPA-Fe content in soils of organic farms varied narrowly (5.56 to 5.89 ppm). The overall average increase in iron content due to organic farming over conventional farming was 35.50 per cent and 39.94 per cent in surface and subsurface soils, respectively. The highest increase in iron contents was noticed in soils of S₃ farmer (41.30%) and lowest was in soils of S₁ farmer (34.20%),

The iron content of three soils under vineyards (Table 21), increased due to organic farming to the extent of 6.14 and 4.96 ppm in surface and subsurface soils, respectively from 4.72 and 3.65 ppm in conventional farms. The average increase in iron in surface soil was 30.08 per cent and it was 35.89 per cent in subsurface soil. The soil from V₃ farmer recorded highest increase in iron content (36.03%), while the lowest increase was in soils of V₂ farmer (27.68%).

4.4.5.3 Manganese

The results on DTPA-extractable manganese (DTPA-Mn) content of soils are presented in Table 22, 23, 24 and 25. All the soils, irrespective of type of farming and cropping system, contained DTPA-Mn content above the critical concentration.

In cotton based cropping system (Table 22), the mean DTPA-Mn content in soils of organic farms ranged from 7.25 ppm (C₄) to 8.25 ppm (C₁) as against 5.50 to 6.37 ppm in conventional farms. On an average, manganese content increased from 6.80 to 8.71 ppm and 5.06 to 6.63 ppm in surface and subsurface soils, respectively under the influence of organic farming. Among the soils of four organic farms, the highest increase in manganese content was observed in soils of C₄ farmer (31.20%) followed by C₃ farmer (30.35%) and lowest increase was observed in soils of C₁ farmer (27.50%).

In *kharif* jowar based cropping system (Table 23), the average of two soils indicated an increase of manganese from 7.83 ppm in conventional farm to 9.76 ppm in organic farm in surface soil and from 5.85 to 7.72 ppm in subsurface soil. The overall increase in available manganese due to organic farming was 27.77 per cent. The highest increase was observed in soils of K₁ farmer (30.90%) than K₂ farmer (24.80%).

The soils under *rabi* jowar based cropping system (Table 23) also showed an increase in available manganese due to organic farming (7.77 to 9.50 ppm and 6.16 to 7.76 ppm in surface and subsurface soils, respectively). Among the three soils, the highest increase in available manganese was observed in soils of R₂ farmer (29.50%) and lowest was in soils of R₁ farmer (20.60%).

The average increase in available manganese content of soil due to organic farming in sugarcane based cropping system (Table 24) was 23.04 (8.47 to 10.36 ppm) and 29.61 per cent (6.28 to 8.14 ppm) in surface and subsurface soils, respectively. The Mn content soils of S₃ farmer accounted for highest increase (32.45%), while soils of S₁ farmer accounted for lowest increase (20.90%).

In vine yard system (Table 25), the average of three soils indicated that available manganese content increased due to organic farming from 8.45 to 10.51 ppm and 6.31 to 7.73 ppm in surface and subsurface soils, respectively. The highest and lowest increase in manganese content due to organic farming were recorded in soils of V₃ farmer (25.88%) and V₂ farmer (20.32%), respectively.

Table 22. DTPA-extractable manganese and copper in soils under cotton based cropping system

Code	Depth (cm)	Manganese (ppm)			Copper (ppm)		
		Organic farming	Conventional farming	% increase over conventional farming	Organic farming	Conventional farming	% increase over conventional farming
C ₁	0-15	9.19	6.79	35.34	0.45	0.37	21.62
	15-30	7.06	5.96	18.45	0.39	0.33	18.18
	Mean	8.12	6.37	27.50	0.42	0.35	20.00
C ₂	0-15	8.48	6.68	26.94	0.41	0.34	20.58
	15-30	6.08	4.59	32.46	0.35	0.29	20.69
	Mean	7.28	5.63	29.30	0.38	0.31	22.60
C ₃	0-15	8.87	7.23	22.70	0.42	0.35	20.00
	15-30	7.19	5.09	41.25	0.37	0.30	23.33
	Mean	8.03	6.16	30.35	0.39	0.32	21.90
C ₄	0-15	8.31	6.41	29.64	0.50	0.39	28.20
	15-30	6.2	4.60	34.78	0.45	0.35	28.60
	Mean	7.25	5.50	31.20	0.47	0.37	27.02
Average of C ₁ – C ₄	0-15	8.71	6.80	20.10	0.44	0.36	22.22
	15-30	6.63	5.06	31.02	0.39	0.32	21.90
	Mean	7.67	5.93	29.34	0.41	0.34	20.60

Table 23. DTPA-extractable manganese and copper in soils under jowar based cropping system

