Impact of organic amendments on soil carbon sequestration and biomass carbon allocation of crops

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Division of Environmental Sciences

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Thesis

Submitted to

The Faculty of Horticulture
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in partial fulfilment of requirement for the award of the degree of

Doctor of Philosophy in Environmental Sciences

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Dedicated To My Parents

To whom I am indebted for their
blessings & affection and who
encouraged me to proceed along a path
"where tireless striving stretches its
arms towards perfection"

Sher-e-Kashmir
University of Agricultural Sciences and Technology of Kashmir
Faculty of Horticulture
Division of Environmental Sciences

Certificate – I

This is to certify that the thesis entitled “Impact of organic amendments on soil carbon sequestration and biomass carbon allocation of crops” **submitted in partial fulfilment of the requirements for the award of the degree of** Doctor of Philosophy in Environmental Sciences**, to the Faculty of Horticulture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, is a record of bonafide research work carried out by** Ms. Gowhar Bashir (Regd. No. 2010-334-D) **under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.**

It is further certified that any help or information received during the course of investigation have duly been acknowledged.

Dr. Shoukat Ara
Chairman
Advisory Committee

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Prof. & Head,
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Certificate – II

We, the members of the Advisory committee of **Ms. Gowhar Bashir (Regd. No. 2010-334-D)**, a candidate for the degree of **Doctor of Philosophy in Environmental Sciences**, have gone through the manuscript of the thesis entitled, **"Impact of organic amendments on soil carbon sequestration and biomass carbon allocation of crops"** and recommend that it may be submitted by the student in partial fulfilment of the requirements for the award of degree.

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Certificate – III

This is to certify that the thesis, **"Impact of organic amendments on soil carbon sequestration and biomass carbon allocation of crops"** submitted by **Ms. Gowhar Bashir (Regd. No. 2010-334-D)** to the Faculty of Horticulture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, in partial fulfilment of the requirements for the award of the degree of **Doctor of Philosophy in Environmental Sciences** was examined and approved by the Advisory Committee and external examiner on ………………..

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ABSTRACT

The present investigation was carried out during 2011, 2012 and 2013 to study the impact of organic amendments on soil carbon sequestration and biomass carbon allocation of crops. Three different types of organic amendments used were farmyard manure (FYM), poultry manure (PM) and vermicompost (VC). Ten different treatment combination of organic amendments were applied. Two test crops used were Kale (*Brassica oleraceae* var. *acephala* L.) and French bean (*Phaseolus vulgaris* L.). The experiment was laid out in a randomized block design with three replications of each treatment. Organic amendments play an important role in maintaining soil quality and carbon sequestration and thereby greenhouse gas mitigation. Maintaining and increasing soil organic matter (SOM) adds to soil fertility, water retention and crop production. In addition to applying carbon rich soil amendment it provides a high content of carbon to low carbon soils and thereby an improved environment for plant growth. This study was specifically conducted in a temperate climate to evaluate soil carbon sequestration under different nutrient management strategies. Results revealed a significant increase in soil carbon storage with organic treatments i.e. 100% VC followed by inorganic + organic treatment. Highest biomass productivity was observed in (organic + inorganic treatments) followed by recommended fertilizer dose. Above ground and below ground carbon content of Kale and French bean was significantly higher in 100% VC treatment followed by 100% FYM. Significantly lowest values were recorded in RFD in both the test crops. Significantly highest values for above and belowground carbon content were recorded in French beans. In an era when global warming is increasingly becoming an environmental threat to human existence, there is a need for studies of this nature which can provide information on the best soil amendments and cropping systems which will enhance soil carbon sequestration in the short term with increased crop yield/productivity. Organic amendments also restore soil quality by balancing pH, adding organic matter, increasing water holding capacity and re-establishing microbial communities. An understanding of the dynamics of carbon stock in soils, as effected by management strategies, is necessary to identify the pathways of carbon sequestration in soils and for maintaining soil organic carbon at a level critical for up keeping soil health and also for restraining global warming.

From the present study it was concluded that for achieving high carbon sequestration in soils, the crops should be fertilized with 100% vermicompost and French bean crop is recommended for better carbon storage in crop. However, for obtaining highest yield, combination of organic and inorganic fertilizers are recommended.

Key words : Carbon sequestration, Vermicompost, Organic amendments, Kale, Poultry manure, Farmyard manure

Signature of Student

Dated:____________

Signature of Major Advisor

Dated:________________

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بسم الله الرحمن الرحيم

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Gowhar Bashir

Place : Srinagar

Date :

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Chapter – 1

INTRODUCTION

Atmospheric concentration of CO_2 has increased from ~280 ppm in pre-industrial era to ~385 ppm (Pachauri, 2007) and is presently increasing at the rate of ~2 ppm/yr. Over the past 150 years, the amount of carbon in the atmosphere has increased by 30 per cent. The increase in CO_2 emission by human activity is attributed to industrialization, urbanization and increasing vehicular traffic. As the atmospheric concentration of CO_2 grows, there is increasing interest in restraining this growth in order to minimize potential impacts on the global climate by global warming, which is the most dreaded problem across the world. Thus several options of CO_2 sequestration being considered are soils, annuals, organic additives etc. (Lal, 2004). One of the main options for carbon mitigation identified by the IPCC is the sequestration of carbon in soils.

There is a growing concern that increasing levels of carbon dioxide in the atmosphere will change the climate, making the Earth warmer and increasing the frequency of extreme weather events. Organic matter in soils acts as a large carbon sink and plays an important role in the CO_2 balance. However, there is little information on how different nutrient management strategies could influence soil carbon sequestration in the short term during cropping cycles. Earlier studies considered soil carbon sequestration in the long term and mostly in temperate climates (Logah *et al*., 2011).

Soil organic matter is of central importance in maintaining soil quality and is also now receiving attention due to potential for carbon sequestration in soils. Soil quality is an integrated characteristic determined by biological, chemical and physical soil properties defining a soil's capacity to function. Maintaining or increasing soil organic matter is critical to achieving optimum soil function. In many parts of the world, organic wastes represent an inexpensive and plentiful resource for the treatment of soil quality (Sundermeier *et al*., 1996). Soil organic carbon is the most frequently reported soil attribute and is commonly selected as the key indicator of soil quality and agronomic sustainability because of its impact on other physical, chemical and biological elements. Thus organic amendments play an important role in maintaining soil quality and carbon sequestration and thereby green house gas mitigation Maintaining and increasing soil organic matter (SOM) adds to soil fertility, water retention and crop production. Recently, many soil scientists have suggested that the sequestration of atmospheric carbon dioxide in SOM could also contribute significantly to attempts to adhere to the Kyoto Protocol (Schlesinger, 1999).

Terrestrial carbon sequestration in this context is defined as the enhanced removal of carbon-dioxide from the atmosphere through the accelerated carbon storage in soils. In addition to applying carbon rich soil amendment it provides a high content of carbon to low carbon soils thereby an improved environment for plant growth. The underlying premise of building soil organic matter is a climate change mitigation strategy. Healthy soils store carbon and support plant growth which can remove more carbon-dioxide from the atmosphere than existing poor. In any biological system, carbon is present in several known forms in pools and compartments. In terrestrial systems, it is convenient to divide these reserves into aboveground and belowground pools (Xu and Juma, 1992). Roots play an important role in the carbon cycle as they transfer considerable amounts of carbon to the ground where it may be stored for a relatively long period of time. The plant uses part of the carbon in the roots to increase the total biomass through photosynthesis. Some roots can extend to greater depths, but the greatest proportion of the total root mass is within the first 30 cm of the soil surface. Root biomass is an important carbon pool because it often represents 10-40 per cent of total biomass.

In agricultural systems, optimization of carbon and nitrogen cycling through soil organic matter can improve soil fertility and yields while reducing negative environmental impact. A basic tenet that has guided the management of soil organic matter for decades has been that equilibrium levels of carbon and nitrogen are controlled by their net input and that qualitative differences in these inputs are relatively unimportant. This contrasts with natural ecosystems in which there are significant effects of species composition and litter quality on carbon and nitrogen cycling. Quantitative differences in net primary productivity and nitrogen balance across agroecosystems do not account for the observed changes in soil carbon and nitrogen (Drinkwater *et al.*, 1998). We suggest that the use of low carbon-to-nitrogen organic residues to maintain soil fertility, combined with greater temporal diversity in cropping sequences, significantly increases the retention of soil carbon and nitrogen, which has important implications for regional and global carbon and nitrogen budgets, sustained production and environmental quality.

Annuals and herbaceous plants like sorghums, annual ryegrass, Egyptian clover etc. reach physiological maturity much sooner than woody plants and therefore can sequester maximum amounts of carbon in as little as sixty days from germination. Perennial grassy and herbaceous plants generally take 1 to 2 growing seasons to reach physiological maturity before sequestering maximum amounts of CO_2. Actively managed annual and perennial grassy and herbaceous plants, by providing optimal levels of fertilizer and with optimal defoliation, stimulate the plant to photosynthesize at maximum levels, remove maximum amounts of CO_2 from the atmosphere and perpetuate the plant indefinitely.

With the adoption of improved technology for obtaining higher yields per unit area. Requirement of the nutrients has increased to many folds. Continuous use of inorganic fertilizers resulted in deficiency of micronutrients, imbalance in soil physicochemical properties and unsustainable crop production. With the increased cost of inorganic fertilizers, application of recommended dose is difficult to be afforded by the small and marginal farmers. Hence renewable and low cost sources of plant nutrients for supplementing and complementing chemical fertilizers should be substituted which can be affordable to the majority of farming community. In this context, integrated nutrient management would be a viable strategy for advocating judicious and efficient use of chemical fertilizers with matching addition of organic manures (Jayathilake *et al*., 2006). Farmyard manure is a conspicuous organic component of an integrated nutrient supply system, which improves soil health, increases the productivity and releases macro and micronutrients. The compost produced by using earthworms commonly called vermicompost is a rich source of macro and micro nutrients, vitamins, growth hormones etc. Vermicompost plays a significant role in improving the fertility of topsoil and in boosting the productivity of the crop (Ansari and Sukhraj, 2010).

The nutrient use efficiency of plants grown with chemical Nitrogen fertilizer is approximately 60 per cent. The principal loss results from leaching of nutrients and denitrification. During Nitrogen fertilizer production for every Kg of NH_3 produced, there is 10 Kg of carbon-dioxide emission. Legume crops can fix upto 100 Kg of N/ha annually. For each legume crop grown, approximately 1ton of carbon-dioxide carbon emission is avoided. Thus there is clearly a carbon emission benefit in using legume crops. In addition to increased plant residue input and increased soil organic carbon content, more importantly the carbon emission savings by using legume plants is permanent where soil carbon content increase resulting from increased inputs must be maintained continuously.

Generally, excessive amounts of inorganic fertilizers are applied to vegetables in order to achieve a higher yield and maximum value of growth. However, the use of inorganic fertilizers alone may cause problems for human health and the environment (Ouda and Mahadeen, 2008). So, inorganic fertilizer is considered a major source of plant nutrients. Organic manure can serve as alternative practice to mineral fertilizers for improving soil structure and microbial biomass. Therefore, utilization of locally produced manures by vegetable production operations may increase crop yields with less use of chemical fertilizer.

Thus, sequestration of carbon in soils be achieved by either reduced decomposition or increased carbon input. Incorporation of legumes for Nitrogen fixation in the crop rotation is a strategy that can lead to long term, permanent savings in green house gas emissions. Addition of manure and composts in soils can results in significant carbon accumulation in soils. Reducing tillage can result in soil organic carbon increase.

The primary way that carbon is stored in the soil is as soil organic matter. Soil organic matter is a complex mixture of carbon compounds, consisting of decomposing plant and animal tissue and microbes. Carbon can remain stored in soils for millenia, or be quickly released back into the atmosphere. Climatic condition, natural vegetation, soil texture and drainage all affect the amount and length of time for which carbon is stored. Soil microbial population drives the soil organic carbon and nutrient cycles. As the plant residue or other organic materials are attacked by the soil microbial population, a portion is assimilated by soil microbes becoming part of soil microbial biomass. The second fraction is released into the atmosphere as carbon-dioxide. The remainder is partially transformed and may be attacked later by the microbial population. The continued cycle of microbial residues in a soil is thus the most important process affecting long-term changes in soil organic carbon.

With the recent interest in the potential for agriculture to capture atmospheric carbon-dioxide, through the accumulation soil organic carbon, measurements in this area have been viewed as increasingly important promoting soil health and encouraging the development of soil organic matter have always been central tenets of the organic approach and the contribution of organic systems to this area has therefore been of considerable importance. The potential of agricultural systems to sequester atmospheric carbon-dioxide through building levels of soil carbon, has been an area of considerable interest in recent years in view of green house gas reduction targets set through policy measures like Annexure ‘B’ of the Kyoto Protocol.

Organic fertilizers and soil additives such as compost and manure are derived from waste outputs generated by other systems. These inputs are assumed to enter the farming systems without any environmental burden. Organic amendments have the great potential to improve soil organic carbon which helps to sustain soil fertility and conserve soil and water quality. Therefore organic amendments not only help to mitigate global warming by carbon sequestration but to establish a sustainable food system. Organic amendments also restore soil quality by balancing pH, adding organic matter, increasing water holding capacity and re-establishing microbial communities. Soil fertility is noticeably affected by microbial activity. Changes in the size and activity of the biomass can affect Carbon mineralization, turnover of organic matter and the cycling of N and P as well as their availability for plants as the biomass is a dynamic pool containing considerable reserves of these elements (Luna and Dager, 2010). The microbial biomass itself can be an important indicator of soil quality and the ratio of microbial carbon to soil organic carbon can provide an early warning of the improvement or deterioration of soil quality. The soil microbial biomass carbon (MBC) is an important component of soil organic matter and comprises 1-3per cent of total organic carbon in soil, but it has a rapid turnover rate and represents a labile reservoir of nutrients. Due to its dynamic character, microbial biomass responds to agricultural management practices (cultivation, crop rotation, residue management and amendments application) and other environmental variables often before effects are measurable in organic carbon content.

The organic matter content is a significant component and a key indicator of the quality of the soil. In fact, this parameter is directly related to different physical soil properties like, bulk density, porosity, water infiltration and water holding capacity. Of particular interest, manure and composts have received much interest and their positive impact on soil structure, stability, nitrogen and carbon content have been reported. Organic additives like manure, composts, sludge etc. decrease soil bulk density and reduces element toxicity. These amendments also increase soil aggregate stability, improve water holding capacity, enhance total and water soluble organic carbon, improve nutrient availability to plants and increase biomass production (Bouajila and Sanaa, 2011). Soils are the largest terrestrial sinks for carbon on the planet. The ability of agriculture lands to store or sequester carbon depends on several factors including climate, soil type, type of crop or vegetation cover and management practices (Diacono and Montemurro, 2010).

Soil microbes function as a transient nutrient sink and are responsible for releasing nutrients (N, P and S) from organic matter for use by plants. An understanding of microbial processes is important for the management of farming systems, particularly those that rely on organic inputs of nutrients. The soil microbial community is involved in numerous ecosystem functions, such as nutrient cycling and organic matter decomposition and plays a crucial role in the terrestrial carbon cycle. The microbial community is a more reactive component of a terrestrial ecosystem to external stress than plants and animals. Recognition of the importance of soil microorganisms has led to increased interest in measuring the nutrients held in their biomass. Besides living plant roots and organisms, soil microbial biomass is a living portion of soil organic matter. Soil microbial biomass is considered to act both as the agent of biochemical changes in soil and as a repository of plant nutrients such as nitrogen (N) and phosphorus (P) in agricultural ecosystems. The changes in soil organic carbon contents are directly associated with changes in microbial biomass carbon and biological activity in the soil. The response to changes in inputs of organic material is much quicker in soil microbial biomass than in soil organic matter as a whole. Microbial biomass contains labile fraction of organic carbon and nitrogen, which are mineralized rapidly after the death of microbial cells. Soil microbes are typically carbon limited. Lower microbial biomass in soils from conventional agroecosystems is often caused by reduced organic carbon content in the soil. The quantity and quality of organic inputs are the most important factors affecting microbial biomass and community structure (Nakhro and Dkhar, 2010).

This study was specifically conducted in a temperate climate to evaluate soil carbon sequestration under different nutrient management strategies. In an era when global warming is increasingly becoming an environmental threat to human existence, there is a need for studies of this nature which can provide information on the best soil amendments and cropping systems which will enhance soil carbon sequestration in the short term with increased crop yield. An understanding of the dynamics of carbon stock in soils, as impacted by management strategies, is necessary to identify the pathways of carbon sequestration in soils and for maintaining soil organic carbon (SOC) at a level critical for up keeping soil health and also for restraining global warming.

In view of the fact that the annuals and organic additives are helpful in increasing soil carbon pool the present investigation on “Impact of organic amendments on soil carbon sequestration and biomass carbon allocation of crops” was carried out with the following objectives:

1) To estimate the soil carbon pool.
2) To estimate the carbon stock of aboveground and belowground biomass of crops, and
3) To estimate the potential of crops in sequestering carbon.

Chapter – 2

REVIEW OF LITERATURE

Total organic matter accumulated in soils constitutes a major portion of the world’s fixed carbon reserves. Bohn (1976) estimated that the soil contains approximately 30×10^{14} Kg organic carbon. Distribution of this organic matter among soil type is highly variable and generally not easily predictable from aboveground vegetation type. The quantity of organic material retained within the soil matrix is the difference between total biomass production and decomposition.

Studies on carbon sequestration and management of soil quality with application of organic additives showed significant increase in nutrient availability. Application of Farmyard manure (7.5 t/ha), paddy straw (10 t/ha) and green manure (8 t/ha) alongwith inorganic fertilizer exhibited increase in microbial biomass carbon and mineralizable carbon. There was also a significant increase in non-labile carbon fraction (Ghosh *et al*., 1986).

Soil from a long-term crop rotation study conducted at Lethbridge, Alberta was analyzed to determine the influence of various spring wheat rotations with and without perennial forages on total and mineralizable soil organic matter contents. Effects of crop rotation on carbon mineralization were similar to those observed for N. Differences in amounts of mineralizable organic matter among treatments were attributed to varying frequencies and patterns of crop residue additions. The pronounced effects of crop rotation on the distribution of organic matter among labile and humified organic matter will have a strong impact on soil fertility and may need to be taken into consideration in the development of fertilizer recommendations (Janzen, 1987).

Campbell *et al.* (1991) worked on the effect of crop rotations and cultural practices on soil organic matter, microbial biomass and respiration in a thin black chernozem and concluded that fertilizer increased soil organic carbon and microbial biomass, soil organic carbon, C mineralization and microbial biomass carbon and N increased with increasing frequency of cropping and with the inclusion of legumes as green manure in the rotation. The influence of treatments on soil microbial biomass carbon was less pronounced than on microbial biomass N. Carbon mineralization was a good index for delineating treatment effects. Changes in amount and quality of the soil organic matter were associated with estimated amount and C and N content of plant residues returned to the soil. Organic carbon content of soils of Kinnaur and Lahaul & Spiti district ranged from 0.11 to 4.05 per cent as stated by Sharma and Singh (1991).

The soil organic carbon pool in the top 1m depth of world soils ranges between 1462 to 1576 Pg. It is nearly three times that in the aboveground biomass and approximately double that in the atmosphere, 32 per cent of this is contributed by soils in the tropics (Eswaran *et al*., 1993).