Code	Depth (cm)	Manganese (ppm)			Copper (ppm)		
		Organic farming	Conventional farming	% increase over conventional farming	Organic farming	Conventional farming	% increase over conventional farming
<i>Kharif jowar based cropping system</i>							
K ₁	0-15	9.90	7.65	29.41	0.63	0.50	26.00
	15-30	7.74	5.84	32.53	0.54	0.42	28.57
	Mean	8.82	6.74	30.90	0.58	0.46	26.10
K ₂	0-15	9.62	8.02	19.95	0.61	0.49	24.50
	15-30	7.70	5.87	31.17	0.53	0.43	23.25
	Mean	8.66	6.94	24.80	0.57	0.46	23.91
Average of K ₁ – K ₂	0-15	9.76	7.83	24.65	0.62	0.49	26.53
	15-30	7.72	5.85	32.00	0.53	0.42	26.20
	Mean	8.74	6.84	27.77	0.57	0.45	26.66
<i>Rabi jowar based cropping system</i>							
R ₁	0-15	10.50	8.24	27.42	0.67	0.40	67.50
	15-30	8.64	6.54	32.11	0.39	0.32	21.88
	Mean	9.57	7.39	29.50	0.53	0.36	47.22
R ₂	0-15	8.96	7.34	22.07	0.59	0.49	20.41
	15-30	7.66	6.45	18.75	0.46	0.37	24.32
	Mean	8.31	6.89	20.60	0.52	0.43	20.10
R ₃	0-15	9.04	7.73	16.94	0.43	0.36	19.44
	15-30	6.98	5.48	27.37	0.35	0.33	6.06
	Mean	8.01	6.60	21.40	0.39	0.34	14.70
Average of R ₁ – R ₃	0-15	9.50	7.77	22.30	0.56	0.42	33.33
	15-30	7.76	6.16	26.00	0.40	0.34	17.64
	Mean	8.63	6.96	24.00	0.48	0.38	26.31

Table 24. DTPA-extractable manganese and copper in soils under sugarcane based cropping system

Code	Depth (cm)	Manganese (ppm)			Copper (ppm)		
		Organic farming	Conventional farming	% increase over conventional farming	Organic farming	Conventional farming	% increase over conventional farming
S ₁	0-15	9.90	8.25	20.00	0.53	0.47	12.77
	15-30	8.04	6.59	22.00	0.42	0.35	20.00
	Mean	8.97	7.42	20.90	0.47	0.41	11.90
S ₂	0-15	11.68	9.59	21.80	0.59	0.48	22.91
	15-30	9.37	7.09	32.15	0.47	0.34	38.23
	Mean	10.52	8.34	26.14	0.53	0.41	29.30
S ₃	0-15	9.72	7.56	28.57	0.61	0.48	27.10
	15-30	7.42	5.39	37.66	0.49	0.37	32.43
	Mean	8.57	6.47	32.45	0.55	0.42	30.10
S ₄	0-15	10.17	8.27	22.97	0.44	0.37	18.91
	15-30	7.75	6.05	28.10	0.40	0.33	21.21
	Mean	8.96	7.16	25.14	0.42	0.35	20.06
Average of S ₁ – S ₄	0-15	10.36	8.42	23.04	0.54	0.45	20.00
	15-30	8.14	6.28	29.61	0.44	0.35	25.71
	Mean	9.25	7.35	25.85	0.49	0.40	22.50

Table 25. DTPA-extractable manganese and copper in soils under vineyard system

Code	Depth (cm)	Manganese (ppm)			Copper (ppm)		
		Organic farming	Conventional farming	% increase over conventional farming	Organic farming	Conventional farming	% increase over conventional farming
V ₁	0-15	10.53	8.45	24.61	0.49	0.40	22.50
	15-30	7.73	6.31	22.50	0.36	0.32	12.50
	Mean	9.13	7.38	23.71	0.42	0.36	16.70
V ₂	0-15	10.16	8.45	20.23	0.44	0.40	10.00
	15-30	7.60	6.31	20.44	0.35	0.32	9.37
	Mean	8.88	7.38	20.32	0.39	0.36	8.33
V ₃	0-15	10.84	8.45	28.28	0.51	0.40	27.50
	15-30	7.74	6.31	22.67	0.39	0.32	21.87
	Mean	9.29	7.38	25.88	0.45	0.36	25.00
Average of V ₁ – V ₃	0-15	10.51	8.45	24.37	0.48	0.40	20.00
	15-30	7.73	6.31	22.50	0.36	0.32	12.50
	Mean	9.12	7.38	23.58	0.42	0.36	16.70

4.4.5.4 Copper

The results on influence of organic farming on DTPA-extractable copper (DTPA-Cu) content of soils are presented in Table 22, 23, 24 and 25. The copper content in all the soils was above the critical concentration.

In cotton based cropping system (Table 22), on an average the copper content increased from 0.36 ppm in conventional farms to 0.44 ppm in organic farms in surface soil and from 0.32 to 0.39 ppm in subsurface soil, accounting for an increase of 22.22 and 21.90 per cent, respectively. Among the soils of four organic farms, the soils of C₄ farm recorded highest increase in copper content (31.20%).

In *kharif* jowar based cropping system (Table 23), the average of two soils indicated an increase of copper content due to organic farming from 0.49 to 0.62 ppm and 0.42 to 0.53 ppm in surface and subsurface soils, respectively. The average increase in surface soil was 26.53 per cent and subsurface was 26.20 per cent. The soils of K₁ farmer recorded higher increase in copper content (26.10%) than K₂ farmer (23.91%).

In *rabi* jowar based cropping system (Table 23), the soils on an average, showed an increase in copper content due to organic farming in both surface and subsurface soils (0.42 to 0.56 ppm and 0.34 to 0.40 ppm, respectively). The average increase copper content in surface and subsurface soils was 33.33 per cent and 17.64 per cent, respectively. Among the three organic farms, the highest increase in DTPA-Cu content was observed in soils of R₁ farmer (47.22%) and lowest increase was in soils of R₃ farmer (14.70%).

In sugarcane cropping system (Table 24), a substantial increase in DTPA-extractable copper was observed in soils of S₃ and S₂ farms due to organic farming practice (30.10 and 29.30%, respectively) than the other two farms *viz.*, S₄ and S₁ (20.06 and 11.90%, respectively). The overall average of copper content of sugarcane soils under organic farming was 0.49 ppm compared to 0.40 ppm in soils under conventional farming accounting for an increase by 22.50 per cent.

In vineyard system (Table 25), the average of three soils indicated an increase in copper content due to organic farming from 0.40 to 0.48 ppm and 0.32 to 0.36 ppm in surface and subsurface soils, respectively. The average increase in copper content in surface soil was 20.00 per cent and subsurface was 12.50 per cent. The highest and lowest increase in copper content was recorded in soils of V₃ farmer (25.00%) and V₂ farmer (8.33%), respectively.

4.5 EFFECT OF ORGANIC FARMING ON SOIL BIOLOGICAL PROPERTIES

4.5.1 Dehydrogenase activity

The results on dehydrogenase activity, a measure of total biological activity in soils under different cropping systems are presented in Table 26. All the soils under organic farming recorded an enhanced dehydrogenase activity over conventional farming in all the cropping systems studied.

The results from cotton based cropping system showed that on an average, the dehydrogenase activity due to organic farming increased from 10.82 to 18.30 μ g TPF per g per day in surface soil and 8.64 to 13.25 μ g TPF per g per day in subsurface soil. The soils of C₄ farmer showed highest increase in dehydrogenase activity (94.4%), followed by C₃ farmer (61.30%), whereas lowest increase was in soils of C₂ farmer (46.8%). The over all increase in dehydrogenase activity was from 9.73 μ g TPF per g per day in conventional farming to 15.77 μ g TPF per g per day in organic farming, accounting for an increase by 62.10 per cent.

Table 26. Dehydrogenase activity ($\mu\text{g TPF/g/day}$) in soils under different cropping systems

Table 26. Dehydrogenase activity ($\mu\text{g TPF/g/day}$) in soils under different cropping systems

Code	Depth (cm)	Organic farming	Conventional farming	% increase over conventional farming
Cotton based cropping system				
C ₁	0-15	17.59	11.01	60.00
	15-30	13.20	9.42	37.80
	Mean	15.39	10.21	50.70
C ₂	0-15	16.48	10.9	51.20
	15-30	12.50	8.8	42.00
	Mean	14.46	9.85	46.80
C ₃	0-15	20.18	12.06	67.30
	15-30	14.12	9.2	54.30
	Mean	17.15	10.63	61.30
C ₄	0-15	18.83	9.33	101.80
	15-30	13.18	7.14	84.50
	Mean	16.00	8.23	94.40
Average of C ₁ - C ₄	0-15	18.30	10.82	69.10
	15-30	13.25	8.64	53.30
	Mean	15.77	9.73	62.10
Kharif jowar based cropping system				
K ₁	0-15	24.02	9.82	144.60
	15-30	16.81	7.34	129.00
	Mean	20.41	8.58	137.90
K ₂	0-15	21.18	10.18	108.00
	15-30	14.82	8.92	66.14
	Mean	18.00	9.55	88.50
Average of K ₁ - K ₂	0-15	22.60	10.00	126.00
	15-30	15.82	8.13	94.60
	Mean	19.21	9.06	112.00
Rabi jowar based cropping system				
R ₁	0-15	19.59	10.09	94.15
	15-30	13.71	9.56	43.40
	Mean	16.65	9.82	69.55
R ₂	0-15	22.53	11.56	95.00
	15-30	15.77	9.94	58.65
	Mean	19.15	10.75	78.13
R ₃	0-15	17.73	9.23	92.10
	15-30	12.41	8.62	43.96
	Mean	15.07	8.92	68.94
Average of R ₁ - R ₃	0-15	19.95	10.56	88.90
	15-30	13.96	9.37	48.98
	Mean	16.75	9.96	68.20

Table 26 (Contd....)

Table 26 (Contd.....)