Biomass estimation by Jensen (1993) in Java showed that 16 MgC/ha/yr could be stored if rice fields were transformed in home-garden. Kern and Johnson (1993) reviewed data from 17 fields comparing no tillage plots in USA and observed that soil organic carbon gains were 27% for 0-8 cm layer, 16% for 8-15 cm layer and no gains for depth > 15cm.

Gupta and Harsh (1994) stated that the present stock of carbon in the Indian soils (24.3 Pg) could be increased to 34.9 Pg. Thus, there is a potential of 10.6 Pg for sequestrating additional carbon.

Quantifying changes in soil microbial biomass and mineralizable carbon and nitrogen is important in understanding the dynamics of the active soil C and N pools. The objectives were to quantify long-term and seasonal changes in soil organic C (SOC), soil microbial biomass C (SMBC) and N (SMBN) and mineralizable C and N in continuous sorghum [*Sorghum bicolor* (L.) Moench] and sorghum-wheat (*Triticum aestivum* L.)/soybean [*Glycine max* (L.) Merr.] sequences under conventional tillage (CT) and no tillage (NT) with and without N fertilization. Mineralizable C and SMBC averaged 18% greater in rotation than in monoculture, probably due to greater C input via crop roots and residues in rotation and a shorter fallow. Mineralizable N with N fertilization was 36% greater in continuous sorghum but not different in rotated sorghum. (Franzluebbers *et al*., 1995).

Ghoshal and Singh (1995) worked on changes in the soil microbial biomass following applications of farmyard manure and inorganic fertilizer, alone and in combination, for two annual cycles in a rice-lentil crop sequence. During the two annual cycles the microbial biomass carbon range ($\mu g\ g^{-1}$) was 146-241 (x = 204), 191-301 (245), 244-382 (305) and 294-440 (365) in control, fertilizer, manure and manure + fertilizer plots, respectively. The maximum increase in the microbial biomass, due to these inputs was observed under the manure + fertilizer treatment followed, in decreasing order, by manure alone and fertilizer alone. The maximum levels of microbial biomass C and P were observed during the summer fallow. The maximum accumulation of microbial biomass N occurred in the early rainy season, immediately after the soil amendments. Microbial biomass C, N and P were positively related to each other throughout the annual cycle.

Microbial biomass determinations may indicate changes in soil organic matter before they can be detected by measuring total soil carbon (Jenkinson and Ladd, 1981; Powlson *et al*., 1987) making possible its use as an indicator of early changes in soil organic matter content (Costantini *et al*., 1996).

To quantify the masses of soil C, N and P stored in soils from the agricultural regions of Ontario and to assess the impacts of agriculture by comparing soils under cropland and adjacent forests or woodlots. Ellert and Gregorich (1996) compared the forest soil with the surface layers of the cultivated soils (averaged for the 15 sites) and reported 34 per cent less C, 19 per cent less N and 24 per cent more P. Decreases in carbon storage were attributed to reduced carbon inputs and enhanced rates of plant litter decay. Changes in N storage were dependent on management of N fertility and cultivation-induced narrowing of C/N ratios indicated preferential maintenance of N relative to C storage. Increases in P storage were attributed to fertilization. These quantitative comparisons indicated that decreases in carbon storage were less severe than frequently suspected and that the increases in P storage may have an equally important influence on ecosystem function.

Cooper and Warman (1997) worked on the effects of three fertility amendments on soil dehydrogenase activity, organic carbon (OC) and pH. An Acadia silty clay and a Pugwash sandy loam were each fertilized with three rates of either composted chicken manure, fresh chicken manure, or synthetic fertilizer. The effects of these amendments on soil microbial activity (dehydrogenase enzyme activity, DHA), organic C and pH were monitored. There was no treatment effect on soil organic C in the sandy loam, while organic treatments increased organic C in the silty clay soil. Soil pH was affected by treatments to both soils with compost amendments producing the greatest increases in this parameter. The results emphasize the importance of considering initial soil organic C and soil texture when planning studies of the effect of organic amendments on soil microbial activity.

In a long-term field experiment started in 1956 on a clay loam soil at Uppsala, Sweden, changes of organic carbon in the topsoils receiving various organic amendments at the rate of 200 kg C/ha/year were studied to determine soil organic matter characteristics, variations of $\delta^{13}C$ in the soil and to estimate a carbon balance. Fallow and mineral fertilizer without N led to a significant decrease of soil organic matter (SOM) in the soil, green manure maintained the SOM content and animal manure and peat increased the SOM content significantly. Mineralization of microbially available organic substances led to an increase in the degree of humification on plots not receiving organic amendments. Adding peat and animal manure resulted in a decrease of the humification index due to the continuous input of poorly humified material (Gerzabek *et al.*, 1997).

As the amount of crop residue returned to the soil is increased, soil organic carbon sequestration is expected to increase if the residue carbon is not lost as

CO_2 to the atmosphere because of tillage induced decomposition (Larney *et al.*, 1997; Reicosky, 1997a,b).

Potter *et al.* (1997) determined crop rotation, tillage and fertilizer effects on SOC distribution and mass in the semiarid southern Great Plains. Total SOC content in the surface 20 cm was increased 5.6 t C/ha in the CW no-till treatment and 2.8 t C/ha in the CS no-till treatment compared with the stubble mulch treatment. Differences were not significantly different between tillage treatments in the wheat/fallow (WF) and wheat/fallow/sorghum/fallow (WSF) systems. No-till management with continuous crops sequestered carbon in comparison to stubblemulch management on the southern Great Plains. Fallow limits carbon accumulation.

Ritz *et al.* (1997) worked on temporal behaviour of microbial biomass C, N and respiration measured under barley crops in two experiments on successive years in a recently converted organic production system in Scotland. Soils were fertilised with farmyard manure or poultry manure. Control soils received no manure at the start of the growing season. C-flush values approximately doubled over the growing season in both years of the trial, showing a decline to pre-sowing values between the two seasons. Manure tended to increase the C-flush in the 2nd year only. N-flush in the 2nd year showed no increase in planted control plots but did increase in fallow soils. C-flush also showed a consistent and persistent increase in incubated soils. This suggests that the fundamental C-supplying characteristics of these soils was such that the biomass was moving towards a new equilibrium value fuelled by the relatively recent introduction of the organic farming regime.

Smith *et al.* (1997) studied the potential for carbon sequestration in European soils and reported only limited potential to increase soil carbon stocks over the next century by addition of animal manure, sewage sludge or straw (< 15 Tg C/yr) but greater potential through intensification is estimated to increase the total soil carbon, stock of European Union by 17 per cent.

Zueng Sang *et al*. (1997) tested 172 soil pedons of cultivated lands and forest of Taiwan for estimation of organic carbon pools. They found total organic carbon of 347 Tg from the soil surface to a depth of 100 cm. As estimated the organic carbon in soils was 196 Tg in the upper 50cm from the surface. They also reported that the mean soil organic carbon storage in the upper 30 cm depth of different cultivated soils ranged from 2.8 kg/m^2 in oxisols to 18.3 kg/m^2 in Andisols and in forest soils ranged from 383 kg/m^2 in Entisols to 36.9 kg/m^2 in Histosols.

Bronson *et al*. (1998) observed that despite straw removed in the low producing rainfed regions and straw burning in the productive and irrigated areas, carbon levels are constant in tropical and sub-tropical Asia. In clayed acid upland soils, carbon levels are usually higher than in the rice-rice, rice-wheat soils of the south and south eastern regions. In both regions, agroforestry appears effective in sequestering in soil organic carbon.

A study carried out by Drinkwater *et al*. (1998) on legume based cropping systems revealed that even in the intensely managed agroecosystems, plant species composition and litter quality influence soil organic matter (SOM) turnover markedly. Increase in SOM in the MNR (primary nitrogen source for maize) and LEG (legume system) were highly significant in terms of ecosystem function and soil quality. Greater retention of both carbon and nitrogen suggests that use of low carbon-to-nitrogen residues to maintain soil fertility combined with increased temporal diversity restores the biological linkage between carbon and nitrogen cycling in these systems and could lead to improved global carbon and nitrogen balance.

Haynes and Naidu (1998) worked on the effects of fertilizer and manure applications on soil organic matter status and soil physical properties and concluded that fertilizers are applied to soils in order to maintain or improve crop yields. In the long-term, increased crop yields and organic matter returns with regular fertilizer applications result in a higher soil organic matter content and biological activity being attained than where no fertilizers are applied. Additions of organic manures result in increased soil organic matter content. Many reports have shown that this results in increased water holding capacity and decreased bulk density.

A field study was conducted to evaluate the effect of different composts, spring-applied alone or in combination with ammonium nitrate (AN), on microbial biomass carbon (MBC) and alkaline phosphatase activity (APA) in two soils cropped with spring wheat (*Triticum aestivum* L.) in eastern Quebec, Canada. Generally, larger MBC and APA values were found at wheat harvest in soils treated with composts alone than with AN alone or unfertilized. These effects were related to soil C content and climatic conditions. Compost type affected soil biochemical properties which could be attributed to the total C supply and material maturation state. Compost addition constitutes an efficient short-term way to promote soil microbial biomass and enzyme activity in cold climates (Lalande *et al*., 1998). The benefit of increasing soil organic carbon is not only improved soil structure and water nutrient relationship, but includes the ability to store carbon in the soil to reduce atmospheric CO_2 (Lal *et al*., 1998; 1999).

Rochette and Gregorich (1998) reported that application of manure and fertilizer affects the rate and extent of mineralization and sequestration of C in soil. The objective of this study was to determine 3 yr of application of N fertilizer and different manure amendments on CO_2 evolution and the dynamics of soil microbial biomass and soluble C in the field. Manure amendments increased soil respiration and levels of soluble organic C and microbial biomass C by a factor of 2 to 3 compared with the control, whereas the N fertilizer had little effect on any parameter. The total manure-derived CO_2-C was equivalent to 52 per cent of the applied stockpiled-manure C and 67 per cent of the applied rotted-manure C. Estimates of average turnover rates of microbial biomass ranged between 0.72/yr and 1.22/yr and were lowest in manured soils. Manured soils also had large quantities of soluble C with a slower turnover rate than that in either fertilized or unamended soils.

Ball *et al*. (1999) concluded that low or zero CO_2 fluxes under no tillage are associated with reduced gas diffusivity and air filled porosity, while increased CO_2 emission with plough is due to degassing of soil carbon-dioxide.

Bruce *et al*. (1999) worked on carbon sequestration in soils and reported that application of nutritive amendments, including commercial fertilizers and organic amendments, favors soil carbon by increasing yields and, consequently, the amount of residues returned to the soil. Addition of organic amendments like livestock manure also promotes soil carbon by adding carbon directly, although this carbon is merely a recycling of crop carbon and does not necessarily represent a new input. Other agronomic options that may furnish higher yields include improved crop varieties, better pest control, more efficient fertilizer practices and improved water management (including irrigation). These higher yields will translate into higher soil carbon contents, provided the higher residue amounts are returned to the soil.

The effects of tillage and crop rotation on soil microbial biomass and activity were studied in 1995-1997 in the wheat phase of different cropping rotations that had been established in 1992 under zero tillage or conventional tillage in northern Alberta. Soil microbial biomass was often significantly ($P < 0.05$) higher, but never significantly lower, under zero tillage than under conventional tillage. The higher additions but lower losses of labile C under zero tillage mean that more C is sequestered in the soil in the zero-tillage system (Lupwayi *et al*., 1999).

Zebarth *et al*. (1999) worked on the influence of organic waste amendments on selected soil physical and chemical properties and concluded that annual applications of organic wastes for as long as 4 yr increased soil organic matter content, decreased soil bulk density and increased soil water retention of a coarse-textured soil. However, soil water-holding capacity was not necessarily increased and there was a limited effect on soil cation exchange capacity.

Dalal and Carter (2000) reported that the soil organic carbon in the 10cm layer decreased with cultivation duration from 7.5-22.1 to 4.4-10.2 Mg C/ha. The rate of loss was lower in coarse textured soils in Australia.

Manjaiah *et al.* (2000) investigated the soil organic C and N stocks, storage profiles and microbial biomass as influenced by different crop management systems in a tropical agricultural ecosystem. The different crop management systems significantly affected the C and N stocks and microbial biomass C and N at different soil depths. Amongst the systems evaluated, the rice-wheat system maintained a higher soil organic C content. Inclusion of legumes in the system improved the soil organic matter level and also soil microbial biomass activity, vital for the nutrient turnover and long-term productivity of the soil. Irrespective of the cropping system, approximately 58.4, 25.7 and 15.9 per cent of the C was distributed in 0-15, 15-30 and 30-60 cm depths, respectively.

A study was carried out by Muller (2000) on sequestration potential of organic agriculture and found that organic crop rotations with deep rooting legumes increased the carbon content in deep soil layer by rhizodeposition and dead root mass.

Witt *et al.* (2000) carried out studies on rapid chloroform-fumigation extraction method for measuring soil microbial biomass carbon and nitrogen in flooded rice soils and reported that chloroform-fumigation extraction method with fumigation at atmospheric pressure (CFAP, without vacuum) was developed for measuring microbial biomass C (CBIO) and N (NBIO) in water saturated rice soils. The method was tested in a series of laboratory experiments and compared with the standard chloroform-fumigation extraction. For both methods, there was little interference from living rice roots or changing soil water content (0.44-0.55/ kg wet soil). A comparison of the two techniques showed a highly significant correlation for both CBIO and NBIO ($P \leq 0.001$) suggesting that the simple and rapid CFAP is a reliable alternative to the CFE.

Carlos *et al*. (2001) studied the carbon sequestration rates for a tillage chronosequence and concluded that the carbon sequestration rates for no tillage was 80.6 g/cm^2/yr for the 0-20cm depth. The no tillage carbon sequestration potential for South Brazil was estimated as 9.37 TgC/yr.

Follet (2001) reported that crop rotations and winter cover crops have the potential to sequester 14-29MMTC/yr in zinc cropland soils. Biomass production was increased by efficient use of production inputs and optimum fertility levels and water availability in soils was found to affect the quantity of crop residues and carbon sequestration.

Gregorich *et al*. (2001) reported that legume-based cropping systems could help to increase crop productivity and soil organic matter levels, thereby enhancing soil quality, as well as having the additional benefit of sequestering atmospheric C. Cropping sequence (i.e., rotation or monoculture) had a greater effect on soil C levels than application of fertilizer. The difference in soil C levels between rotation and monoculture maize systems was about 20 Mg C/ha. The effects of fertilization on soil C were small (~6 Mg C/ha) and differences were observed only in the monoculture system.

Biomass serves as a carbon sink absorbing carbon from the atmosphere and storing it in the form of living plants matter and decomposed plant matter in the soils. Vast amount of carbon are continually being exchanged between this biosphere sink and the atmosphere. Approximately 120 billion tonnes of carbon is absorbed annually through photosynthesis and comparable amount is released through respiration and decomposition (Kartha, 2001).

In addition to nutrient cycling, residue retention also enhances numerous ecosystem services including improvement in soil quality, increase in agronomic productivity and profitability and decrease in risks of soil erosion, water runoff, loss of fertilizers, amendments and soil organic carbon (Lal, 2001).

Organic amendments increase soil organic matter level significantly. Carbon sequestration in agricultural soils is controlled by the balance of added organic residues and microbial oxidation of both residues and native organic matter as moderated by management and tillage (Rickman *et al*., 2001).

Singh (2001) worked on soil quality parameters and carbon sequestration as influenced by the management practices in rice-wheat maize-wheat cropping systems. The treatments consisted of two tillage, three water regimes and twelve nutrient levels. The results indicated that organic carbon and microbial biomass carbon increased in the treatments receiving application of organic manure (particularly FYM), green manure and biofertilizers in conjunction with inorganic fertilizers.

The Carbon sequestration potential of any soil depends on its capacity to store resistant plant components in the medium term and to protect and accumulate the humic substances (HS) formed from the transformations or organic materials in the soil environment. The sequestration potential of a soil depends on the vegetation it supports, its mineralogical composition, the depth of the solum, soil drainage, the availability of water and air and the temperature of the soil environment. The sequestration potential also depends on the chemical characteristics of the soil organic matter and its ability to resist microbial decomposition. It is encouraging to know that improved soil and crop management systems now allow field yields to be maintained and soil C reserves to be increased, even for soils with depleted levels of soil C (Swift, 2001).

Chellem and Lazarovits (2002) reported that application of 560 N, 110 P, 440 K (kg/ha) resulted in an increase in soil pH and counts of total soil fungi but not total soil bacteria. A second location that had been previously cropped to vegetables under certified organic production guidelines and had moderate levels of soil fertility, was used to test the effect on cantaloupe yields. An application rate of 110 N, 22 P, 88 K (kg/ha) of Nature Safe increased early yields as compared to a formulation of dried poultry manure applied at 112 N, 90 P, 112 K (kg/ha) or an unfertilized control. This study demonstrated that organic fertilizers can provide multiple benefits for Florida vegetable production systems including improving fertility and increasing soil microbial populations.

The goal of long-term agroecological research (LTAR) sites in four distinct agroecological zones in Iowa was to examine the short-and long-term physical, biological and socioeconomic effects of organic and conventional farming systems. By establishing long-term experiments, Delate (2012) tested the hypothesis that longer crop rotations, typical of organic farms, provide yield stability, improve plant protection and enhance soil health and economic benefits compared to conventional systems with shorter rotations and greater off-farm inputs. Examples of research results from two LTAR experiments in Iowa include pepper (*Capsicum annuum*) and soybean (*Glycine max*) yields in the conventional and organic systems. Organic systems used mechanical weed control and locally produced compost in place of synthetic fertilizers.

Halvorson *et al*. (2002) worked on the tillage system and crop rotation effects on dryland crop yields and Soil Carbon. The study was conducted from 1990 through 1994 and evaluated the effect of tillage system with the varying degrees of soil disturbance and crop rotations on crop yield and SOC and found that reduced tillage and intensified cropping increased SOC and reduced soil erosion potential.

Incorporation of legumes in nitrogen fixation in the crop rotation is a strategy that can lead to long term permanent savings in green house gas emission. Addition of the manure and composts in the soil can result in significant carbon accumulation in soils and reduced tillage can result in increase carbon sequestration (Feng and Xiaomei, 2002).

Lal (2002b) reported that the most soils in the mid Western USA have lost 30-50per cent of their original pool or 25-40 Mg C/ha upon conversion from natural to agricultural ecosystems. About 60-70% of the carbon thus depleted can be resequestered through adoption of recommended soil and crop management practices. The gross rate of soil organic carbon sequestration ranges from 500-800 kg/ha/yr in cold and humid regions and 100-300 kg/ha/yr in dry warm regions and there is also a large potential to sequester soil carbon in arid and semi-arid regions.

Stopping erosion by surface mulching was found to be an effective way to keep soil carbon intact in Thailand (Limtong and Manu, 2002). Returning 15-30% of the crop residues lead to stabilization of soil carbon content. In India, Rastogi *et al*. (2002) reported the amount of carbon stored in the soil is 23.4-27.1 Gt which is 1.6 to 1.8% of carbon stored in the world's soils.

Tristram (2002) reported an increase in gross carbon sequestration of approx. 168 kg/ha/yr conventional to no till practices and the potential to sequester carbon varies considerably between crop type, crop rotation and the amount of fertilizer necessary for crop growth. The lower gross carbon sequestration value obtained using all crop types was found to be lower for cereal grains than from continous corn crops.