Code	Depth (cm)	Organic farming	Conventional farming	% increase over conventional farming
Sugarcane based cropping system				
S ₁	0-15	24.72	11.92	107.40
	15-30	17.30	10.22	69.27
	Mean	21.01	11.07	89.80
S ₂	0-15	15.65	10.12	54.70
	15-30	10.95	8.52	28.52
	Mean	13.30	9.32	42.70
S ₃	0-15	21.58	9.84	119.30
	15-30	15.10	8.34	81.05
	Mean	18.34	9.09	101.80
S ₄	0-15	23.88	12.02	98.70
	15-30	16.71	10.22	63.50
	Mean	20.29	11.12	82.50
Average of S ₁ - S ₄	0-15	21.45	10.97	95.53
	15-30	15.01	9.32	61.05
	Mean	18.23	10.14	79.80
Vineyard system				
V ₁	0-15	18.72	10.08	85.70
	15-30	13.10	8.50	54.11
	Mean	15.91	9.29	71.25
V ₂	0-15	16.92	10.08	67.80
	15-30	11.84	8.50	82.50
	Mean	14.38	9.29	54.80
V ₃	0-15	19.52	10.08	93.65
	15-30	13.66	8.50	60.70
	Mean	16.59	9.29	78.60
Average of V ₁ - V ₃	0-15	18.38	10.08	82.34
	15-30	12.86	8.50	51.30
	Mean	15.62	9.29	68.13

In *kharif* jowar based cropping system, the average of two soils indicated an increase in dehydrogenase activity from 10.00 to 22.60 and 8.13 to 15.82 $\mu\text{g TPF per g per day}$ in surface and subsurface soils, respectively. The average increase in dehydrogenase activity due to organic farming worked to 126.00 per cent in surface soil and 94.60 per cent in subsurface soil. The highest increase in dehydrogenase activity was observed in soils of K₂ farmer (137.90%). Similarly, in *rabi* jowar based cropping system, the average of the three soils showed an increase in dehydrogenase activity of subsurface soil from 10.56 $\mu\text{g TPF per g per day}$ in conventional farms to 19.95 $\mu\text{g TPF per g per day}$ in organic farm and it was from 9.37 to 13.96 $\mu\text{g TPF per g per day}$ in subsurface soil. Among the three soils, the highest increase in dehydrogenase activity over conventional farming was observed in soils of R₂ farmer (78.13%) and lowest increase was in soils of R₃ farmer (68.94%).

The average increase in dehydrogenase activity of soils under organic farming over conventional farming in sugarcane based cropping system was 95.53 and 61.05 per cent in surface and subsurface soils, respectively. The highest increase in dehydrogenase activity was noticed in soils of S₄ farmer (101.80%) and lowest was in soils of S₂ farmer (42.70%).

In vineyard system, dehydrogenase activity due to organic farming increased 18.38 $\mu\text{g TPF per g per day}$ and 12.86 $\mu\text{g TPF per g per day}$ in surface and subsurface soils, respectively compared to 10.08 and 8.50 $\mu\text{g TPF per g per day}$ in conventional farms. The average increase in dehydrogenase activity in surface soil was 82.34 per cent and 51.30 per cent in subsurface soil. The soils from V₂ farmer recorded highest increase in dehydrogenase activity (78.60%), while the lowest increase was in soils of V₃ farmer (54.80%).

In all the cropping systems surface soils showed greater increase in dehydrogenase activity due to organic farming than subsurface soil.

V. DISCUSSION

Organic farming is slowly gaining importance in recent days. Farmers have experienced deterioration in soil health and either decline or stagnation in yield levels under long-term chemical farming introduced through 'Green Revolution'. Although the benefits of adding organic residues and manures in improving soil health are well known, the information on changes in soil properties by shifting to total organic farming from conventional chemical farming is lacking. Since, some farmers have already started practicing organic farming in Karnataka during the last few years, a study was conducted in the farmers field to know the changes in soil physical, chemical and biological properties under the influence of organic farming practice in different cropping systems. The results of the study are discussed under following heads.

- 5.1 Nutrient content in organic manures and quantity of nutrients added to soil through organics
- 5.2 Effect of organic farming on physical properties of soil
- 5.3 Effect of organic farming on chemical properties of soil
- 5.4 Effect of organic farming on availability of plant nutrients in soil
- 5.5 Effect of organic farming on total microbial activity in soil

5.1 NUTRIENT CONTENT IN ORGANIC MANURES AND QUANTITY OF NUTRIENTS ADDED TO SOIL THROUGH ORGANICS

5.1.1 Nutrient content in organic manures

The organic farmers in the study area have used farmyard manure (FYM) and vermicompost as organic sources. Vermicompost contained higher amount of the major nutrients with narrow C:N ratio than the FYM (Table 2). The nitrogen in vermicompost varied from 2.10 per cent (V_2) to 3.10 per cent (C_3), while its content in FYM varied from 0.68 per cent (K_1) to 1.20 per cent (K_2). Such a wide variation in N content of organics was expected since the organic wastes used for production of these organic manures vary widely from farmer to farmer. Kale *et al.* (1992) also observed a wide variation in N content in vermicompost. Due to higher N content, vermicomposts had narrow C:N ratio (13:1 to 20:1) compared to FYM (25:1 to 38:1).

The phosphorus content varied narrowly from 0.52 per cent (C_1) to 0.78 per cent (K_1) in vermicompost and 0.30 per cent (C_1) to 0.54 per cent (V_2) in FYM.

Potassium content also varied narrowly within the same type of organic manure (0.98 to 1.24% in vermicompost and 0.64 to 1.02% in FYM). The higher nutrient content in vermicompost than FYM could be due to better and uniform decomposition of the organic residues by the earthworms.

5.1.2 Quantity of nutrients added to soil through organics (Table 3)

The quantity of nutrients added to soil through organic manure was calculated based on nutrient analysis of organic manures (Table 2) and quantity applied to soil by the farmer (Table 1).

The quantity of N, P and K added to soil through organic varied widely among the organic farms in all the cropping systems studied. This was due to variation in quantity of organic applied to soil and the nutrients contained in them.

Although, the vermicompost contained higher quantity of nutrients, addition of FYM contributed more nutrients since its quantity applied to soil was much higher (10 to 20 t/ha/year) than vermicompost (1 to 2 t/ha/year).

5.2 EFFECT OF ORGANIC FARMING ON PHYSICAL PROPERTIES OF SOILS

5.2.1 Soil texture

The texture of soils under different cropping system studied was clay in both conventional and organic farms (Table 4). The soil texture, being inherent property of soil was not affected by shifting from conventional farming to organic farming practice.

5.2.2 Bulk density

The soils under organic farming recorded lower values of bulk density than soils under conventional farming irrespective of cropping system followed (Table 5, 6, 7 and 8). The reduction in bulk density of soil under organic farming was to the tune of 3.10 per cent (S₂) to 12.00 per cent (R₁). The reduction in bulk density could be due to better soil structure as evidenced from increase in water stable aggregates. Sharma *et al.* (2000) attributed the reduction in bulk density in residue and FYM incorporated soils to build up of soil organic matter and better soil structure. Srikanth *et al.* (2000) also observed a significant decrease in bulk density of soil amended with compost compared to the inorganic fertilizer applied to soil. A decrease in bulk density due to incorporation of FYM, vermicompost, crop residue *etc.* into the soil have also been reported by several earlier workers (Bhatia and Shukla, 1982; Pikul and Allmarks, 1986; Chenkai, 1993; Bellakki and Badanur, 1994 and Itnal, 1997).

There was variation in reduction of bulk density due to organic farming from farmer to farmer within the same type of cropping system, which could be ascribed to the variation in number of years of organic farming practice and quantity of organics applied to soil. The reduction in bulk density of soil was highest in soils of C₄ farmer under cotton (9.40%), K₁ farmer under *kharif* jowar (10.65%), R₁ farmer under *rabi* jowar (12.00%), S₃ farmer under sugarcane (9.22%) and V₃ farmer under vineyards (10.45%). A longer period of organic farming (more than 6 years) and/or application of larger quantities of organic manures by above farmers were responsible for higher reduction in bulk density of soil. Biswas *et al.* (1971) and Shanmugam and Ravikumar (1980) had also observed a decrease in bulk density of soil by application of larger quantities of FYM.

5.2.3 Maximum water holding capacity

The data on maximum water holding capacity (MWHC) of soils (Table 5, 6, 7 and 8) indicated that its values were higher in soils under organic farming than conventional farming, irrespective of cropping system followed. The increase in MWHC of soils due to organic farming ranged from 2.28 per cent (S₁) to 10.50 per cent (V₂). Biswas and Khosla (1971), Bhatia and Shukla (1982) and Acharya *et al.* (1988) observed improvement in water holding capacity of soil due to addition of organic manures compared to only inorganic fertilizer application. Application of vermicompost @ 5 tonnes per ha increased MWHC compared to control as reported by Jadhav *et al.* (1993). Build up of soil organic matter and improvement in soil structure by application of residue and FYM to soil were responsible for significant increase in water holding capacity of soil (Sharma *et al.*, 2000).

5.2.4 Water stable aggregates

Data on percentage of water stable aggregates (>0.25 mm) in soils under different cropping systems (Table 5, 6, 7 and 8) revealed that soils under organic farming recorded slightly higher values than soils under conventional farming. On an average, the per cent increase in water stable aggregates in soil under organic farming over conventional farming was around 4 per cent in cotton, *kharif* jowar and vineyard systems and 3 per cent in *rabi* jowar and sugarcane cropping systems. The improvement in aggregate stability of soils under organic farming could be attributed to the humic substances released during decomposition of organic manures which bind the soil particles to form larger size aggregates. Formation of larger sized water stable aggregates under long-term application of organic manures was also observed by Singh (1964). A considerable increase in percentage of water stable aggregates due to incorporation of organic manure was noticed by Havanagi and Mann (1970). Hirekurubar (1989) observed a highly significant correlation between per cent aggregate stability and organic carbon in Vertisols of North Karnataka.

5.3 EFFECT OF ORGANIC FARMING ON CHEMICAL PROPERTIES OF SOIL

5.3.1 Soil reaction (pH) and electrical conductivity (EC)

Both the surface and sub-surface soils under organic farming recorded comparatively lower pH than the conventional farming in all the cropping systems (Table 9). The decrease in pH with addition of organic manures in organic farms might be due to formation of organic acids during decomposition and mineralization of organic manures as described by Ramaswamy and Raj (1973). Singh *et al.* (1980) also made similar observations wherein pH decreased by one unit due to application of 15 tonnes of FYM over a period of four years. Badanur *et al.* (1990) observed a significant decrease in soil reaction due to organic manure application as compared to fertilizer application.