Soil microbial biomass is a living pool containing 1-5% of the soil organic matter (Jenkinson and Ladd, 1981; Sparling, 1992), excluding root, meso and macro fauna. Its activity and often fast turnover impact soil characteristics affecting its quality by conduction of biochemical transformation of organic matter being a source or a sink of plant nutrients (Franzluebbers, 2002; Haubensak *et al*., 2002; Hargreaves *et al*., 2003).

To monitor the impact of crop rotations and compost applications on C sequestration, soil organic matter (SOM) decomposition and the turnover time of C_4-derived C in the soil via changes in the C content. Fortuna *et al*. (2003)

conducted studies on management practices that influence the quantity of C inputs returned to the soil from cropping systems and compost applications alter subsequent biotic activity broadly, contribute to seasonal fluctuations in nutrient dynamics and may increase carbon sequestration. They reported POM-C in the soil 45 per cent higher and SOC 16 per cent greater where compost was applied in place of N fertilizer.

Adoption of recommended management practices (RMPs) can enhance the soil organic carbon (SOC) pool to fill the large C sink capacity on the world's agricultural soils. This article collates, reviews and synthesizes the available information on SOC sequestration by RMPs, with specific references to crop rotations and tillage practices, cover crops, ley farming and agroforestry, use of manure and biosolids, N fertilizationand precision farming and irrigation. There is a strong interaction among RMPs with regards to their effect on SOC concentration and soil quality (Jarecki and Lal, 2003).

Sherrod *et al.* (2003) evaluated the effect of no-till systems of wheat (*Triticum aestivum*)-fallow (WF), wheat-corn (*Zea mays*)-fallow (WCF), wheat-corn-millet (*Panicum miliaceum*)-fallow, continuous cropping (CC) without monocultureand perennial grass (G) on SOC and total N (TN) levels at three eastern Colorado locations. Soil organic C and TN increased 20% in the CC system compared with WF in the 0-to 10-cm depth. The greatest impact was found in the 0 to 2.5-cm layerand decreased with depth. Annualized stover biomass explained 80% of the variation in SOC and TN in the 0 to 10-cm soil profile. Cropping systems that eliminate summer fallowing are maximizing the amount of SOC and TN sequestered.

Smith (2003) worked on carbon sequestration in croplands and concluded that the biological potential for carbon storage in European cropland is of the order of 90-120 MtC per year with a range of options available including use of organic amendments (animal manure, sewage sludge, cereal straw, compost) improved rotations, reduced and zero tillage and deep rooting crop.

Foereid (2004) reported an increase in soil organic matter of about 10-40 g/cm^2/yr in Northern Europe , the use of grass clover in the rotation and as cover crops was particularly important for the increase in organic matter.

Cropping systems that included wheat contained the greatest amount of CT and NT. Continuous wheat contained 2910 g C/m^2 and 287 g N/m^2, compared to 2225 g/C m^2 and 222 g N/m^2 (0-15 cm) for continuous soybean. No-tillage contained 1128 g C/m^2 and 109 g N/m^2 at 0-5 cm compared to 918 g C/m^2 and 87 g N/m^2 for CT. Sorghum contained 51% more C_o than soybean and NT accounted for 59% more C_o than CT. More crop residue was produced and retained in rotations that included sorghum. No-tillage increased C 2440 kg/ha, while CT increased C 340 kg/ha across all soybean/sorghum rotations. The highest sequestration rate (122 kg C/ha/y) was observed with NT sorghum and was equivalent to ~3.2% of the plant material (root and shoot, less gain harvest) remaining in the soil annually (Doyle *et al*., 2004).

Total, particulate organic matter (POM)and soil microbial biomass (SMB)-C and-N pools were assessed for each experiment by (Griffin and Porter, 2004). Total C and N stocks were not affected by red clover (*Trifolium pratense* L.) cover crop or legume GM, but were increased by 25-53% via a single application of annual manure and/or compost amendment. With the exception of continuous potato production which dramatically reduced the SMB-C and SMB-N concentration, SMB-C and-N were minimally affected by changes in cropping sequence, but were quite sensitive to amendments, even those that were primarily C. POM-C and-N, associated with the coarse mineral fraction (53-2,000 µm), were more responsive to management factors compared to total C and N in soil. The change in soil C fractions was a linear function of increasing C supply, across all experiments and treatments. Within these intensively tilled, 2-year crop rotations, substantial C and N inputs from amendments are needed to significantly alter soil C and N pools, although cropping sequence changes can influence more labile pools responsible for nutrient cycling.

Lal (2004) worked on the potential of carbon sequestration in soils and concluded that soil carbon sequestration increases on agricultural soils with manuring and cover cropping, mulch farming and conservation tillage.

Pan *et al*. (2004) worked on estimation of the topsoil soil organic carbon (SOC) pool and the sequestration potential of paddy soils in China was made by using the data from the 2nd State Soil Survey carried out during 1979-1982 and from the nationwide arable soil monitoring system established since then. Results showed that the SOC density ranged from 12 to 226 t C/ha with an area-weighted mean density of 44 t C/ha, which is comparable to that of the US grasslands and is higher than that of the cultivated dryland soils in China and the US. The estimated total topsoil SOC pool is 1.3 Pg, with 0.85 Pg from the upper plow layer and 0.45 Pg from the plowpan layer. Therefore, practicing sustainable agriculture is urgently needed for enhancing SOC storage to realize the ultimate SOC sequestration of rice-based agriculture of China, as the current C sequestration rate is significantly lower than the potential rate.

Antil *et al*. (2005) worked on the influence of fertilizer amendments (organic manure and mineral fertilizers) and management practices (fallow *vs.* cropped) on changes in organic carbon (OC) associated with different particle-size fractions. Organic Carbon in plots receiving organic manures increased depending on the quality of the organic manures applied. The ranking among the different treatments under both fallow and cropped plots was: animal manure (liquid) > animal manure (solid) > cattle slurry = slurry + straw = PK = NPK. Results showed that the two types of management practices, fallow (non-tilled) *vs.* cropped (tilled) had effects on OC concentrations. Comparing the OC contribution of particle-size fractions to the total OC amount revealed the following ranking: silt > clay > fine sand > coarse sand except in the plots receiving solid or liquid animal manure.

The effectiveness of no-till (NT) farming in reducing loss of soil organic matter (SOM) depends on climate and soil properties. Tillage treatments for continuous corn (*Zea mays*) were NT, chisel plow (CP)and moldboard plow (MP). No-till increased SOC and N pools in the 0 to 5-cm layer in silt loam soil but had no effect in clay soil. The rate of SOC sequestration in the silt-loam soil under NT was 175 kg C/ha/y. For both soils, there were no differences between tillage treatments in several soil properties including texture, available water capacity, hydraulic conductivity (K_s) and cation exchange capacity. The NT decreased soil bulk density and pH in the 0 to 15-cm layer in the silt loam soil. The plow till treatments had a small impact on soil aggregation in clayey soil (Jarecki and Lal, 2005).

Jorg and Silke (2005) reported the long-term effects of applying different organic amendments and mineral N fertilizer levels to soils on the content of: (1) microbially decomposable carbon (Cdec); and (2) microbial biomass carbon (Cmic). The Cdec content of soils that were covered with a vegetable crop rotation were determined and established that the differences between treatments with and without organic amendments corresponded very well to those found under arable crop rotations. Under the given experimental conditions, leaving the crop residues on the field generated an optimum level of soil organic matter content. When the Cdec content of the soils after applying different organic amendments as based on the C input were compared, they were found them to be similar. 10 t ha/yr farmyard manure (FYM) has been reported to be sufficient to generate an optimum level of organic matter in arable soils.

Lupwayi *et al.* (2005) applied cattle manure, hog manure or inorganic fertilizers annually or triennially in field trials conducted at two sites over 3 yr. A control treatment without manure or fertilizer was also included. Canola (*Brassica napus*) was grown in year 1, hulless barley (*Hordeum vulgare*) in year 2 and wheat (*Triticum aestivum*) in year 3. Cattle manure increased soil microbial biomass carbon (MBC) by 26% to three-fold, hog manure by 31% to two-fold and inorganic fertilizers reduced MBC by 20-64%. Similar effects, except the reduction by inorganic fertilizers, were observed for functional diversity of soil bacteria and Shannon index, H′.

Sainju *et al.* (2005) reported that aboveground biomass yield of rye decreased from 6.1 to 2.3 Mg/ha from 2000 to 2002, but yield of hairy vetch varied (2.4 to 5.2 Mg/ha). In contrast, biomass yield of vetch and rye biculture (5.6 to 8.2 Mg/ha) was greater than that of rye and vetch planted alone in all years. Compared with winter weeds in no cover crop treatment, C content in rye (1729 to 2670 kg/ha) was greater due to higher biomass yield, but N content in vetch (76 to 165 kg/ha) was greater due to higher N concentration, except in 2002. As a result, C (2260 to 3512 kg/ha) and N (84 to 310 kg/ha) contents in biculture were greater than those from monocultures in all years. Similarly, belowground biomass yield and C and N contents were greater in biculture than in monocultures. Because of higher biomass yield and C and N contents, biculture of hairy vetch and rye cover crops may increase N supply, summer crop yields and N uptake compared with rye and may increase potentials to improve soil organic matter and reduce N leaching compared with vetch.

Flavel and Murphy (2006) worked on Carbon and Nitrogen Mineralization Rates after Application of Organic Amendments to Soil. The objective of this study was to quantify C and N mineralization rates from a range of organic amendments that differed in their total C and N contents and C quality. There was a highly significant relationship between CO_2-C evolution and gross N mineralization (R^2=0.95). Some of the chemically determined C quality parameters had significant relationships (p<0.05) with both the cumulative amounts of C and N evolved.

Goyal *et al.* (2006) worked on Soil organic matter level, microbial biomass C and N, mineralizable C and Nand dehydrogenase activity in soils from a field experiment under rice-barley rotation receiving inorganic fertilizers and a combination of inorganic fertilizers and organic amendments. The amounts of soil organic matter and mineralizable C and N increased with the application of inorganic fertilizers. Microbial biomass C and N increased significantly with the addition of organic along with inorganic fertilizers (536 mg/kg soil) than unfertilized soil (241 mg/kg soil). The results indicated that the improvement in organic matter, microbial activities and crop yields due to use of inorganic fertilizers along with organic manures can help in sustaining the long-term productivity of the soil.

Makumba *et al*. (2006) worked on long term impact of a gliciridia-maize intercropping system on carbon sequestration in Southern Malawi. The studies involved two field plots, 7-year (MZ21) and 10 year (MZ12), two production systems (sole maize and gliciridia maize simultaneous intercropping system). The amount of organic carbon recycled varied from 0.8-4.8 Mg C/ha in gliricidia maize and concluded that gliricidia maize intercropping system sequesters more carbon in soil than sole maize.

Pendell *et al*. (2006) examined the economic potential of no-tillage versus conventional tillage to sequester soil carbon by using two rates of commercial N fertilizer for continuous corn (*Zea mays* L.) production. The values of carbon credits that provide an incentive for managers to adopt production systems that sequester carbon at greater rates were derived. No-till systems had greater annual soil carbon gains, net carbon gainsand net returns than conventional tillage systems. Systems that used beef cattle manure had greater soil carbon gains and net carbon gains, but lower net returns, than systems that used commercial N fertilizer. Carbon credits would be needed to encourage the use of manure-fertilized cropping systems.

Ghosh *et al.* (2007) reported no effect on Soil nitrate-N content by the addition of organic materials, but addition of cattle manure produced higher exchangeable potassium and phosphorus concentration over two years in cotton crop. Higher nutrient uptake was observed by mature cotton, leaving the soil depleted of these nutrients during that period, no significant effect on the short-term microbiological properties measured by microbial biomass and respiration.

Soil management strategies have great potential to contribute to carbon sequestration, since the carbon sink capacity of the world's agriculture and degraded soil is 50-60 per cent of the historic carbon loss of 42-72 Pg, although the actual carbon storage in cultivated soil may be smaller if climate changes lead to increasing mineralization. No tillage practices, cover crop management and manure application are recommended to enhance soil organic carbon storage and to contribute to sustainable food production, which also improves soil quality (Komatsuzaki and Ohta, 2007).

Mandal *et al*. (2007) carried out their work on potential of cropping systems and soil amendments for carbon sequestration in soils under long term experiment in subtropical India and concluded that for sustenance of soil organic carbon level a minimum quantity of 2.9MgC is required to be added per hectare per annum as inputs.

Bhattacharyya *et al*. (2008) reported that soils are one of the most important natural resources in enhancing carbon capture and storage. They also reported that soils capture and store both organic and inorganic forms of carbon and thus act both as source and sink for atmospheric carbondioxide.

Bradley *et al*. (2008) determined the effect of cover crops, manure and compost on short-term carbon sequestration rates and net global warming potential (GWP) in a corn-soybean [*Glycine max* (L.) Merr.] rotation with complete corn stover removal. Field experiments consisting of a corn-soybean-corn rotation with whole-plant corn harvest, were conducted near East Lansing, MI over a 3-yr period beginning in the fall of 2001. Carbon amendments were: compost, manure and a winter cereal rye (*Secale cereale* L.) cover crop. Compost and manure amendments raised soil C levels in the 0 to 5 and 0 to 25 cm soil profile but not in the 5 to 25 cm soil profile over the relatively short-term duration of the study. Total soil organic C (SOC) (kg/ha) in the 0 to 25 cm profile increased by 41 and 25% for the compost and manure treatments, respectively and decreased by 3% for the untreated check. Compost and manure soil amendments resulted in a net GWP of −1811 and −1060 g CO_2/m^2/yr, respectively, compared to 12 g CO_2/m^2/yr for untreated.

Joginder *et al.* (2008) reported that application of sodic water and organic amendments significantly increased MBC; GM and FYM were more effective than WS (wheat straw). Changes in soil ESP (exchangeable sodium percentage) explained 85 and 75% variation in MBC in the unamended and organically amended SW (sodic water) treatments, respectively. Soil pH as additional variable improved the predictability of MBC to 96 and 77%. Application of organic amendments significantly increased the rice and wheat yield; it was significantly correlated with MBC (r = 0.56, n = 60).

Lu (2008) worked on assessment of the availability of nitrogen fertilization in improving carbon sequestration potential of China's cropland soil. The results showed that the application of synthetic nitrogen fertilizer could bring about a carbon sequestration potential of 21.9 Tg C in current situation and 30.2 Tg C with fertilization as recommended. However, under the two scenarios, the greenhouse gas leakage caused by fertilizer production and application would reach 72.9 and 91.4 Tg C and thus, the actual available carbon sequestration potential would be-51.0 and-61.1 Tg C, respectively. The situation was even worse under the 'fertilization as recommended' scenario, because the increase in the amount of nitrogen fertilization would lead to 10. 1 Tg C or more net greenhouse gas emission. All these results indicated that the application of synthetic nitrogen fertilizer could not be taken as a feasible measure for the carbon sequestration of cropland soil in China.

Singh (2008) while studying carbon sequestration in soils of cool temperate regions of Europe and reported that the northern regions have a large potential of soil organic carbon sequestration. However, with predicted global warming soils in these areas may become source of atmospheric carbon dioxide. The rehabilitation of peat lands has shown a potential for SOC sequestration ranging from 25 to 45 g/cm^2/yr in Scandinavian countries. He also reported that conservation tillage, reduced soil erosion, restoring wetlands and degraded lands coupled with improved cultivation practices e.g, fertilizer application, crop rotation and cover crops can make the soil of this as carbon sink.

Abrahamson *et al.* (2009) worked on predicting soil organic carbon sequestration in the South eastern United States with EPIC and the soil conditioning index and concluded sequestration of soil organic carbon was greater under no tillage than under the conventional tillage and found dairy manure input had a large positive effect on simulated soil organic carbon.

Masakazu and Faiz (2009) carried out their studies on organic rice production system and soil carbon storage in West Java, Indonesia and the results from soil analysis indicated that organic farming had significantly higher soil carbon storage capacity than conventional farming, organic farming increases 1.85MgC/ha/yr soil carbon storage compared to conventional farming system.

Ahlgreacute and Turpeinen (2007) worked on the potential of cropping systems and soil amendments for carbon sequestration in soils in sub-tropical India and concluded that long-term application of organic amendments (5-10 Mg ha/yr) through farmyard manure (FYM) or compost could increase SOC hardly by 10.7% constituting only 18% of the applied C, the rest getting lost through oxidation. The total quantity of soil C sequestered varied from −11.5 to 14.5 Mg C/ha and was linearly related (r^2=0.40, P=0.005) with cumulative crop residue C inputs to the soils. On an average, the rate of its conversion to SOC came out to be 6.4 per cent. This was more in presence of added organics (6.9%) than in its absence (4.2%). For sustenance of SOC level (zero change due to cropping) we found that a minimum quantity of 2.9 Mg C is required to be added per hectare per annum as inputs. The cropping systems and the management practices that could provide C input higher than the above critical level are likely to sustain the SOC level and maintain good soil health in the subtropical regions of the Indian subcontinent.

To determine whether a topsoil addition with a corn (*Zea mays*)-soybean (*Glycine max* (L). Merr.) annual rotation could improve soil carbon in areas that have had topsoil removed. Grote and Kaisi (2007) conducted survey on the aboveground biomass production and root biomass of corn grown in topsoil was 7.14 and 0.8 Mg/ha (3.18 and 0.40 ton/ac) more than corn grown in the subsoil, respectively. This led to greater potential C inputs from corn grown in topsoil. The improvement in soil organic carbon in the subsoil 0 to 60 cm (0 to 24 in) soil depth with corn and soybean crops over the past 28 years averaged at 0.70 Mg/ha/yr (0.31 ton/ac). It was also observed that microbial biomass carbon contents were 247 and 157 μg/g (247 and 157 parts per million) for topsoil and subsoil, respectively.

Soil organic carbon associated with the fine fraction of forest soils was significantly greater than the calculated protective capacity, with clay-rich soils averaging 141 per cent more C than this limit and coarser soils having 56 per cent more than predicted. In contrast, C content of cropped soils was well below the calculated protective capacity, averaging ~32-60 per cent less than this limit, showing the potential of these soils for sequestering C. The study illustrates that (i) the capacity of soils to preserve soil organic C in clay-and silt-sized particles was greater than that of agricultural soils and (ii) in highly saturated soils, the N mineralization is a function of the quantity of organic-matter input, which in turn accumulates as free organic C in the sand-size fraction (Matus *et al*., 2007).

Yang *et al*. (2007) reported that the microbial biomass carbon (MBC), nitrogen (MBN) and phosphorus (MBP) ranged from 646.32 to 1132.05, 31.46 to 100.57 and 13.00 to 51.62 μg/g respectively. Furthermore, the microbial biomass at the upper layer was higher than those at the lower layer and showed positive correlation with each other. Under *R. simsii* brushland, *P. viviparum* grassland and grass steppe, the MBC, MBN and MBP showed significant negative correlation with the soil water content and bulk density. The microbial biomass also showed significant positive correlation with the pH under *R. simsii* brushland and *S.*

cupularis brushland, however, significant negative correlation with pH under *P. fruticosa* brushland, *P. viviparum* grassland and *K. capillifolia* grassland. The contribution of MBC, MBN and MBP to soil organic matter, total nitrogen and total phosphorus varied from 0.45 to 0.84%, 0.65 to 1.30% and 0.54 to 3.39% respectively. The microbial biomass C:N ratios ranged from 9.59 to 24.95 and the microbial biomass C:P ratios from 17.13 to 91.65.