The data on soil EC values (Table 9) indicated that the practice of organic farming had no influence on the salt content of soils. Unlike inorganic fertilizers used in conventional farming, organic manures do not contain salts and hence there was no influence of organic farming on soil salt content. However, soils under conventional farming recorded slightly higher EC values than soils under organic farming in all the cropping systems. Contribution of salts from inorganic fertilizers used in the conventional farming was probably responsible for higher EC values in those soils. Bajpai *et al.* (1980) observed a slight decrease in pH and EC at later stage of decomposition with application of organic residue (paddy-straw) in soil.

5.3.2 Organic carbon

The results of organic carbon content of surface and sub-surface soils indicated that it increased under organic farming in all the cropping systems compared to conventional farming (Table 10, 11, 12 and 13).

The increase in organic carbon content of soils under organic farming was quite obvious since the carbonaceous materials contribute to soil organic carbon after their decomposition. These observations are in agreement with the findings of Grawel *et al.* (1981), Sinha *et al.* (1983), Kaushik *et al.* (1984), Gupta *et al.* (1988) and Bhandari *et al.* (1992).

The highest increase in soil organic carbon content was observed in soils of C₄ farmer (47.30%) in cotton based cropping system. R₂ farmer (102.94%) in jowar based cropping system, S₃ farmer (45.76%) in sugar based cropping system and V₃ farmer (33.80%) in vineyards. Addition of higher quantity of organic manures and/or longer period of organic farming practice by the above farmers were responsible for build up of organic carbon in soil. A significant increase in organic carbon content of Vertisol after four years of decomposition of organic manure over fertilizer application was observed by Bellakki and Badanur (1994).

Among the cropping systems studied, the build up in organic carbon was more in soils of R₁ and R₂ organic farms under rabi jowar cropping system. Low organic carbon content in soils under conventional farming rather than the high organic carbon in soils under organic farming was responsible for such marked increase.

5.3.3 Cation exchange capacity

The soils under organic farming recorded higher values of cation exchange capacity (CEC) than soils under conventional farming irrespective of cropping system followed (Table 10, 11, 12 and 13). The increase in CEC was due to improvement in soil organic matter content of soil after decomposition of organic materials. A slight increase in soil organic matter can enhance the CEC of soil to a greater extent because of its high CEC (200-400 cmol (p+)/kg). A significant increase in CEC of soil due to application of farmyard manure was observed by Singh *et al.* (1980), who associated it with the rise in organic matter. The increase in CEC due to incorporation of organic manures into the soil have also been reported by several workers (Swarup and Ghosh, 1979; Yaduvanshi *et al.*, 1985 and Patiram and Singh, 1993).

The increase in CEC of soils due to organic farming varied from farm to farm within the same type of cropping, which could be due to variation in quantity of organic materials added. The increase in CEC of soil was highest in soils of C₄ farmer under cotton (10.20%), K₁

farmer under *kharif* jowar (10.90%), R₂ farmer under *rabi* jowar (10.20%), S₃ farmer under sugarcane (11.70%) and V₃ farmer under vineyards, which could be ascribed longer duration of organic farming practice and larger quantity of organics added to the soil by those farmers (Table 1).

5.4 EFFECT OF ORGANIC FARMING ON AVAILABILITY OF PLANT NUTRIENTS IN SOIL

5.4.1 Available nitrogen

The data on available nitrogen (N) content of soil (Table 14) indicated that its values were higher in soils under organic farming than conventional farming, irrespective of cropping system followed. Production of appreciable quantities of carbonic acids during decomposition of organic matter mineralize the complex organic substances, which in turn would contribute to N pool. An increase in available N by application of vermicompost and FYM was reported by Phule (1993), Balaji (1994) and Pawar (1996). The increase in available nitrogen due to organic matter application is also attributable to the greater multiplication of soil microbes caused by the addition of organic materials which mineralize organically bound N to inorganic form (Bellakki and Badanur, 1997).

In cotton based cropping system, among the soils of four organic farms, the highest increase of 21.90 per cent in available nitrogen content was observed in soils of C₄ farmer, which might be due to addition of higher quantities of nitrogen added to the soil through organics *i.e.*, 162.60 kg N per ha per year (Table 3).

Among the soils from jowar cropping systems, the highest increase in available N content was observed in soils of R₁ farmer (15.12%). Addition of higher quantities of nitrogen through organics (123.90 kg N/ha/year) was responsible for build up of available nitrogen in soil.

In sugarcane based cropping system, the highest increase in available N content was recorded in soils of S₃ farmer (19.82%), which could be ascribed to the addition of 147.90 kg N per ha per year through organics and more number of years of organic farming practice (10 years).

In vineyard system, the highest increase in available N content due to organic farming was recorded in soils of V₃ farmer (12.95%), which is attributable to the addition of higher quantities of nitrogen (150.80 kg N/ha/year) to the soil through organics.