Dinesh *et al.* (2008) worked on the influence of short term incorporation of organic manures and biofertilizers on biochemical and microbial characteristics of soils under an annual crop (Turmeric) and concluded that application of organic manures and biofertilizers positively influenced microbial biomass carbon, nitrogen mineralization, soil respiration and enzyme activities. The findings imply that even short term incorporation of organic manures and biofertilizers promoted soil microbial and enzyme activities and these parameters are sensitive enough to detect changes in soil quality.

Gilani and Bahmanyar (2008) worked on the impact of organic amendments with and without mineral fertilizers on soil microbial respiration. Organic amendments were added to soil at rate of 0 (control treatment), 20 and 40 Mg/ha. Furthermore each level of organic fertilizers with ½ normal of chemical fertilizer was also enriched. Soil samples were taken after one year of fertilization. Results illustrated that application of organic amendments increased TOC and SMR and soybean yield compared to control and chemical fertilizer treatments. An increasing trend was observed in all studied parameters, as rates of application increased. All parameters were greater in treatments receiving a combination of chemical fertilizers and organic amendments (enriched treatments) compared to soils receiving organic amendments alone.

Lin *et al.* (2008) analyzed the change of soil organic carbon (SOC) under different cropland management regimes, estimated carbon sequestration under cropland management in China. The most successful management system for increasing SOC was using inorganic and organic fertilizers together, which could increase SOC 0.889 t/ha/yr. Next came straw returning, using organic fertilizer and no-tillage, respectively achieving SOC 0.597, 0.545, 0.514 t/ha/yr. Results also showed the change of SOC varied with different management systems and different areas. The cropland management techniques of using inorganic and organic fertilizer together, straw returning, using organic fertilizer and no-tillage could all increase SOC significantly.

No effect of mulching on any of soil properties but significant effects of manuring and chiseling was reported by Shrestha *et al.* (2008). Aboveground biomass production, biomass Nitrogen content, soil Nitrogen and soil organic carbon pools were also significantly higher in the manure and chiseling treatments probably due to exploration of the soil volume by plant roots and more efficient uptake of water and available nutrients.

Koga and Tsuji (2009) worked on the effects of different tillage and C input management (residue management and manure application) practices on crop yields, residue C and annual changes in total soil organic carbon (SOC) (0-30 cm depth) over one cycle of a 4-year crop rotation (2003-2006) on a cropped Andisol in northern Japan. The combination of RT, residue return and manure application (20 Mg/ha in each year) increased spring wheat and potato yields significantly; however, soybean and sugar beet yields were not influenced by tillage practices. For all crops studied, manure application enhanced the production of above-ground residue C. Thus, manure application served not only as a direct input of C to the soil, but the greater crop biomass production engendered enhanced subsequent C inputs to the soil from residues. When soil C sequestration rates, as represented by annual changes in total SOC (0-30 cm), were assessed on a total soil mass basis, an anova showed that tillage practices had no significant effect on total C sequestration, but C input management practices had significant positive effects ($p \leq 0.05$). These results indicate that continuous C input to the soil through crop residue return and manure application is a crucial practice for enhancing crop yields and soil C sequestration.

Tweeten *et al*. (2009) worked on possibilities and constrains for the consideration of organic agriculture within carbon accounting system and found that carbon sequestration through soil organic amendments improves soil tilth, nutrient release and moisture holding capacity.

A pot experiment was set up by Xinjian *et al*. (2009) to investigate the effects of different organic fertilizers on soil microbial biomass and yield of groundnut. The results show that economic and biologic yields of groundnut are improved by applying fertilizers. It is found that the certain microbe population increases by the application of various organic fertilizers compared with the treatments of inorganic fertilizer. Also the application of different organic fertilizers improves microbial biomass though to different degrees. Therefore different organic fertilizers affect both soil microbial biomass and diversity trait.

Yang *et al*. (2009) results show that the soil organic matter varies from 82.3 to 207.2/kg and is influenced by vegetation type. K_2SO_4 extractable carbon and microbial biomass carbon range from 23.61 to 138.81 mg/kg and from 156.19 to 1182.84 mg/kg respectively. Contribution of K_2SO_4 extractable carbon to soil organic matter and MBC varies from 0.03 to 0.06% and from 9.97 to 18.46% respectively.

A field experiment was conducted during *Rabi* season of 2008-09 on clay loamy soil under long term organic manurial trial at TNAU, Coimbatore, to study the effect of green manure and different sources of organic manures on yield and soil chemical properties of rice. Green manure incorporation along with poultry manure application resulted in higher soil available N, P and increased K uptake. Higher N and P uptake and increased soil available K was recorded with green manuring and poultry manure application. Incorporation of green manure *in situ*, vermicompost and poultry manure decreased the soil electrical conductivity (EC), pH and increased the organic carbon content of soil compared to all other combination of treatments **(**Deshpande and Devasenapathy, 2010).

Dhull *et al*. (2010) worked on the effect of chemical fertilizers and organic amendments on soil chemical and microbiological properties over a period of 3 years. Soil organic carbon and total N increased in treatments receiving a combination of organic amendments and different doses of chemical fertilizers compared to soils receiving chemical fertilizers alone. Mineral N and available P in the soil were greater with the integrated use of chemical fertilizers and organic inputs. Microbial biomass C increased significantly with the combined application of chemical fertilizers and organic amendments, in comparison to soils receiving chemical fertilizers alone. The results indicated that there is improvement in soil organic matter, microbial activities and crop yields due to the use of chemical fertilizers along with organic manures. Such positive effects of organic inputs can help in maintaining organic matter level and sustain good crop yields over a period of time without deteriorating soil health.

Leifld (2010) reported increase in soil organic carbon content in organic systems by 2.2 per cent annually on average, where as in conventional systems soil organic carbon did not change significantly.

Pasture and conventionally cultivated vegetable cropping land were converted to ‘organic’ vegetable cropping, compost was applied and 0, 1, or 2 legume green manure crops grown in rotations. Microbial biomass carbon (C) and nitrogen (N) (fumigation-incubation): and water content was monitored over 18 months. Microbial biomass C and N declined during the first 6 months in ex-pasture soils, but remained larger than in ex-vegetable soils, in which there was little change in microbial biomass C and N with time. In ex-vegetable soils, water content and microbial C and N were increased by the inclusion of 2 (and sometimes 1) legume phases in the relation, but only after the legume residues had been substantially decomposed. The history and rotation effects were attributed to greater organic matter and water contents (Robertson and Morgan, 2010).

Samiran *et al*. (2010) worked on the effect of organic amendments of soil on growth and productivity of three common crops viz. *Zea mays*, *Phaseolus* *vulgaris* and *Abelmoschus esculentus*. The study revealed that different amendments affected crops differently and the pre-treatment of crop/plant residues like vermicomposting are invariably beneficial and contributed to crop growth and available N in soil.

Yan (2010) worked on role of chemical and organic fertilizers on yield, yield variability and carbon sequestration and concluded that use of organic fertilizers increased soil organic matter and soil fertility and consequently resulted in a larger yield trend when compared to a balanced chemical fertilizer and long term use of organic fertilizer also contributes to carbon sequestration by favouring root development.

Nakhro and Dkhar (2010) worked on the impact of organic and inorganic fertilizers on microbial populations and biomass carbon in paddy field soil. Results obtained showed that the organically treated plot recorded the maximum microbial population counts and microbial biomass carbon, followed by the inorganically treated plot and control. The application of organic fertilizers increased the organic carbon content of the soil and thereby increasing the microbial counts and microbial biomass carbon. The use of inorganic fertilizers resulted in low organic carbon content, microbial counts and microbial biomass carbon of the soil, although it increased the soil’s NPK level which could be explained by the rates of fertilizers being applied.

Adebayo *et al*. (2011) worked on assessment of organic amendments on vegetative development and nutrient uptake of *Moringa oleifera* Lam in the Nursery and results indicated that treatments significantly affected ($p<0.05$) growth parameters, except stem girth. Cow dung application significantly had higher number of leaves at five and six (WAP) and also recorded higher plant height throughout the observation period. Dry matter accumulation was also influenced by organic amendment. Significantly higher stems, leaves and root dry weights were recorded under cow dung application.

Ge *et al*. (2011) reported that increasing soil organic matter content is important in improving soil fertility; however, conventional farming practices generally lead to a reduction in such organic material. A comparative study of organic and conventional arable farming systems was conducted in Shanghai, China, to determine the influence of management practices on soil chemistry, microbial activity and biomass. Organic production systems significantly improved soil microbial characteristics and increased soil organic C, thus improving soil quality and fertility.

Gupta and Sharma (2011) states that the sequestration of the atmospheric CO_2 in the soil, as stable soil organic matter, provides a long lasting solution to decrease the CO_2 in the atmosphere. The soil organic carbon pool was estimated in forests, tree plantations, horticulture and grasslands in the Garhwal area of Himalayan region which has a wide variety of landuses and land cover. Differences in SOC pool under different landuses were statistically significant ($P<0.05$). SOC pool was maximum in the forest lands followed by grasslands, orchards and plantation areas.

A field experiment to evaluate soil organic carbon and maize grain yield under different soil amendments and cropping systems was conducted in 2006 and 2007 at the Soil Research Institute, Kwadaso, Kumasi. Generally, poultry manure + chemical fertilizer produced the highest range of SOC (1.14-1.37%). The least (0.98-1.28%) was recorded on control plots. Plots amended with chemical fertilizer alone or in combination with poultry manure out yielded the control in maize grain yield (Logah *et al*., 2011).

Min *et al*. (2011) worked on the dairy manure effects on soil quality properties and carbon sequestration in Alfalfa-Orchardgrass System and reported that long-term application of dairy manure slurries significantly increased total organic, microbial biomass, potentially mineralizable, extractable and labile C pools, respectively and improved soil aggregate stability by associated decrease in specific maintenance respiration rates and subsequently enhanced soil quality. The continuous cover of forage species, especially alfalfa, significantly improved soil quality over time as compared to orchardgrass species. The beneficial effects of organic amendments are important for proper disposal and utilization of dairy manures in forage production systems with an accompanied improvement in soil quality and C sequestration.

Mutegi *et al*. (2011) reported that over the autumn-winter growing period, total below-ground C input by fodder radish within the 0-45 cm soil depth was approximately 1.0 and 1.2 Mg C/ha for conventionally tilled (CT) and direct-drilled (DD), respectively. The figures for spring barley straw removal with fodder radish establishment would be between 4.9 and 5.1 Mg C/ha, while with no fodder radish establishment, C input to the soil would range between 3.2 Mg C/ha and 3.4 Mg C/ha, which is approximately 0.6 Mg C/ha lower than the 4 Mg C/ha biomass C input required to maintain long-term soil organic C. In comparison, under straw retention and fodder radish catch-crop establishment the total spring barley and fodder radish C input would be approximately 6.1 and 6.5 Mg C/ha for DD and CT, respectively. We conclude that fodder radish catch-crops have a potential for mitigating against soil C depletion resulting from export of cereal straw to other uses.

Significantly higher amount of microbial biomass C and N were produced in all the amended soils over control. A significantly higher amount of microbial biomass C (246.33 mg/kg soil) was found in Sugarcane trash amended soil followed by MOC (229.39 mg/kg soil), PM (220.27 mg/kg soil), cowdung (189.05 mg/kg soil) and control (123.41 mg/kg soil). Similarly, a higher significant quantity of microbial biomass N (43.60 mg/kg soil) was found in ST-amended soil followed by MOC (41.38 mg/kg soil), PM (39.76 mg/kg soil), CD (37.05 mg/kg soil) and control (22.04 mg/kg soil). The apparent percentage of N assimilation in microbial biomass from added OM was linearly and positively correlated with the C:N ratios of added OM (Paul and Solaiman, 2011).

Adding organic materials such as crop residues or animal manure to soil, whilst increasing SOC, generally does not constitute an additional transfer of C from the atmosphere to land, depending on the alternative fate of the residue. Increases in SOC from reduced tillage now appear to be much smaller than previously claimed, at least in temperate regions and in some situations increased N_2O emission may negate any increase in stored C (Powlson *et al*., 2011).

On average a change from conventional tillage to no till can sequester 57± 14 $g/cm^2/yr$, excluding wheat (*Triticum aestivum* L.) fallow systems which may not result in soil organic carbon accumulation with a change from CT to NT (Smith *et al*., 2011).

Kong *et al*. (2012) reported results of the studies which included a total of 6 land use and management treatments including: (i) no fertilizer (CK); (ii) chemical fertilizers separately(UF); combined application of chemical fertilizer N,P and K(CF); wheat and maize straw retention or manures including that from soybean (*Glycine max*) cake, chicken, horse and cow dung or manures only (O); combined application N, P and K and organic fertilizers (CFO); combined application of chemical fertilizer and organic fertilizers (UFO). The data indicated the following: (i) The baseline SOC stock of arable land was 18.9±1.8 Mg/ha and the corresponding crop yield was 4.4±1.5 Mg/ha; the highest SOC stock was 24.6±1.8 Mg/ha for CFO and the corresponding crop yield was 9.7±3.2 Mg/ha; (ii) The rate of increase of SOC stock was in the order of CFO>UFO>CF>O>UF, while that of increase in crop yield was in the order of CFO>CF>UFO>UF>O. Therefore, the combined application of chemical and organic fertilizers is the best choice for the developing countries to adapt to and mitigate climate change while advancing food security.

Filippini *et al*. (2012) studied effects of organic amendment application on soil quality and garlic yield in Central-Western Argentina and found that: a) different doses and types of amendments did not have any significant effects on soil fertility; b) chicken manure and soil before planting and c) crop yields were quite similar in all treatments, only treatments with 8 Mg ha-^{1} of both amendments (chicken manure and vermicompost) without N fertilized, were significantly higher than control in both garlic assay.

Datasets from 74 studies from pairwise comparisons of organic vs. nonorganic farming systems were subjected to metaanalysis to identify differences in soil organic carbon (SOC). Significant differences and higher values for organically farmed soils of 0.18±0.06% points (mean ± 95% confidence interval) for SOC concentrations, 3.50 ± 1.08 Mg C/ha for stocks and 0.45 ± 0.21 Mg C/ha/yr for sequestration rates compared with non-organic management. Restricting the analysis to zero net input organic systems and retaining only the datasets with highest data quality (measured soil bulk densities and external C and N inputs), the mean difference in SOC stocks between the farming systems was still significant (1.98 ± 1.50 Mg C/ha), whereas the difference in sequestration rates became insignificant (0.07 ± 0.08 Mg C/ha/yr). Analyzing zero net input systems for all data without this quality requirement revealed significant, positive differences in SOC concentrations and stocks (0.13 ± 0.09% points and 2.16 ± 1.65 Mg C/ha, respectively) and insignificant differences for sequestration rates (0.27 ± 0.37 Mg C/ha/yr) (Gattinger *et al*., 2012).

Total organic carbon (TOC), soil microbial biomass carbon (SMBC), available N, P and K status of the soil after 3 years were maximum when 50 % recommended dose of NPK were applied through inorganic and remaining 50 % RDN through PM (Kumar *et al*., 2012).

Gupta and Sharma (2013) reported that vegetative growth serves as an important means to capture and store atmospheric carbon dioxide in biomass and soil. The study therefore, was conducted to estimate SOC pool in the grasslands occurring between the wild altitudinal range of 500 to 4200 m above msl. Maximum SOC pool of 142.14 t/ha was observed in the altitudinal range of 2501 to 4200m, followed by 105.28 t/ha between 2001-2500 m, 97.80 t/ha between 1501-2000 m, 41.15 t/ha between 1001-1500 m and the least was 37.09 t/ha at

501-1000m altitude. The grasslands in Uttarakhand extend over an area of 2,28,900 hectare at different altitudes and contain 26.77 million tons of soil organic carbon pool.

A field study was carried out at Vanavarayar Institute of Agriculture, Manakkadavu, during November 2012-January 2013 to study the effect of INM on soil fertility and productivity on maize (*Zea mays*). INM practice including vermicompost and recommended dose of NPK showed its best results with respect to leaf area, yield parameters and plant height as compared to other treatments. Bulk density and pore space was recorded maximum in INM practice including vermicompost and recommended dose of NPK. Organic carbon was recorded maximum in INM treatment including vermicompost and recommended dose of NPK (Kannan *et al*., 2013).

An experiment was conducted during Kharief season, 2005 to ascertain the response of different organic sources viz., wheat straw, farm yard manure (FYM), vermicompost and poultry manure to rice (*Oryza sativa*) and also to monitor the effect of manuring on soil carbon pools. Application of poultry manure and vermicompost alongwith chemical fertilizers for supply of nitrogen, phosphorus and potassium (NPK) resulted in highest grain yield. Soil carbon, labile carbon and water soluble carbon contents also improved with application of organic sources of N application (Khursheed *et al*., 2013).

Chapter – 3

MATERIALS AND METHODS

The present investigation entitled “Impact of organic amendments on soil carbon sequestration and biomass carbon allocation of crops” was carried at Seed Multiplication Unit (Shuhama), Division of Vegetable Science, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir. The details of the materials used, experimental procedures followed and techniques adopted have been described in this chapter:

3.1 Experimental site

The investigation was conducted for two consecutive Rabi seasons of 2011 and 2012 and Kharief seasons of 2012 and 2013 at Seed Multiplication Unit (Shuhama), SKUAST which is situated 12 km away from the city centre and lies between 35^{o} 30' N latitude and 75^{o} 15'E longitude at an altitude of 1619 metres above msl. The experimental site was well drained and had uniform topography.

3.2 Climate

Climatically the experimental site is in mid to high altitude temperate zone characterized by hot summers and very cold winters. The average annual precipitation is 812 mm and more than 80% of precipitation is received from western disturbances. The mean monthly meteorological data collected during the growing season recorded at meteorological observatory, Division of Agronomy Shalimar, are presented in Appendix-I, II and III and illustrated in Figs. 1, 2 and 3. Mean maximum temperature was 16.73, 32.79 and 32.71^{o}C and mean minimum temperature was 2.71, 6.30 and 7.14 ^{o}C during the cropping season of 2011, 2012 and 2013, respectively. Maximum relative humidity was 85.74, 93.14 and 71.86 per cent for the years 2011, 2012 and 2013, respectively, whereas total annual precipitation amounted to 383.70, 251.40 and 449.40 mm during 2011, 2012 and 2013, respectively.