5.4.2 Available phosphorus

The results of available phosphorus content of surface and sub-surface soils indicated that it increased under organic farming in all the cropping systems compared to conventional farming (Table 15). Singh *et al.* (1982) noticed an increase in available phosphorus content of soil due to incorporation of FYM alone or in combination with inorganic fertilizers and attributed it to the enhanced solubilization of native phosphorus and added phosphorus by the decomposition product of organic manures. Venkateshwarulu (1983) noticed an increase in available phosphorus with the application of organic residues over a period of five years in red soils of Hyderabad. Tandon (1987) attributed the increase in available phosphorus with FYM application to the contribution of P by the organics to the soil available pool and coating of organic material on sesquioxides which reduces the phosphate fixing capacity of soil. Similar observations were also reported by Bharadwaj and Omanwar (1994).

Under cotton based cropping system, the highest increase of 19.60 per cent in phosphorus content due to organic farming was recorded in soils of C₄ farmer, which might be due to addition of higher quantities of phosphorus added to the soil through organics *i.e.*, 79.90 kg per ha per year.

Among the soils from jowar based cropping systems, the highest increase in available phosphorus content over conventional farming was observed in soils of R₁ farmer (27.90%) and it was due to addition of more quantities of phosphorus to the soil through organics (58.80 kg P/ha/year).

In sugarcane based cropping system, the highest increase in phosphorus content due to organic farming was recorded in soils of S₃ farmer (33.10%), which could be ascribed to the addition of 88.80 kg P per ha per year through organics and long-term organic manuring (10 years).

In vineyards, the highest increase in available phosphorus content due to organic farming was recorded in soils of V₃ farmer (30.23%). Addition of higher quantity of phosphorus (74.20 kg P/ha/year) to the soil through organics was responsible for build up of available phosphorus in the soil.

5.4.3 Available potassium

Data on available potassium content of soils under different cropping system (Table 16) revealed that all soils were high in available K in both conventional and organic farming. However, soils under organic farming recorded slightly higher available potassium than those under conventional farming. The increase in available potassium in soils of organic farms could be attributed to the direct addition of potassium to the available pool of the soil from FYM and vermicomposts. The beneficial effect of FYM on the available potassium might be also ascribed to the reduction of potassium fixation (Tandon, 1988). Similar observations of increase in available potassium due to addition of organic manures were made by Grawel *et al.* (1981) and Bharadwaj and Omanwar (1994).

On an average, the per cent increase in available potassium in soil under organic farming over conventional farming was slightly more than 4.00 per cent in cotton, *kharif* jowar and sugarcane based cropping systems, 3.20 per cent in *rabi* jowar and 2.64 per cent in vineyard system. Although, the organic manures applied to soil under organic farming practice added substantial quantity of potassium to the soil (70.60 in case of V₂ farm to 159.60 kg/ha/year in case of S₃ farm), the increase in its availability in soil was not high. All the soils studied were Vertisols which are known to have higher K fixation capacity and this could be the reason for lower increase in K availability inspite of addition of K through organics.

5.4.4 Available sulphur

The soils under organic farming recorded higher values of available sulphur content than soils under conventional farming, irrespective of cropping system followed (Table 17). The average increase in available sulphur in soils of organic farms was higher by 3.60 (*kharif* jowar) to 10.40 (cotton) per cent over conventional farms. Increased available S in soils of organic farming was due to the addition of sulphur through the organic manures applied to the soil after decomposition. Vadiraj *et al.* (1992) attributed the increase in available S content to the release of organic bound sulphur through mineralization.

Among different cropping systems, the highest increase in available sulphur was observed in soils of C₄ farmer in cotton based cropping system (14.30%). R₁ farmer in jowar based cropping system (6.50%), S₃ farmer in sugarcane based cropping system (10.00%) and V₃ farmer in vineyards (5.23%). Addition of higher quantities of organic manures and/or longer period of organic practice by above farmers were probably responsible for buildup of available sulphur in soil.

5.4.5 DTPA-extractable micronutrients

The data on DTPA-extractable micronutrients in soils studied (Table 18, 19, 20, 21, 22, 23, 24 and 25) revealed that concentration of available Zn, Fe, Mn and Cu in all the soils, irrespective of type of farming or cropping system was above critical limits. But, however, the soils under organic farming recorded much higher concentration of the micronutrients than soils under conventional farming in all the cropping systems. The overall increase in availability of zinc, iron, manganese and copper ranged from 31.45, 32.45, 23.58 and 16.70 per cent, respectively in soils of vineyards to 47.80, 39.88, 27.77 and 26.66 per cent, respectively in soils of *kharif* jowar. Addition of large quantities of organic manures every year under organic farming practice was the cause for such marked increase in the DTPA-extractable micronutrients. Bellakki and Badanur (1997) attributed the increase in micronutrients in soils with addition of organics to the enhanced microbial activity and

consequent release of complex organic substances (chelating agents) besides addition of these nutrients to the available pool on decomposition of organics. Sharma *et al.* (2000) also observed the significant enhancement in DTPA-extractable micronutrients due to incorporation of crop residues and FYM compared to chemical fertilizers application.