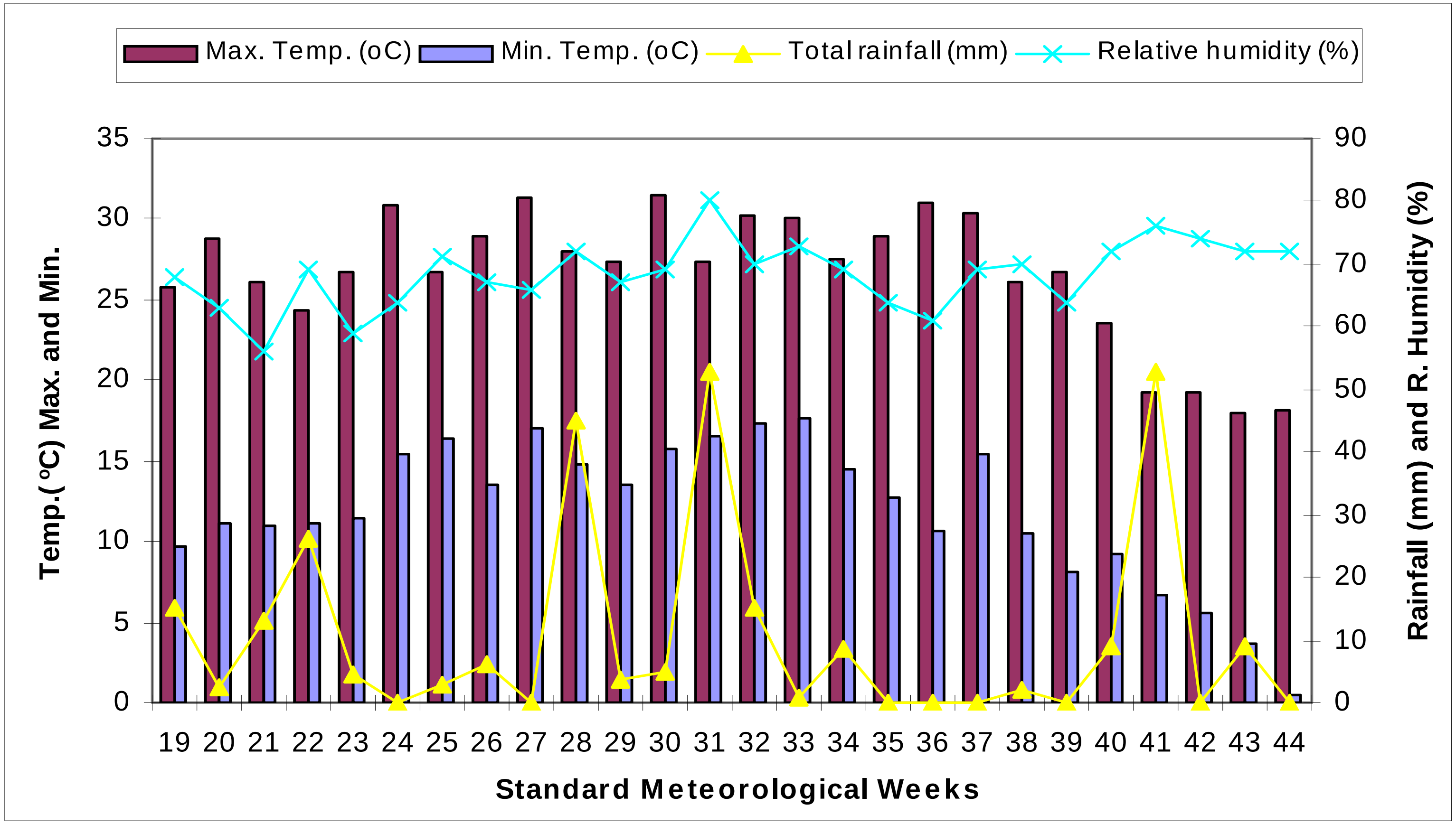

Fig. 1 : **Mean weekly meteorological parameters during crop growth period of 2011**

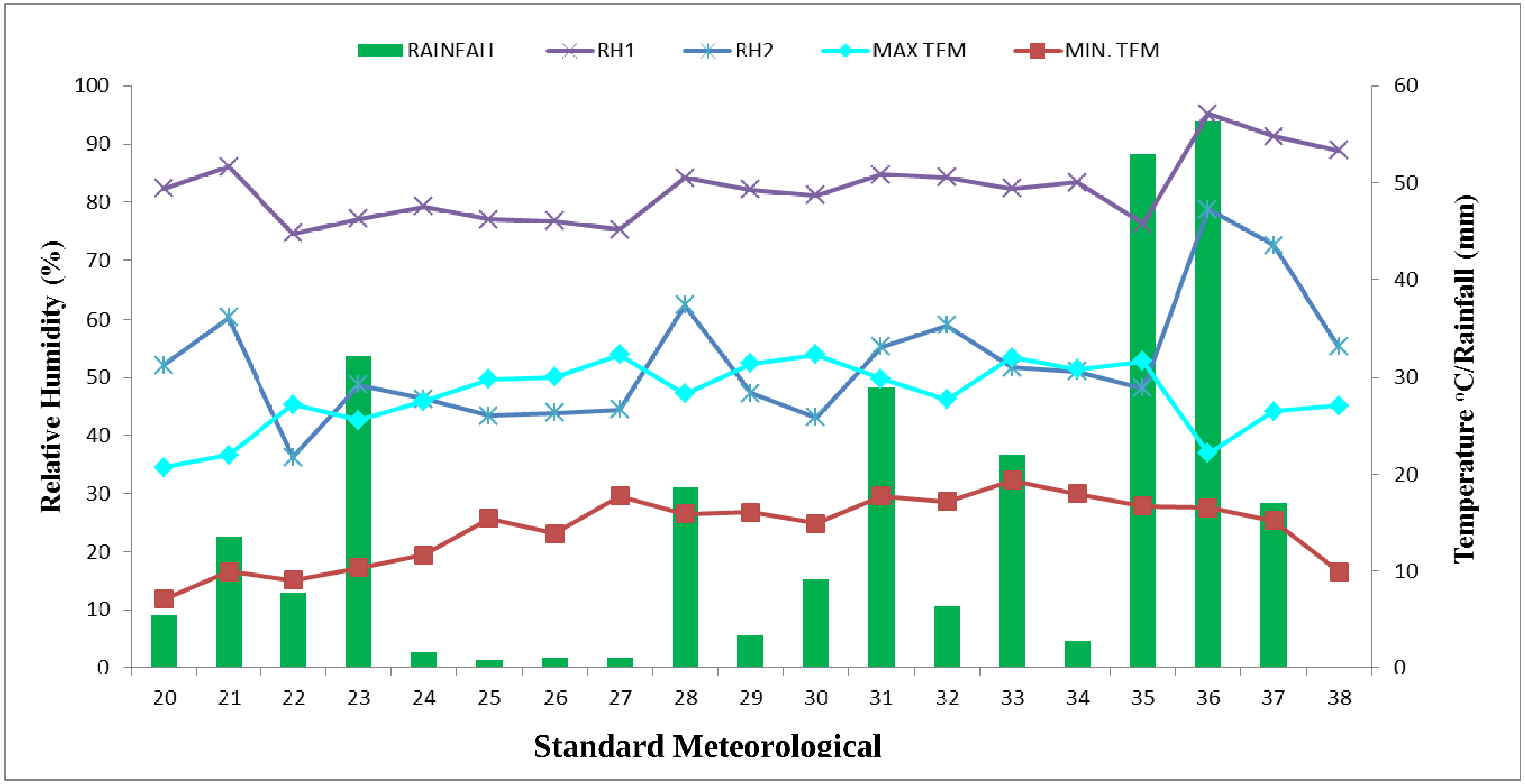

Fig. 2: Mean weekly meteorological data during the crop growth period of 2012

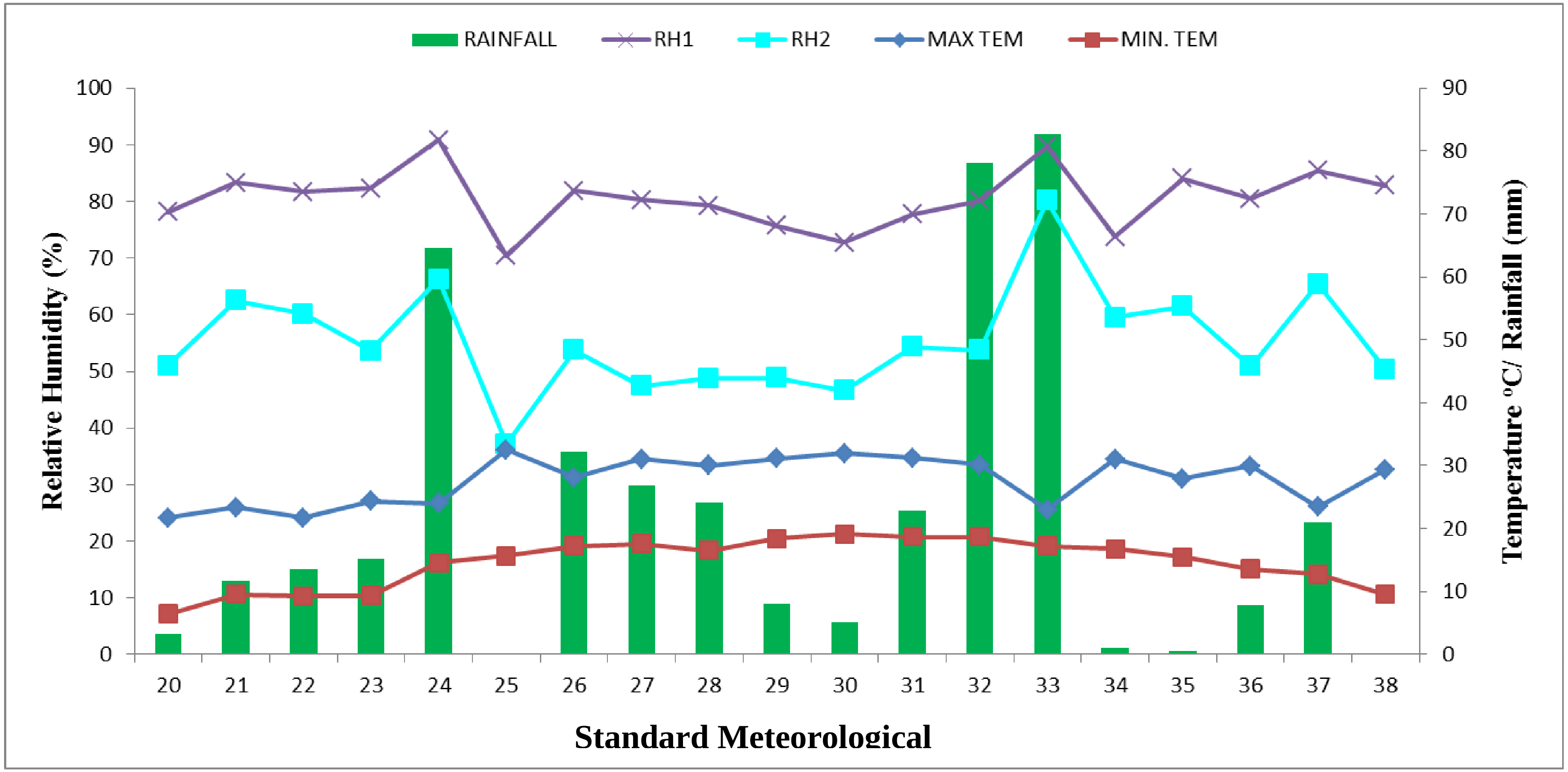

Fig. 3 : Mean weekly meteorological data during the crop growth period of 2013

Kale (*Brassica oleraceae* var. *acephala* L.)

French bean (*Phaseolus vulgaris* L.)

Plate-1 : Test crops

3.3 Experimental details:

3.3.1 Crop species

Crop	Variety	Spacing	Year of Evaluation
Kale	Jumadari	15×30 cm	Rabi-2011
Beans	French yellow	10×30 cm	Kharief-2012
Kale	Jumadari	15×30 cm	Rabi-2012
Beans	French yellow	10×30 cm	Kharief-2013

3.3.2 Treatment details

T_1	RFD (a) Kale 90 : 60 :60; (b) Beans 30 : 60 :60
T_2	75% RFD + 25% FYM
T_3	50% RFD + 50% FYM
T_4	75% RFD + 25% Poultry manure
T_5	50% RFD + 50% Poultry manure
T_6	75% RFD + 25% Vermicompost
T_7	50% RFD + 50% Vermicompost
T_8	100% FYM
T_9	100% Poultry manure
T_{10}	100 % Vermicompost

3.3.3 Layout deatails

Design : Randomized block design

Treatments : 10

Replications : 3

Total No. of plots : 30

Plot size : 1.5 × 1.5 m = 2.25 m^2

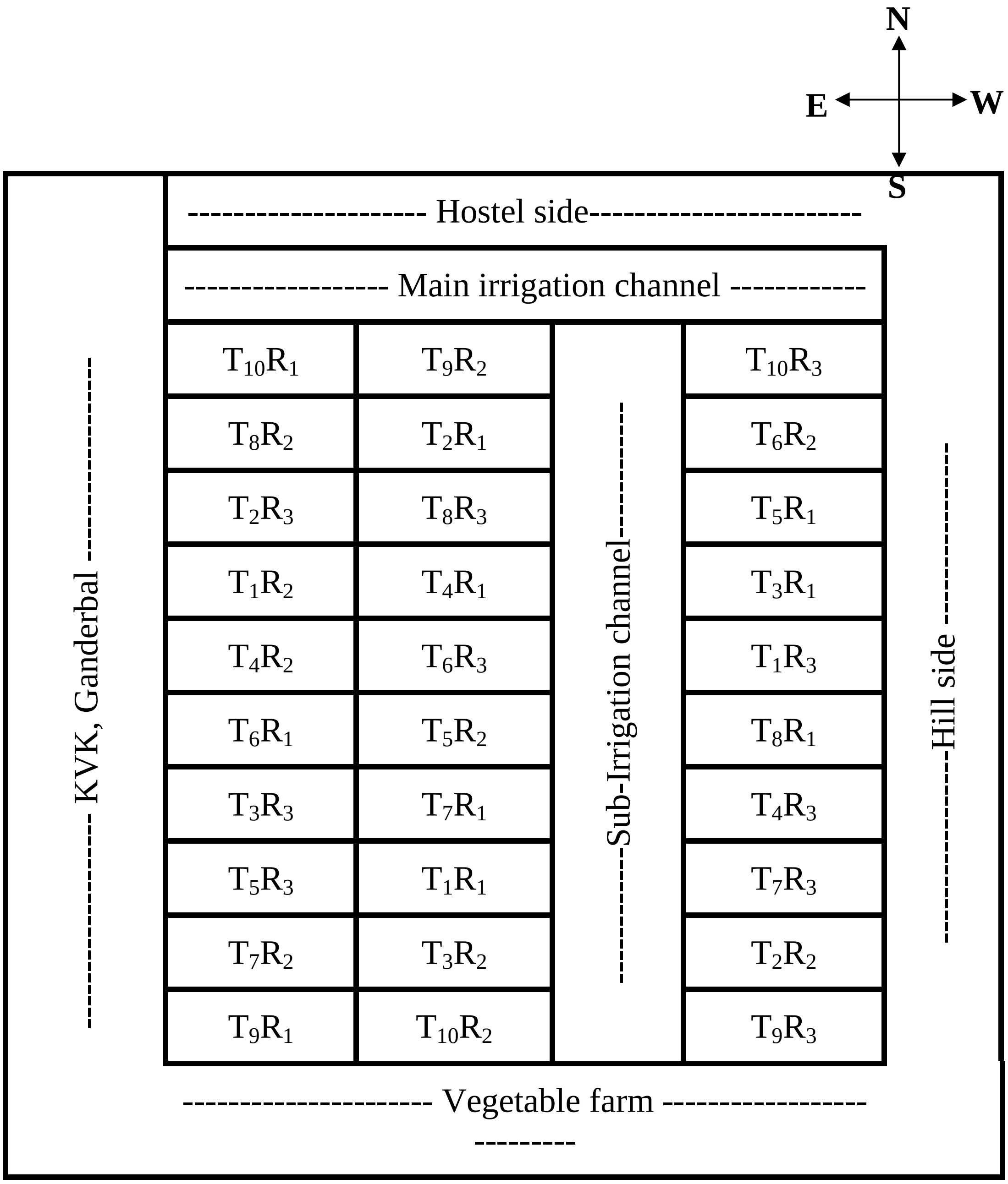

Fig. 4 : **The plan of layout of the experiment**

T_1	RFD (a) Kale 90 : 60 :60; (b) Beans 30 : 60 :60
T_2	75% RFD + 25% FYM
T_3	50% RFD + 50% FYM
T_4	75% RFD + 25% Poultry manure
T_5	50% RFD + 50% Poultry manure
T_6	75% RFD + 25% Vermicompost
T_7	50% RFD + 50% Vermicompost
T_8	100% FYM
T_9	100% Poultry manure
T_{10}	100 % Vermicompost

3.4 Field operations

The site selected for experiment was well leveled with uniform soil fertility and good drainage. The experimental fields were divided into 30 plots of 1.5×1.5 m^2 plot size, by making 30 cm wide bunds between the plots as per the layout specifications (Fig. 4). Irrigation to field was carried out by manual means.

3.4.1 Field preparation and sowing

The experimental fields were well prepared and recommended package of practices were followed to raise the crops. Beans seeds were sown directly to experimental plots, while seeds of kale were sown in separately raised nursery beds.

3.4.2 Transplanting and irrigation

The nursery beds were watered prior to lifting of the seedlings. Vigorous and healthy seedlings of almost uniform size were transplanted in well prepared plots. Plant spacing of 30×15 cm were maintained for kale, while for beans it was maintained at 30×10 cm. After transplanting, light irrigation was given and subsequent irrigation was carried out as and when required.

3.4.3 Plant protection and intercultural operations

Plant protection measures against pests and diseases were carried out during the growing period of both the crops in both years of experimentation. The necessary cultural practices such as weeding and hoeing were done from time to time, so as to keep the plots free from weeds. The intercultural operations were carried out soon after the seedlings got established in the field.

3.5 Observations

3.5.1 Soil attributes

Representative soil sample of the experimental site before the start of experiment as well as after the harvest of crop from each treatment was taken from a depth of 0-15 cm and analyzed for physico-chemical properties by using

Plate-2 : **Transplantation of seedlings Kale (*Brassica oleraceae* var. *acephala* L.)**

standard procedures. The initial status of experimental site with respect to above characteristics is given below :

Physico-chemical properties of soil of experimental site

Parameter	**Initial status**	**Rating**	**Methods employed**
1) Particle size distribution			
Sand (%)	35.4	Silty clay loam	Piper (1962)
Silt (%)	64.8		
Clay (%)	30.0		
Texture class			
2) Chemical Analysis			
Soil pH	6.80	Normal	1:2.5 soil water suspension using pH meter (Jackson, 1973)
Electrical conductivity (dS/m)	0.13	Normal	1:2.5 Soil water suspension with solubridge conductivity meter (Jackson, 1973).
Organic carbon (%)	1.20	Medium	Wet digestion method Walkley and Black's rapid titration method (1934)
Available Nitrogen (kg/ha)	301.76	Medium	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
Available phosphorus (kg/ha)	14.05	Medium	Olsen's method of extraction with 0.5 N, $NaHCO_3$ (Olsen *et al.*, 1954) using Systronics Spectro-photometer
Available potassium (kg/ha)	291.2	Medium	Ammonium acetate extraction (Jackson 1967)
Cation exchange capacity (meq/100g)	8.4	Low	Rhoades (1982)
Soil moisture (%)	21.1	Medium	Gravimetric method
Bulk density (g/cm^3)	1.25	Medium	Core method (Wilde *et al*., 1964),

3.5.1.1 Soil analysis

Soil samples collected from each replication of all treatments were air dried in shade, ground with wooden pestle, passed through 2 mm sieve mesh and stored in cloth bags for further analysis. After the crop harvest, soil samples from each plot were taken and analyzed for following physico-chemical characteristics:

3.5.1.1.1 pH

The pH was determined in 1:2.5 suspension with glass electrode pH meter or systronic expanded scale pH meter (Jackson, 1973).

3.5.1.1.2 Electrical conductivity (dS/m)

After determining pH, soil sample suspensions were kept undisturbed overnight and EC was measured by direct reading on EC meter (Jackson, 1973).

3.5.1.1.3 Organic carbon (%)

Organic carbon was determined by Walkley and Black rapid titration method, as given by Walkley and Black (1934). Soil samples were treated with potassium dichromate, conc. sulphuric acid and phosphoric acid before titrating with ferrous ammonium sulphate solution using diphenylamine as indicator.

3.5.1.1.4 Available nitrogen (kg/ha)

Available nitrogen was estimated following the procedure given by Subbiah and Asija (1956). 0.32% potassium permanganate and 2.5% sodium hydroxide was added to samples and dilution was carried out in 4% boric acid containing mixed indicators for the estimation of available nitrogen.

3.5.1.1.5 Available phosphorus (kg/ha)

Available phosphorus was extracted with Olsen’s extractant (0.5 $NaHCO_3$) and the intensity of blue colour developed from ammonium molybedate and stannous chloride was measured by spectrophotometer at 660nm wavelength as described by Jackson (1973).

3.5.1.1.6 Available potassium (kg/ha)

Available potassium was extracted from samples with the help of suitable extractant (CH_3COONH_4) by shaking, followed by filtration and determination was carried out with the help of flame photometer (Jackson, 1973).

3.5.1.1.7 Bulk density (g/cm^3)

Bulk density was determined by core method (Wilde *et al*., 1964). In this method, a cylindrical metal sampler was pressed into the soil to the desired depth and was carefully removed to preserve a known volume of sample. The samples were dried at 105 to 110ºC and weighed. Bulk density was calculated by the formula:

$$\text{Bulk density} = \frac{\text{Oven dried mass of soil}}{\text{Field volume of the sample}}$$

3.5.1.1.8 Soil moisture (%)

A labeled beaker was weighed, 10 g of soil sample were added and total weight of the sample + container was recorded. Samples were dried in an oven at 105°C for 48 hours. Again, weight of the container + sample were recorded and dry weight of soil sample was recorded by deducting the total weight minus weight of container. Moisture per cent and dry soil weight of soil was calculated by the formula:

$$\text{Soil moisture (\%)} = \frac{\text{wet weight (g) - dry weight (g)}}{\text{Dry weight (g)}} \times 100$$

3.5.1.1.9 Soil carbon pool inventory/soil organic carbon storage (SCS)

The soil organic carbon pool inventory for a specific depth was worked out following Carlos *et al*. (2001).

$$\text{SCS (Mg/ha)} = \text{BD} \times \text{SOC} \times \text{DP}$$

Where,

BD = Bulk density (g/cm^3)

SOC = Soil organic carbon (%)

DP = Soil depth (cm)

3.5.2 Crop attributes

Five plants were randomly selected and tagged from every plot of each replication and then average for every parameter was worked out. The details of the observations recorded are as follows:

3.5.2.1 Plant growth attributes

3.5.2.1.1 Plant height (cm)

Plant height was measured in centimeters with the help of a meter scale from the ground level to the tip from five randomly selected plants and the average height was worked out.

3.5.2.1.2 Plant spread (cm)

Plant spread was measured in centimeters from North to South and East to West directions. The average of five randomly selected plants was worked out.

3.5.2.1.3 Number of branches/plant

The number of branches in five randomly selected plants was counted and the mean was calculated.

3.5.2.1.4 Number of leaves/plant

Total number of leaves harvested from five randomly selected plants in each treatment was added and average was worked out to obtain total number of leaves per plant.

3.5.2.1.5 Number of pods/plant

Total number of pods from five randomly selected plants in each treatment was added and their average was worked out to obtain the number of pods per plant of bean.

3.5.2.1.6 No. of nodules/plant

Healthy growing bean plants were uprooted using digging tools. Roots were washed carefully with a jet of water. Total number of nodules from five randomly selected plants in each treatment were added and their average was worked out to obtain the number of nodules per plant.

3.5.2.1.7 Leaf area ratio (cm$^{2/}$g)

Leaf area ratio is the ratio of total leaf area to whole plant dry weight to estimate the carbon assimilating capacity of leaves or to estimate the leafiness of plant. Leaf area was calculated following the formula (Briggs *et al*., 1920).

$$\text{LAR} = \frac{(A_2-A_1)\ 2.303\ (\text{Log}_{10} W_2-\text{Log}_{10} W_1)}{2.303\ (\text{Log}_{10} A_2-\text{Log}_{10} A_1)\ (W_2-W_1)}$$

3.5.2.2 Plant biomass attributes:

3.5.2.2.1 Fresh and dry biomass of roots and shoots

Fresh and dry weight of roots and shoots were calculated by selecting 5 random plants from each treatment in each replication.

3.5.2.2.2 Yield/plot (kg)

The total weight of five randomly selected plants was pooled and average yield/plant (g) calculated. The yield/plant was then multiplied by the number of plants in a plot to get the yield/plot (kg).

3.5.2.2.3 Root mass ratio (RMR)

Root mass ratio is the fraction of total plant biomass allocated to roots and was calculated as

$$\text{RMR} = \frac{\text{Root biomass}}{\text{Total plant biomass}} \times 100$$

3.5.2.2.4 Shoot mass ratio (SMR)

Shoot mass ratio is the fraction of total plant biomass allocated to shoots and was calculated as

$$\text{SMR} = \frac{\text{Shoot biomass}}{\text{Total plant biomass}} \times 100$$

3.5.2.2.5 Shoot :root ratio

The shoot: root ratio (dry weight basis) was calculated by dividing the weight of dry shoot by the weight of dry root of each plant separately.

3.5.2.3 Plant analysis

Plant samples of kale were collected at harvest from each plot and then oven dried at 60-65°C for 48 hours to a constant weight. The samples were ground and subsequently used for chemical analysis. The methods followed for the chemical analysis are as under:

3.5.2.3.1 Total nitrogen (%)

The nitrogen determination was carried out by Micro-Kjeljhl's method as described by Jackson (1973). 1gm of plant sample was reacted with sulphuric acid and salicylic acid and sodium thiosulphate mixture. Distilled NH_3 was collected in 4% boric acid solution in presence of mixed indicator.

3.5.2.3.2 Biomass carbon content (%)

Carbon stock in plant was estimated by ash content method as described by Negi *et al.* (2003). In this method oven dried plant components were burnt in muffle furnace at 400°C temperature. The ash content left after burning was weighed and carbon content was calculated by using the equation:

$$\text{Carbon (\%)} = 100-(\text{Ash weight} + \text{molecular weight of } O_2 \text{ (53.3) in } C_6H_{12}O_6)$$

3.5.3 Soil microbial biomass carbon

The soil microbial biomass carbon was determined by chloroform fumigation extraction method prescribed by Voroney *et al.* (1993). Soil microbial biomass carbon was estimated by taking 5 sets of 10g of soil from each sample. One set was kept in moisture box after taking weight of the empty box and placed in the oven at 100ºC for 24 hrs or until a constant oven dry weight was achieved. Out of the four remaining sets of the soil, 2 sets were placed in 50ml glass beakers with ethanol free chloroform for fumigation. Samples designated for fumigation were placed in the vacuum desiccators. Allowing the chloroform to boil for approx. 5min. Samples were fumigated for 24 hrs in the dark at 25ºC. After the chloroform was removed, soils were transferred to 250ml conical flasks and 25ml of 0.5M K_2SO_4 was then added. At the same time, remaining two unfumigated soil samples were placed in the conical flasks and treated in the same way. All the conical flasks were shaken for 30min. on a reciprocating shaker and supernatants were filtered through Whatman No.1 filter paper.

Microbial biomass carbon was measured in 10ml of aliquots of K_2SO_4 extracts after oxidation with 2ml of 0.2 N $K_2Cr_2O_7$, 10ml of H_2SO_4 and 5ml of orthophosphoric acid at 100ºC for 30 min. and back titrated with ferrous ammonium sulphate.

$$\text{MB} - \text{C } (\mu\text{g/g soil}) = \left(\frac{\text{EC}_f - \text{Ec}_{uf}}{\text{K}_{ec}} \right)$$

Where, EC_f is extractable carbon in the fumigated and unfumigated (EC_{uf}) soil sample and $k_{ec} = 0.35$ represents the efficiency of extraction of organic carbon.

3.6 Statistical analysis

The data obtained were subjected to suitable statistical tools viz., standard error of mean and 95 per cent confidence intervals.

Kale (*Brassica oleraceae* var. *acephala* L.)

French bean (*Phaseolus vulgaris* L.)

Plate-3 : Test crops in the field

Plate-4 : Full view of kale (*Brassica oleraceae* var. *acephala* L.) in the field

Plate-5 : Full view of French bean (*Phaseolus vulgaris* L.) in the field

Chapter – 4

EXPERIMENTAL FINDINGS

The results pertaining to the present study entitled “Impact of organic amendment on soil carbon sequestration and biomass carbon allocation of crops” are presented in this chapter under following heading :

4.1 Soil physico-chemical attributes under Kale and French beans

4.2 Soil nutrients under Kale and French beans

4.3 Soil carbon storage under Kale and French beans

4.4 Growth and yield attributes of Kale and French beans

4.5 Above and belowground biomass production of Kale and French beans under organic amendments.

4.6 Partitioning of above and below ground biomass of Kale and French beans under organic amendments.

4.7 Carbon detail and total nitrogen of Kale and French beans grown in organically amended soils.

4.1 Soil physico-chemical attributes under Kale and French beans

4.1.1 Soil pH

The data pertaining to the impact of organic amendments on soil pH under Kale after harvest (Table-1) shows decreasing trend in the soil pH as affected by different treatments. T_1 (RFD) recorded highest pH of 8.02, 7.94 and 7.98 during 2011, 2012 and pooled data, respectively which is statistically significant over rest of treatment combinations. The significantly lowest soil pH of 7.64, 7.54 and 7.59 during 2011, 2012 and pooled data, respectively was noticed in treatment T_{10} (100% VC). The impact of organic amendments on soil pH under French beans has been presented in (Table-2). The perusal of the data of two years reveals highest soil pH of 7.55, 7.48 and 7.51 in T_1 during 2012, 2013 and pooled data

Table-1 : Impact of organic amendments on soil physico-chemical parameters under Kale

Treatment	pH (1:2.5)			Electrical conductivity (dS/m)			Cation exchange capacity (meq/100 g)			Soil moisture (%)		
	2011	**2012**	**Pooled**	**2011**	**2012**	**Pooled**	**2011**	**2012**	**Pooled**	**2011**	**2012**	**Pooled**
T_1	8.02	7.94	7.98	0.10	0.14	0.12	5.80	6.30	6.05	14.62 (3.82)	16.52 (4.06)	15.57 (3.95)
T_2	7.91	7.81	7.86	0.06	0.20	0.13	10.26	13.80	12.03	18.72 (4.32)	19.22 (4.38)	18.97 (4.36)
T_3	7.75	7.64	7.69	0.15	0.23	0.19	14.73	16.83	15.78	18.28 (4.27)	20.18 (4.49)	19.23 (4.39)
T_4	7.95	7.87	7.91	0.11	0.15	0.13	7.86	11.40	9.63	14.54 (3.81)	17.04 (4.12)	15.79 (3.97)
T_5	7.77	7.66	7.71	0.10	0.24	0.17	12.20	15.66	13.93	18.50 (4.30)	19.53 (4.41)	19.02 (4.36)
T_6	7.88	7.77	7.82	0.12	0.17	0.14	11.26	14.83	13.05	17.50 (4.18)	20.53 (4.53)	19.02 (4.36)
T_7	7.72	7.62	7.67	0.11	0.26	0.19	15.00	17.00	16.00	17.11 (4.13)	22.61 (4.75)	19.86 (4.46)
T_8	7.70	7.60	7.65	0.20	0.35	0.27	15.30	18.80	17.05	20.50 (4.52)	22.43 (4.73)	21.47 (4.63)
T_9	7.71	7.61	7.66	0.18	0.33	0.25	15.36	17.40	16.38	19.51 (4.41)	22.51 (4.74)	21.01 (4.58)
T_{10}	7.64	7.54	7.59	0.33	0.39	0.36	17.26	19.36	18.31	22.13 (4.70)	24.03 (4.90)	23.08 (4.80)
C.D ($P \leq 0.05$)	**0.015**	**0.017**	**0.016**	**0.012**	**0.013**	**0.013**	**0.113**	**0.102**	**0.098**	**0.009**	**0.016**	**0.012**

*Figures in parenthesis are square root transformed means

Table-2 : Impact of organic amendments on soil physico-chemical parameters under French beans

Treatment	pH (1:2.5)			Electrical conductivity (dS/m)			Cation exchange capacity (meq/100 g)			Soil moisture (%)		
	2012	**2013**	**Pooled**	**2012**	**2013**	**Pooled**	**2012**	**2013**	**Pooled**	**2012**	**2013**	**Pooled**
T_1	7.55	7.48	7.51	0.10	0.22	0.16	5.10	8.00	6.55	8.01 (2.83)	10.80 (3.28)	9.40 (3.07)
T_2	7.47	7.39	7.43	0.13	0.25	0.19	10.10	13.00	11.55	12.14 (3.48)	13.04 (3.61)	12.59 (3.55)
T_3	7.37	7.29	7.33	0.15	0.27	0.21	13.10	15.00	14.05	13.53 (3.67)	14.43 (3.79)	13.98 (3.74)
T_4	7.48	7.40	7.44	0.13	0.25	0.19	9.50	12.40	10.95	14.91 3.86)	15.81 (3.97)	15.36 (3.92)
T_5	7.38	7.30	7.34	0.15	0.27	0.21	12.50	15.40	13.95	10.40 (3.22)	12.30 (3.50)	11.35 (3.37
T_6	7.41	7.32	7.36	0.15	0.27	0.21	12.00	14.90	13.45	12.38 (3.51)	13.28 (3.64)	12.83 (3.58)
T_7	7.37	7.29	7.33	0.19	0.25	0.22	14.80	16.70	15.75	11.20 (3.34)	14.10 (3.75)	12.65 (3.56)
T_8	7.26	7.18	7.22	0.21	0.33	0.27	16.10	19.00	17.55	14.06 (3.75)	14.96 (3.86)	14.51 (3.81)
T_9	7.30	7.22	7.26	0.17	0.28	0.22	16.10	18.00	17.05	13.17 (3.62)	15.97 (3.99)	14.57 (3.82)
T_{10}	7.30	7.21	7.22	0.20	0.32	0.26	16.86	18.40	17.63	14.68 (3.83)	17.48 (4.18)	16.08 (4.01)
C.D ($P \leq 0.05$)	**0.014**	**0.014**	**0.014**	**0.016**	**0.016**	**0.015**	**0.168**	**0.144**	**0.154**	**0.072**	**0.077**	**0.075**

*Figures in parenthesis are square root transformed means

respectively which are statistically significant. The lowest soil pH 7.26, 7.18 and 7.22 was recorded in T_8 (100% FYM) during 2012, 2013 and pooled data which are statistically at par with T_{10}.

4.1.2 Electrical conductivity (d S/m)

Application of 100% vermicompost recorded highest electrical conductivity of 0.33, 0.39 and 0.36 dS/m during 2011, 2012 and pooled data in soil under Kale and 0.21, 0.33and 0.27 dS/m in soil under French beans during 2012, 2013 and pooled data respectively which are statistically at par with T_8 (100% FYM) (Tables-1 and 2). The lowest electrical conductivity of 0.10, 0.14 and 0.12 dS/m in soil under Kale and 0.10, 0.22 and 0.16 dS/m in soil under French beans during 2012, 2013 and pooled data respectively were recorded under T_1.

4.1.3 Cation exchange capacity (meq/100 g)

From the perusal of data (Tables-1 and 2) it is clear that application of 100% Vermicompost recorded significantly highest cation exchange capacity (17.26, 19.36 and 18.31 meq/100 g) in soil under Kale. In French beans the highest values for cation exchange capacity (16.86, 19.00 and 17.63 meq/100 g) during 2012, 2013 and pooled data were recorded in T_{10}, T_8 and T_{10} respectively. However, T_{10} treatment of pooled data was statistically at par with T_8. The lowest cation exchange capacity of 5.80, 6.30 and 6.05 meq/100 g in soil under Kale and 5.10, 8.00 and 6.55 meq/100 g in soil under French beans during 2012, 2013 and pooled data respectively were recorded under T_1.

4.1.4 Soil moisture (%)

It is inferred from the data (Tables-1 and 2) that significantly higher soil moisture of 22.13, 24.03 and 23.08% during 2011, 2012 and pooled data respectively was observed in T_{10} under Kale as compared to other treatments. Significantly lowest soil moisture of 14.54, 16.52 and 15.57% was noticed in T_4, T_1 and T_1 during 2011, 2012 and pooled data respectively. In French bean, higher soil moisture of 14.91, 17.48 and 16.08% was recorded in T_4, $T_{10}$and T_{10} during 2012, 2013 and pooled data respectively which are statistically significant. The lowest 8.01, 10.80 and 9.40% was recorded in T_1 during 2012, 2013 and pooled data respectively.

4.2 Soil nutrients under Kale and French beans

4.2.1 Available nitrogen (kg/ha)

From the perusal of data (Tables-3 and 4) it is evident that application of 50% PM + 50% N, P and K recorded significantly higher available nitrogen of 500.40, 530.10 and 515.25 kg/ha under kale during 2011, 2012 and pooled data respectively. However the lowest of 205.80, 218.70 and 212.30 kg/ha are recorded in T_8 during 2011, 2012 and pooled data respectively. It was also observed that available nitrogen of soil under French beans during 2012, 2013 and pooled data was significantly highest (471.40, 507.10 and 488.70 kg/ha) in T_5. However, during 2012, T_5 was at par with T_7. The lowest 110.70, 137.60 and 124.15 kg/ha was noticed in T_8 during 2012, 2013 and pooled data respectively.

4.2.2 Available phosphorus (kg/ha)

The results (Tables-3 and 4) reveal that highest values for available phosphorus of soil under cultivation of test crops were 18.01, 22.01 and 20.01 kg/ha (Kale) during 2011, 2012 and pooled data respectively and 24.41, 26.71 and 25.56 kg/ha (French beans) during 2012, 2013 and pooled data respectively in T_5. However, during 2011, T_5 was at par with T_7. On the other hand the lowest available phosphorus of 12.01, 14.30 and 13.16 kg/ha was recorded in T_8 under kale and12.30, 15.87 and 14.08 kg/ha in soil under French beans in T_8 during 2012, 2013 and pooled data, respectively.