5.5 EFFECT OF ORGANIC FARMING ON TOTAL MICROBIAL ACTIVITY IN SOIL

5.5.1 Dehydrogenase activity

The present study revealed that organic farming improves the enzymatic activities in soil. The dehydrogenase activity was higher in the soils under organic farming compared to conventional farming (Table 26). This might be due to increase in organic carbon, total N and phosphorus content in the soil due to application of organic manures, which are directly related to the dehydrogenase activity in the soil as observed by Baruah and Mishra (1984). Kukreja *et al.* (1991) noticed that the total microbial biomass and dehydrogenase activity of soil were significantly increased in the plots receiving FYM application annually for 20 years. Chandravanshi (1998) noticed that activities of dehydrogenase enzyme in the soil was increased by the application of FYM either alone or in combination with NPK fertilizer.

The highest increase in dehydrogenase activity was recorded in soils of C₄ farmer (94.4%) in cotton, K₁ farmer (137.90%) in jowar, S₃ farmer (101.80%) in sugarcane based cropping system and V₃ farmer (78.60%) in vineyards. Addition of higher quantities of organic manures and also long-term organic manuring (more than 5 years) were probably responsible for such enhanced dehydrogenase activity in those soils.

VI. SUMMARY

A study was conducted in the Northern Dry Zone of Karnataka to know the effect of farmers' practices in organic farming on soil properties and soil health in selected major cropping systems.

The soil samples were collected and analysed for soil physical, chemical and biological properties and also for availability of plant nutrients. The salient findings of the investigation are summarized in this chapter.

- Farmyard manure and vermicompost were the sources of organics used by organic farmers in the study area. The quantity of organics applied to soils varied from 8.0 to 20.0 tonnes of FYM per ha per year and 1.0 to 3.0 tonnes of vermicompost per ha per year.
- The nutrient (N, P and K) concentration was higher in vermicomposts than in FYM. The C:N ratio of vermicomposts was also narrower in vermicomposts (13:1 to 20:1) compared to its ratio in FYM (25:1 to 38:1).
- The quality of nutrients added to soil through organics varied widely depending upon the nutrient concentration and quantity of organics applied by the farmer.
- The physical properties of soils were found to be influenced favourably by the organic farming practice. A reduction in bulk density and an increase in water holding capacity and water stable aggregates was noticed in all the soils under organic farming.
- A reduction in pH was observed in soils under organic farming. But, however there was no appreciable change in the EC of soils.
- A wide variation in increase in organic carbon content (19.42% to 102.94%) of soils of organic farms over conventional farms was observed. The soils under organic farms also recorded higher CEC values than those under conventional farms and the increase was between 5.40 to 16.60 per cent.
- The soils under organic farming recorded higher amounts of available N, P, K and S than the soils under conventional farming.
- The average increase in available nitrogen and phosphorus in soils of organic farms over conventional farms ranged from 7.27 per cent and 6.85 per cent to 15.20 per cent and 23.80 per cent, respectively.
- The available potassium content increased marginally (2 – 5%) in the soils under organic farming.
- The available sulphur in soils, on an average, increased from 3.60 per cent (*kharif* jowar based cropping system) to 10.40 per cent (cotton based cropping system) due to organic farming practice.
- All the soils irrespective of type of farming and cropping system contained DTPA-extractable micronutrients above the critical concentration, with soils under organic farming recording comparatively higher amounts than those under conventional farming. A substantial increase in available status of Zn, Fe, Mn and Cu in soils of organic farms was observed.
- A marked increase in dehydrogenase activity was observed in the soils of organic farms in all the cropping systems.

From the study, it could be concluded that the soil properties get favourably influenced by organic farming practice which in turn would enhance the soil health.

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IMPACT OF FARMERS' ORGANIC FARMING PRACTICES ON SOIL PROPERTIES IN NORTHERN DRY ZONE OF KARNATAKA

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ABSTRACT

A study was conducted in the Northern Dry Zone of Karnataka to know the effect of farmers' organic farming practices on soil properties and health in selected major cropping systems *viz.*, cotton, sugarcane, jowar and vineyard. Farmyard manure and vermicompost were the sources of organics used by organic farmers in the study area. The quantity of organics applied to soils varied from 8.0 to 20.0 tonnes of FYM per ha per year and 1.0 to 3.0 tonnes of vermicompost per ha per year. The nutrient (N, P and K) concentration was higher in vermicomposts than in FYM. The C:N ratio of vermicomposts was also narrower (13:1 to 20:1) compared to its ratio in FYM (25:1 to 38:1).

The physical properties of soils were found to be influenced favourably by the organic farming practice. A reduction in bulk density and an increase in water holding capacity and water stable aggregates was noticed in all the soils under organic farming. A reduction in pH was observed in soils under organic farming, however there was no appreciable change in the EC of soils. Increase in organic carbon content of soils under organic farms varied widely over conventional farms. The soils under organic farms also recorded higher CEC values than those under conventional farms.

The soils under organic farming recorded higher amounts of available N, P, K and S than the soils under conventional farming in all the cropping systems. A substantial increase in available status of Zn, Fe, Mn and Cu in soils of organic farms was observed. A marked increase in dehydrogenase activity was observed in the soils of organic farms in all the cropping systems. It is concluded that the soil properties get favourably influenced by organic farming practice which in turn would enhance the soil health.