4.2.3 Available potassium (kg/ha)

The data on the amount of available potassium in soil (Tables-3 and 4) reveals that application of 50% PM + 50% N, P and K recorded 200.77, 214.80

Table-3 : Soil nutrients under organic amendments of Kale

Treatment	Available nitrogen (kg/ha)			Available phosphorus (kg/ha)			Available potassium (kg/ha)		
	2011	**2012**	**Pooled**	**2011**	**2012**	**Pooled**	**2011**	**2012**	**Pooled**
T_1	319.40	376.30	347.90	14.76	16.75	15.75	147.67	155.00	151.33
T_2	354.60	370.40	362.50	12.51	19.01	15.76	150.33	165.30	157.81
T_3	400.40	436.20	418.30	16.76	21.25	19.00	169.20	181.20	175.20
T_4	376.00	414.80	395.40	16.71	20.71	18.71	161.37	170.40	165.88
T_5	500.40	530.10	515.25	18.01	22.01	20.01	200.77	214.80	207.78
T_6	366.00	401.80	383.90	14.76	21.26	18.01	156.80	164.80	160.80
T_7	454.10	489.90	472.00	17.76	21.26	19.51	182.70	195.80	189.25
T_8	205.80	218.70	212.30	12.01	14.30	13.16	120.67	127.00	123.83
T_9	272.20	285.40	278.80	12.94	15.24	14.09	130.77	141.80	136.28
T_{10}	249.90	262.80	256.40	12.42	14.72	13.57	127.70	133.70	130.70
C.D ($P \leq 0.05$)	**9.851**	**12.641**	**11.351**	**0.324**	**0.495**	**0.409**	**1.556**	**1.89**	**1.725**

Table-4 : Soil nutrients under organic amendments under French beans

Treatment	Available nitrogen (kg/ha)			Available phosphorus (kg/ha)			Available potassium (kg/ha)		
	2012	**2013**	**Pooled**	**2012**	**2013**	**Pooled**	**2012**	**2013**	**Pooled**
T_1	282.20	318.90	300.60	13.16	20.46	16.81	212.80	222.20	217.50
T_2	310.60	324.80	317.70	15.36	19.64	17.50	224.03	233.40	228.72
T_3	376.30	413.00	394.70	18.40	21.70	20.05	235.20	267.40	251.30
T_4	333.60	350.30	341.95	18.40	21.80	20.10	229.60	261.80	245.70
T_5	470.40	507.10	488.70	24.41	26.71	25.56	263.20	273.40	268.30
T_6	323.60	338.80	331.20	16.36	20.66	18.51	212.83	269.13	240.98
T_7	470.40	481.60	476.00	20.60	25.90	23.25	246.40	278.60	262.50
T_8	110.70	137.60	124.15	12.30	15.87	14.08	207.20	216.60	211.90
T_9	250.90	287.60	269.20	14.12	17.52	15.82	196.03	228.30	212.17
T_{10}	125.40	162.10	143.80	13.30	16.70	15.00	196.03	228.20	212.12
C.D ($P \leq 0.05$)	**10.658**	**11.965**	**11.331**	**0.451**	**0.791**	**0.621**	**0.428**	**0.718**	**0.616**

and 207.78 kg/ha during 2011, 2012 and pooled data respectively in soil under Kale and 263.20, 278.60 and 268.30 kg/ha in soil under French beans during 2012, 2013 and pooled data respectively which were significantly higher than recorded for other treatments. Significantly lowest contents of available potassium in soil viz., 120.67, 127.00 and 123.83 kg/ha under Kale during 2011, 2012 and pooled data, respectively was noticed in treatment T_8 and 196.03, 216.60 and 211.90 Kg/ha under French beans was recorded in T_{10}, T_8 and T_8 during 2012, 2013 and pooled data.

4.3 Soil carbon storage under Kale and French beans

4.3.1 Bulk density (g/cm^3)

The impact of organic amendments on soil bulk density under Kale and French beans is presented in Tables-5 and 6. From the perusal of data it is clear that in soil under Kale significantly highest 0.331, 0.336 and 0.333 g/cm^3 was recorded in treatment T_1 during 2011, 2012 and pooled data respectively and the lowest of 0.305, 0.300 and 0.303 g/cm^3 was noticed in T_{10} during 2011, 2012 and pooled data respectively. In French bean, highest bulk density of 0.379, 0.383 and 0.381 g/cm^3 was recorded in T_1 during 2012, 2013 and pooled data which are statistically at par with T_4. However, T_1 is statistically at par with T_4 and T_2 in pooled data. The lowest 0.350, 0.351 and 0.354 g/cm^3 was recorded in T_{10}, T_8 and T_8 , T_{10} during 2012, 2013 and pooled data, respectively.

4.3.2 Organic carbon (%)

The results (Tables-5 and 6) reveal that application of 100% vermicompost recorded highest organic carbon of 1.10, 1.37 and 1.23% during 2011, 2012 and pooled data in soil under Kale which are statistically significant compared to other treatments and 1.79, 1.99 and 1.86% in soil under French beans in T_9, T_8 and T_{10} during 2012, 2013 and pooled data respectively which are statistically at par with T_{10}. However T_{10} is statistically at par with T_8 and T_9 in pooled data. The lowest organic carbon of 0.51, 0.54 and 0.52% in soil under Kale during 2011, 2012 and

Table-5 : Soil carbon storage under organic amendments under Kale

Treatment	Bulk density (g/cm^3)			Organic carbon (%)			Soil carbon storage (Mg/ha)			Soil microbial biomass carbon (µg/g soil)		
	2011	**2012**	**Pooled**	**2011**	**2012**	**Pooled**	**2011**	**2012**	**Pooled**	**2011**	**2012**	**Pooled**
T_1	0.331	0.336	0.333	0.51	0.54	0.52	2.53	2.72	2.59	43.30	51.30	47.30
T_2	0.329	0.324	0.326	0.82	0.97	0.89	4.04	4.71	4.35	84.60	114.60	99.60
T_3	0.320	0.315	0.317	1.04	1.09	1.06	4.99	5.15	5.04	200.20	240.20	220.20
T_4	0.334	0.327	0.330	0.82	0.93	0.87	4.10	4.56	4.30	54.60	74.60	64.60
T_5	0.323	0.316	0.319	1.01	1.09	1.05	4.89	5.16	5.02	150.80	155.10	153.00
T_6	0.328	0.322	0.325	0.99	1.06	1.02	4.87	5.11	4.97	96.30	126.30	111.30
T_7	0.319	0.313	0.316	1.06	1.08	1.07	5.07	5.07	5.07	253.10	304.10	278.60
T_8	0.310	0.307	0.308	1.09	1.21	1.15	5.06	5.57	5.31	390.20	421.20	405.70
T_9	0.312	0.309	0.310	1.07	1.19	1.13	5.00	5.51	5.25	324.30	374.30	349.30
T_{10}	0.305	0.300	0.303	1.10	1.37	1.23	5.03	6.16	5.59	400.90	450.90	425.90
C.D ($P \leq 0.05$)	**0.0028**	**0.0031**	**0.0029**	**0.003**	**0.005**	**0.004**	**0.059**	**0.071**	**0.065**	**15.98**	**23.85**	**19.53**

Table-6 : Soil carbon storage under organic amendments under French beans

Treatment	Bulk density (g/cm^3)			Organic carbon (%)			Soil carbon storage (Mg/ha)			Soil microbial biomass carbon (µg/g soil)		
	2012	**2013**	**Pooled**	**2012**	**2013**	**Pooled**	**2012**	**2013**	**Pooled**	**2012**	**2013**	**Pooled**
T_1	0.379	0.383	0.381	0.40	0.43	0.41	2.27	2.47	2.34	100.00	115.00	107.50
T_2	0.373	0.378	0.375	0.90	1.24	1.07	5.03	7.03	6.01	153.80	203.80	178.80
T_3	0.364	0.368	0.366	1.69	1.81	1.75	9.22	9.99	9.60	253.30	303.30	278.30
T_4	0.376	0.380	0.378	0.45	0.61	0.53	2.53	3.47	3.00	150.40	205.40	157.90
T_5	0.365	0.370	0.367	1.64	1.85	1.74	8.97	10.26	9.57	198.70	249.00	223.80
T_6	0.370	0.375	0.372	1.63	1.70	1.66	9.04	9.56	9.26	103.50	153.50	177.90
T_7	0.360	0.365	0.362	1.70	1.89	1.79	9.18	10.34	9.71	279.40	284.40	281.90
T_8	0.358	0.351	0.354	1.72	1.99	1.85	9.23	10.47	9.82	401.40	496.40	448.90
T_9	0.355	0.358	0.356	1.79	1.88	1.83	9.53	10.09	9.77	279.20	329.20	304.20
T_{10}	0.350	0.358	0.354	1.75	1.97	1.86	9.18	10.57	9.87	700.20	783.50	741.85
C.D ($P \leq 0.05$)	**0.0046**	**0.0035**	**0.0082**	**0.04**	**0.07**	**0.05**	**0.37**	**0.25**	**0.29**	**34.65**	**52.98**	**42.95**

pooled data, respectively and 0.40, 0.43 and 0.41% in soil under French beans during 2012, 2013 and pooled data respectively were recorded under T_1.

4.3.3 Soil carbon storage (Mg/ha)

The data pertaining to the impact of organic amendments on soil carbon storage under Kale after harvest has been presented in Tables-5 and 6. T_{10} recorded highest of 6.16 and 5.59 Mg/ha during 2012 and pooled data, respectively which is statistically significant over rest of other treatment combinations. However, during 2011, T_7 recorded highest of 5.07 Mg/ha which is statistically at par with T_8 and T_{10}. The significantly lowest soil carbon storage of 2.53, 2.72 and 2.59 Mg/ha during 2011, 2012 and pooled data, respectively was recorded in treatment T_1. In French beans highest of 10.57 and 9.87 Mg/ha soil carbon was recorded in T_{10} during 2013 and pooled data respectively which are statistically at par with T_8 and T_7 during 2013 and T_{10} was at par with T_8, T_9, T_7 and T_3 in pooled data. However during 2012, the highest of 9.53 Mg/ha in T_9 was statistically at par with T_7, T_8, T_{10} and T_3. The lowest soil carbon storage of 2.27, 2.47 and 2.34 Mg/ha was observed in T_1 during 2012, 2013 and pooled data.

4.3.4 Soil microbial biomass carbon (µg/g)

From the perusal of data (Tables-5 and 6) it is evident that application of 100% vermicompost recorded significantly higher soil microbial biomass carbon of 400.90, 450.90 and 425.90 µg/g during 2011, 2012 and pooled data, respectively which is statistically significant over rest of other treatment combinations in soil under Kale. However during 2011, T_{10} was statistically at par with T_8. The lowest of of 43.30, 51.30 and 47.30 µg/g during 2011, 2012 and pooled data, respectively was noticed in treatment T_1. It was also observed that soil microbial biomass carbon under French beans during 2012, 2013 and pooled data was significantly highest (700.20, 783.5 and 741.85µg/g) in T_{10}. The significantly lowest of 100.00, 115.00 and 107.50 µg/g during 2011, 2012 and pooled data, respectively was recorded in treatment T_1.

4.4 Growth and yield attributes of Kale and French beans

4.4.1 Plant height (cm)

The data regarding the effect of different organic amendments on plant height of Kale and French beans is presented in Tables-7 and 8. A perusal of pooled data of two years (2011, 2012) reveals that kale plots amended with 50% PM + 50% N, P and K recorded highest plant height of 49.00, 51.66 and 50.33 cm which was statistically at par with T_7 whereas significantly lowest plant height of 36.00cm was recorded in T_{10} during 2011 and lowest of 37.64 and 36.88 cm in T_8 during 2012 and pooled data. In case of French beans also significantly highest plant height of 50.12, 55.01 and 52.56 cm was noticed in T_5 and significantly lowest of 34.81, 35.01 and 34.91 cm was recorded in T_8 during 2012, 2013 and pooled data, respectively.

4.4.2 Plant spread (cm)

The results (Tables-7 and 8) revealed significant variation in plant spread of Kale and French beans as amended by different organic amendments. It is evident from the data that during 2011 highest plant spread of 35.00 cm was recorded in T_7 in Kale which was statistically at par with T_4, however during 2012 and pooled data highest plant spread of 38.68 cm and 51.00 cm were noticed in T_5 which was at par with T_7 during 2012. In French beans significantly highest plant spread of 29.70, 33.75 and 31.72 cm during 2012, 2013 and pooled data was recorded in T_5 which is at par with T_4 during 2013. The lowest plant spread of 25.87, 33.16 and 29.51 cm in Kale during 2011, 2012 and pooled data, respectively and 19.50, 20.83 and 20.16 cm in French beans during 2012, 2013 and pooled data respectively were recorded in T_8.

4.4.3 No. of leaves/plant

From the perusal of data (Tables-7 and 8) it is evident that application of 50% PM + 50% N, P and K recorded significantly highest number of leaves of 19.50, 22.13 and 20.81/plant in Kale during 2011, 2012 and pooled data respectively and 19.23, 23.30 and 21.26 in French beans during 2012, 2013 and pooled data respectively which was at par with T_4 in pooled data. The

Table-7 : Growth attributes and yield of Kale under different organic amendments

Treatment	Plant height (cm)			Plant spread (cm)			No. of leaves/plant			Yield/plot (kg)		
	2011	**2012**	**Pooled**	**2011**	**2012**	**Pooled**	**2011**	**2012**	**Pooled**	**2011**	**2012**	**Pooled**
T_1	39.01	41.49	40.25	29.83	36.43	33.13	10.12	12.60	11.36	8.05	10.6	9.32
T_2	40.67	43.50	42.09	31.50	35.56	33.53	9.10	14.26	11.68	9.60	10.28	9.94
T_3	45.37	47.66	46.51	33.68	36.83	35.25	11.25	16.95	14.10	10.11	13.58	11.84
T_4	43.32	46.50	44.91	35.00	35.25	35.12	11.87	15.13	13.50	11.37	12.09	11.73
T_5	49.00	51.66	50.33	34.00	38.68	51.00	19.50	22.13	20.81	13.50	15.70	14.60
T_6	42.00	46.12	44.06	32.20	35.60	33.90	10.37	16.33	13.35	11.39	12.05	11.72
T_7	48.65	51.33	49.99	36.01	38.33	37.17	12.50	16.60	14.55	12.01	15.14	13.57
T_8	36.12	37.64	36.88	25.87	33.16	29.51	9.25	9.30	9.27	5.21	7.89	6.55
T_9	37.33	40.25	38.79	29.00	36.37	32.69	9.75	11.60	10.67	8.91	9.05	8.98
T_{10}	36.00	38.62	37.31	30.68	34.33	32.51	8.91	10.30	9.60	6.88	8.26	7.57
C.D ($P \leq 0.05$)	**0.595**	**0.833**	**0.429**	**1.258**	**1.598**	**1.428**	**0.013**	**0.596**	**0.45**	**0.012**	**0.015**	**0.013**

Table-8 : Growth attributes of French beans under organic amendments

Treatment	**Plant height (cm)**			**Plant spread (cm)**			**No. of leaves/plant**		
	2012	**2013**	**Pooled**	**2012**	**2013**	**Pooled**	**2012**	**2013**	**Pooled**
T_1	38.60	41.02	39.81	23.33	24.25	23.79	13.03	15.70	14.36
T_2	38.61	42.01	40.31	22.51	25.51	24.01	13.60	16.03	14.81
T_3	39.80	41.01	40.40	24.60	28.50	26.55	12.60	18.20	15.40
T_4	45.01	49.01	47.01	28.25	32.50	30.37	21.03	21.20	21.11
T_5	50.12	55.01	52.56	29.70	33.75	31.72	19.23	23.30	21.26
T_6	39.61	44.60	42.10	24.83	29.51	27.17	15.20	18.30	16.75
T_7	41.66	42.81	42.23	26.25	28.33	27.29	15.60	18.60	17.10
T_8	34.81	35.01	34.91	19.50	20.83	20.16	11.20	13.30	12.25
T_9	36.66	39.01	37.83	20.91	25.25	23.08	12.20	15.06	13.63
T_{10}	35.01	36.40	35.70	20.75	23.10	21.93	11.80	14.33	13.06
C.D ($P \leq 0.05$)	**0.381**	**0.516**	**0.449**	**1.167**	**1.451**	**1.309**	**0.358**	**0.681**	**0.519**

significantly lowest number of leaves of 8.91 during 2011was noticed in T_{10} and 9.30 and 9.27 were recorded in T_8 in Kale during 2012 and pooled data respectively. In French beans the lowest number of leaves/plant of 11.20, 13.30 and 12.25 was recorded in T_8 during 2012, 2013 and pooled data respectively.

4.4.4 Yield/plot (kg)

A perusal of the data presented in Tables-7, 8 and 9 shows significant influence of different organic amendments on yield of Kale and French beans. It is inferred from the results that in Kale significantly highest yield of 13.50, 15.70 and 14.60 kg during 2011, 2012 and pooled data respectively was noticed in T_5 and lowest of 5.21, 7.89 and 6.55 kg was recorded in T_8 during 2011, 2012 and pooled data respectively. In French beans significantly highest yield of 5.10 and 4.68 kg was observed in T_5 during 2013 and pooled data. However, during 2012 highest yield of 4.47 kg was recorded in T_4. The lowest of 3.01, 3.72 and 3.54 kg was noticed in T_2, T_{10} and T_8 during 2012, 20013 and pooled data, respectively.

4.4.5 No. of branches/plant

The data pertaining to the impact of organic amendments on number of branches/plant in French beans has been presented in Table-9. T_5 recorded highest number of branches of 6.80, 7.10 and 6.95 during 2012, 2013 and pooled data, respectively which are statistically at par with T_4 and T_7. The significantly lowest number of branches of 4.20, 4.40 and 4.30 during 2012, 2013 and pooled data, respectively was recorded in T_8.

4.4.6 No. of pods/plant

It is inferred from the results (Table-9) that in French beans significantly high number of pods of 17.00 and 15.60 during 2013 and pooled data respectively was recorded in T_5 which is statistically at par with T_4 in pooled data . However during 2012 the highest of 14.86 was observed in T_4 and lowest of 10.03, 12.43 and 11.93 was recorded in T_2, T_{10} and T_8 during 2011, 2012 and pooled data respectively.

Table-9 : Growth and yield attributes of french beans under organic amendments

Treatment	No. of branches/plant			No. of pods/plant			Yield/plot (kg)		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
T_1	5.60	5.70	5.65	11.30	13.80	12.55	3.39	4.14	3.76
T_2	5.40	6.20	5.80	10.03	15.10	12.56	3.01	4.56	3.78
T_3	6.03	6.40	6.21	11.40	14.50	12.95	3.42	4.35	3.88
T_4	6.60	6.80	6.70	14.86	16.00	15.43	4.47	4.80	4.63
T_5	6.80	7.10	6.95	14.20	17.00	15.60	4.26	5.10	4.68
T_6	6.03	6.63	6.33	13.30	14.40	13.85	4.02	4.29	4.15
T_7	6.50	6.80	6.65	14.03	14.33	14.18	4.20	4.20	4.20
T_8	4.20	4.40	4.30	10.50	13.36	11.93	3.18	3.90	3.54
T_9	4.80	5.80	5.30	11.26	13.80	12.53	3.39	4.14	3.76
T_{10}	5.03	5.30	5.16	11.50	12.43	11.96	3.48	3.72	3.60
C.D ($P \leq 0.05$)	**0.374**	**0.358**	**0.342**	**0.537**	**0.371**	**0.454**	**0.018**	**0.016**	**0.017**

4.5 Above and belowground biomass production of Kale and French beans under organic amendments

4.5.1 Fresh root weight (g)

The data regarding the effect of different organic amendments on fresh root weight of Kale and French beans is presented in Tables-10 and 11. A perusal of pooled data of two years (2011, 2012) reveals that Kale plots amended with 25% PM + 75% N, P and K recorded significantly high fresh weight of 28.20, 33.30 and 30.75 g whereas significantly low fresh weight of 19.20, 15.40 and 17.30 g was recorded in T_7 during 2011, 2012 and pooled data. In case of French beans significantly high fresh weight of 8.10 and 7.55 g was recorded in T_3 which was at par with T_6 during 2012 and pooled data, respectively. However, during 2013, T_3 was at par with T_2 and significantly low fresh weight of 4.00, 4.00 and 4.00g was recorded in T_1 during 2012, 2013 and pooled data, respectively.

4.5.2 Dry root weight (g)

From the perusal of data (Tables-10 and 11) it is evident that application of 25% PM + 75% N, P and K recorded significantly high dry weight of 5.64, 6.66 and 6.15 g in Kale during 2011, 2012 and pooled data respectively and the significantly low of 3.76 during 2011 was noticed in T_8 and 2.86 and 3.35 were recorded in T_7 during 2012 and pooled data respectively. In French beans the significantly high of 3.24 and 3.07 g was recoded in T_3 during 2013 and pooled data respectively. However, during 2012, highest of 2.90 g was observed in T_3 which was statistically at par with T_5, T_6, T_7, T_9 and T_{10} and significantly low of 1.60, 1.60, 1.60 g was observed in T_1 during 2012, 2013 and pooled data, respectively.

4.5.3 Fresh shoot weight (g)

A perusal of the data presented in Tables-10 and 11 reveals significant influence of different organic amendments on fresh shoot weight of Kale and

Table-10 : Above and belowground biomass Production of Kale under organic amendments

Treatment	Fresh root weight (g)			Dry root weight (g)			Fresh shoot weight (g)			Dry shoot weight (g)		
	2011	**2012**	**Pooled**	**2011**	**2012**	**Pooled**	**2011**	**2012**	**Pooled**	**2011**	**2012**	**Pooled**
T_1	22.80	23.30	23.05	4.56	4.66	4.61	114.80	142.03	128.42	22.96	28.40	25.68
T_2	21.23	21.00	21.12	4.24	4.20	4.22	150.40	131.30	140.85	30.08	28.26	29.17
T_3	19.80	23.33	21.57	3.96	4.66	4.31	158.43	157.73	158.08	31.68	31.27	31.47
T_4	28.20	33.30	30.75	5.64	6.66	6.15	269.40	266.70	268.05	49.96	54.60	52.28
T_5	20.23	21.03	20.63	4.03	5.20	4.61	249.80	263.13	256.46	35.88	37.34	36.61
T_6	27.20	30.03	28.61	4.84	5.01	4.92	181.60	162.13	171.87	36.32	32.40	34.36
T_7	19.20	15.40	17.30	3.84	2.86	3.35	138.63	109.03	123.83	27.72	28.01	27.86
T_8	18.80	21.60	20.20	3.76	4.32	4.04	193.20	159.40	176.30	38.64	35.88	37.26
T_9	19.60	24.60	22.10	3.98	4.91	4.44	185.70	173.03	179.37	37.14	34.60	35.87
T_{10}	19.50	23.03	21.26	3.90	4.60	4.25	199.90	184.60	192.25	39.98	36.92	38.45
C.D ($P \le 0.05$)	**0.291**	**0.511**	**0.431**	**0.012**	**0.012**	**0.012**	**3.851**	**2.512**	**3.181**	**0.581**	**0.751**	**0.666**

Table-11 : Above and belowground biomass production of French beans under organic amendments

Treatment	Fresh root weight (g)			Dry root weight (g)			Fresh shoot weight (g)			Dry shoot weight (g)		
	2012	**2013**	**Pooled**	**2012**	**2013**	**Pooled**	**2012**	**2013**	**Pooled**	**2012**	**2013**	**Pooled**
T_1	4.00	4.00	4.00	1.60	1.60	1.60	130.20	118.00	124.10	52.10	47.20	49.65
T_2	5.00	7.60	6.30	2.03	3.04	2.53	127.60	141.40	134.50	51.04	55.56	53.30
T_3	7.00	8.10	7.55	2.90	3.24	3.07	133.03	157.87	145.45	55.20	56.36	55.78
T_4	5.00	5.03	5.01	2.03	2.03	2.03	123.20	129.00	126.10	49.28	51.60	50.44
T_5	6.00	5.50	5.75	2.40	2.20	2.30	125.80	130.50	128.15	49.52	52.20	50.86
T_6	7.00	6.86	5.75	2.60	2.96	2.78	124.80	128.10	126.45	52.12	51.24	51.68
T_7	6.00	5.50	5.75	2.60	1.80	2.55	122.00	124.50	123.25	48.80	45.80	47.30
T_8	5.00	6.10	5.55	2.00	2.72	2.36	125.80	137.20	131.50	49.92	50.88	50.40
T_9	6.00	6.20	6.10	2.40	2.48	2.44	130.20	134.80	132.50	52.98	53.92	53.45
T_{10}	6.00	5.80	5.05	2.40	1.64	2.02	127.40	109.87	118.63	50.96	52.91	51.93
C.D ($P \leq 0.05$)	**0.81**	**0.515**	**0.661**	**0.562**	**0.1**	**0.274**	**0.859**	**0.961**	**0.91**	**0.315**	**0.801**	**0.558**

French beans. It is inferred from the results that in Kale significantly high fresh shoot weight of 269.40, 266.70 and 268.05g during 2011, 2012 and pooled data respectively was recorded in T_4 and low of 109.03 and 123.83 g was recorded in T_7 during 2012 and pooled data respectively. However, lowest fresh shoot weight of 114.80 g was recorded in T_1 during 2011. In French beans the data shows that significantly high fresh shoot weight of 133.03, 157.87 and 145.45 g was observed in T_3 during 2012, 2013 and pooled data. The low of 109.87 and 118.63 g was noticed in T_{10} during 2013 and pooled data, respectively and during 2012 the lowest of 122.00 g was observed in T_7.

4.5.4 Dry shoot weight (g)

It is inferred from the results (Tables-10 and 11) that in Kale significantly high dry weight of 49.96, 54.60 and 52.28 g during 2011, 2012 and pooled data respectively was observed in T_4 and significantly low of 22.96 and 25.68 g during 2011 and pooled data were noticed in T_1, however during 2012 lowest of 28.01 g was recorded in T_7. In French beans significantly high dry weight of 55.20, 56.36 and 55.78 g during 2012, 2013 and pooled data, respectively was recorded in T_3 however during 2013 T_3 was statistically at par with T_2 and lowest of 48.80, 45.80 and 47.30 g was noticed in T_7 during 2012, 2013 and pooled data respectively.

4.6 Partitioning of above and below ground biomass of Kale and French beans under organic amendments

4.6.1 Shoot mass ratio (%)

The data regarding the effect of different organic amendments on shoot mass ratio of Kale and French beans is presented in Tables-12 and 13. A perusal of pooled data of two years (2011, 2012) reveals that Kale plots amended with 25% PM + 75% RFD recorded significantly high shoot mass ratio of 91.13 and 90.21% during 2011 and pooled data, however during 2012 highest of 90.73% was noticed in T_7 whereas significantly lowest of 83.43, 85.90 and 84.78% was recorded in T_1 during 2011 and pooled data. In case of French beans significantly high shoot mass ratio of 97.02 and 96.87% was noticed in T_4 during 2012 and

Table-12 : Partitioning of above and below ground biomass of Kale under organic amendments

Treatment	Root mass ratio (%)			Shoot mass ratio (%)			Shoot:root ratio		
	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled
T_1	10.11 (3.180)	12.22 (3.496)	11.20 (3.35)	83.43 (9.134)	85.90 (9.268)	84.78 (9.21)	5.035	6.09	5.57
T_2	12.35 (3.515)	12.94 (3.598)	12.64 (3.56)	87.64 (9.362)	87.05 (9.330)	87.35 (9.35)	7.09	6.72	6.90
T_3	11.11 (3.333)	12.97 (3.602)	12.05 (3.47)	88.88 (9.428)	87.02 (9.329)	87.94 (9.38)	8.00	6.70	7.29
T_4	10.14 (3.186)	10.87 (3.297)	10.52 (3.24)	91.13 (9.546)	89.25 (9.447)	90.21 (9.50)	8.85	8.19	8.49
T_5	16.56 (4.071)	14.09 (3.754)	15.21 (3.90)	89.88 (9.481)	87.77 (9.369)	88.79 (9.42)	10.27	8.30	9.22
T_6	11.75 (3.429)	13.39 (3.660)	12.53 (3.54)	88.24 (9.394)	86.60 (9.306)	87.46 (9.35)	7.50	6.46	6.97
T_7	12.16 (3.488)	9.26 (3.044)	10.73 (3.28)	87.83 (9.372)	90.73 (9.526)	89.26 (9.45)	7.21	9.79	8.31
T_8	8.86 (2.978)	10.74 (3.278)	9.780 (3.13)	89.85 (9.479)	89.12 (9.441)	89.47 (9.46)	8.88	7.18	7.92
T_9	9.67 (3.111)	12.44 (3.527)	11.03 (3.32)	90.32 9.504)	87.55 (9.357)	88.96 (9.43)	9.33	7.03	8.06
T_{10}	8.88 (2.981)	11.07 (3.328)	9.95 (3.15)	91.11 (9.545)	88.92 (9.430)	90.04 (9.49)	10.25	8.02	9.04
C.D ($P \leq 0.05$)	**0.054**	**0.082**	**0.068**	**0.015**	**0.035**	**0.025**	**0.011**	**0.013**	**0.012**

*Figures in parenthesis are square root transformed means

Table-13 : Partitioning of above and below ground biomass of French beans under organic amendments

Treatment	Shoot mass ratio (%)			Root mass ratio (%)			Shoot:root ratio		
	2012	**2013**	**Pooled**	**2012**	**2013**	**Pooled**	**2012**	**2013**	**Pooled**
T_1	96.03	96.20	96.12	2.97	3.27	3.12	20.63	23.72	22.11
	(9.800)	(9.809)	(9.80)	(1.726)	(1.810)	(1.77)			
T_2	96.16	94.81	95.45	3.83	5.18	4.54	25.10	18.27	21.01
	(9.807)	(9.737)	(9.77)	(1.957)	(2.277)	(2.13)			
T_3	95.00	94.56	94.78	4.62	4.04	4.32	19.03	17.39	18.16
	(9.747)	(9.724)	(9.47)	(2.150)	(2.011)	(2.08)			
T_4	97.02	96.72	96.87	3.96	3.79	3.87	24.23	25.38	24.80
	(9.850)	(9.835)	(9.84)	(1.990)	(1.946)	(1.97)			
T_5	95.37	95.95	95.67	4.99	5.43	5.21	32.56	29.50	31.03
	(9.766)	(9.796)	(9.78)	(2.234)	(2.331)	(2.28)			
T_6	95.24	94.53	94.89	4.75	5.46	5.10	20.04	17.31	18.58
	(9.760)	(9.723)	(9.74)	(2.179)	(2.336)	(2.26)			
T_7	94.94	96.21	94.88	5.05	3.78	5.11	18.76	25.44	18.54
	(9.744)	(9.809)	(9.74)	(2.249)	(1.944)	(2.26)			
T_8	96.14	94.92	95.52	3.85	5.07	4.47	24.96	18.70	21.35
	(9.806)	(9.743)	(9.77)	(1.962)	(2.252)	(2.11)			
T_9	95.66	95.60	95.63	4.33	4.39	4.36	22.070	21.74	21.90
	(9.781)	(9.778)	(9.78)	(2.081)	(2.096)	(2.09)			
T_{10}	95.50	96.99	96.25	4.49	3.00	3.74	21.23	32.26	25.71
	(9.773)	(9.849)	(9.81)	(2.120)	(1.733)	(1.93)			
C.D ($P \leq 0.05$)	**0.022**	**0.054**	**0.038**	**0.014**	**0.031**	**0.022**	**0.174**	**0.144**	**0.159**

*Figures in parenthesis are square root transformed means

pooled data, respectively and T_4 was at par with T_{10} in pooled data. However, during 2013, highest shoot mass ratio of 96.99% was recorded in T_{10} which was statistically at par with T_4 and significantly low shoot mass ratio of 95.00, 94.53, 94.88% was recorded in T_3, T_6 and T_7 during 2012, 2013 and pooled data, respectively.

4.6.2 Root mass ratio (%)

The results (Tables-12 and 13) revealed significant variation in root mass ratio of Kale and French beans by different organic amendments. It is evident from the data that Kale plots amended with 50% PM + 50% RDF recorded significantly high root mass ratio of 16.56, 14.09 and 15.21% whereas significantly lowest root mass ratio of 8.86 and 9.78% was recorded in T_8 during 2011 and pooled data, whereas, during 2012 lowest of 9.26% was recorded in T_7. In case of French beans significantly high values of 5.05, 5.46 and 5.21% were noticed in T_7, T_6 and T_5 during 2012, 2013 and pooled data, respectively. However, during 2013, T_6 was statistically at par with T_5 and T_5 was at par with T_7 in pooled data and significantly low root mass ratio of 2.97 and 3.12% was recorded in T_1 during 2012 and pooled data, respectively and during 2013 lowest of 3.00% was observed in T_{10}.

4.6.3 Shoot root ratio

The data regarding the effect of different organic amendments on shoot root ratio of Kale and French beans is presented in Tables-12 and 13. A perusal of pooled data of two years reveals that Kale plots amended with 50% PM + 50% RFD recorded significantly high shoot root ratio of 10.27 and 9.22 during 2011 and pooled data and T_7 recorded significantly high value of 9.79 during 2012, whereas significantly low shoot root ratio of 5.03, 6.09 and 5.57 was recorded in T_1 during 2011, 2012 and pooled data. In case of French beans significantly highest shoot root ratio of 32.56 and 31.03 was noticed in T_5 during 2012 and pooled data, respectively. However, during 2013, significantly high value of 32.26 was observed in T_{10} and significantly low of 18.76, 17.31 and 18.16 was recorded in T_7, T_6 and T_3 during 2012, 2013 and pooled data, respectively.

4.7 Carbon detail and total nitrogen of Kale and French beans grown in organically amended soils

4.7.1 Root carbon (%)

A perusal of the data presented in Tables-14, 15 and 16 shows significant influence of different organic amendments on root carbon of Kale and French beans. In Kale significantly high root carbon of 11.86, 13.26 and 12.56% during 2011, 2012 and pooled data respectively and in French beans high value of 22.70, 23.70 and 23.20% during 2012, 2013 and pooled data respectively was noticed in T_{10} and significantly low value of 0.73, 1.60 and 1.16% in Kale was recorded in T_1 during 2011, 2012 and pooled data respectively and in French beans the lowest root carbon of 2.70, 2.80 and 2.75 % was noticed in T_1 during 2012, 2013 and pooled data, respectively.

4.7.2 Shoot carbon (%)

It is inferred from the results (Tables-14, 15 and 16) that in Kale significantly high shoot carbon of 10.13, 11.10 and 10.61% during 2011, 2012 and pooled data respectively and in French beans highest of 50.30, 51.80 and 51.05% during 2012, 2013 and pooled data respectively was observed in T_{10} and significantly low value of 1.30, 1.76 and 1.53% during 2011, 2012 and pooled data in Kale and lowest of 38.70, 39.17 and 38.93% in French beans during 2012, 2013 and pooled data were observed in T_1.

4.7.3 Leaf area ratio (cm^2/g)

The data regarding the effect of different organic amendments on leaf area ratio of Kale and French beans is presented in Tables-14 and 15. A perusal of pooled data reveals that Kale plots amended with 100% vermicompost recorded significantly high leaf area of 5.91 and 5.33 cm^2/g during 2012 and pooled data, however during 2011 highest value of 4.98 cm^2/g was noticed in T_8 whereas significantly low of 2.50 and 3.50 cm^2/g was recorded in T_1 during 2011 and pooled data and during 2012 lowest value of 3.97 cm^2/g was observed in T_4. In

Table-14 : Carbon detail and total nitrogen of kale grown in organically amended soils

Treatment	Carbon content						Carbon assimilating capacity			Total nitrogen of leaf (%)		
	Root carbon (%)			Shoot carbon (%)			Leaf area ratio (cm^2/g)					
	2011	**2012**	**Pooled**	**2011**	**2012**	**Pooled**	**2011**	**2012**	**Pooled**	**2011**	**2012**	**Pooled**
T_1	0.73 (0.856)	1.60 (1.264)	1.16 (1.08)	1.30 (1.140)	1.76 (1.329)	1.53 (1.24)	2.50	4.51	3.50	2.11	3.61	2.86
T_2	3.33 (1.826)	3.63 (1.906)	3.48 (1.87)	3.30 (1.816)	3.80 (1.949)	3.55 (1.88)	4.05	4.30	4.17	2.77	3.27	3.02
T_3	9.33 (3.055)	10.16 (3.189)	9.74 (3.12)	9.33 (3.055)	9.53 (3.088)	9.43 (3.07)	4.27	4.81	4.54	2.52	4.01	3.26
T_4	2.73 (1.653)	3.60 (1.897)	3.16 (1.78)	1.33 (1.155)	1.76 (1.329)	1.54 (1.24)	3.08	3.97	3.52	2.81	3.61	3.21
T_5	7.43 (2.726)	8.80 (2.966)	8.11 (2.85)	5.30 (2.302)	5.80 (2.408)	5.55 (2.36)	3.38	5.51	4.44	3.23	4.73	3.98
T_6	3.30 (1.816)	4.23 (2.057)	3.76 (1.94)	5.26 (2.295)	5.80 (2.408)	5.53 (2.35)	4.29	4.28	4.28	2.46	3.95	3.20
T_7	10.43 (3.230)	11.83 (3.440)	11.13 (3.34)	9.30 (3.050)	9.80 (3.130)	9.55 (3.09)	4.16	5.03	4.59	2.45	4.35	3.40
T_8	10.70 (3.271)	11.60 (3.406)	11.15 (3.34)	9.76 (3.125)	10.80 (3.286)	10.28 (3.21)	4.98	5.43	5.20	1.54	3.04	2.29
T_9	10.73 (3.276)	11.56 (3.401)	11.14 (3.34)	9.20 (3.033)	10.20 (3.194)	9.70 (3.11)	4.52	5.11	4.81	2.11	3.61	2.86
T_{10}	11.86 (3.445)	13.26 (3.642)	12.56 (3.54)	10.13 (3.183)	11.10 (3.332)	10.61 (3.26)	4.76	5.91	5.33	2.01	2.80	2.40
C.D ($P \leq 0.05$)	**0.015**	**0.028**	**0.022**	**0.034**	**0.027**	**0.030**	**0.016**	**0.018**	**0.017**	**0.013**	**0.015**	**0.028**

*Figures in parenthesis are square root transformed means

Table-15 : **Carbon detail of French beans grown in organically amended soils**

Treatment	Carbon content						Carbon assimilating capacity		
	Root carbon (%)			Shoot carbon (%)			Leaf area ratio (cm^2/g)		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
T_1	2.70 (1.643)	2.80 (1.810)	2.75 (1.66)	38.70	39.17	38.93	0.49	0.60	0.54
T_2	5.30 (2.302)	6.30 (1.733)	5.80 (2.41)	43.30	43.83	43.56	1.01	0.16	0.58
T_3	8.70 (2.950)	9.40 (1.946)	9.05 (3.01)	45.30	46.30	45.80	0.55	0.65	0.60
T_4	5.30 (2.302)	6.03 (2.331)	5.66 (2.38)	43.30	43.43	43.36	0.51	0.61	0.56
T_5	8.70 (2.950)	9.40 (2.336)	9.05 (3.01)	45.23	46.30	45.76	0.52	0.63	0.58
T_6	6.70 (2.588)	7.40 (2.011)	7.05 (2.66)	45.30	45.77	45.53	0.53	0.64	0.58
T_7	13.30 (3.647)	14.30 (2.096)	13.80 (3.71)	45.30	46.33	45.81	0.57	0.72	0.65
T_8	18.70 (4.342)	19.40 (2.277)	19.05 (4.36)	49.30	49.83	49.56	0.71	0.86	0.78
T_9	16.70 (4.087)	17.40 (1.944)	17.05 (4.13)	47.30	47.80	47.55	0.66	0.77	0.71
T_{10}	22.70 (4.764)	23.70 (2.252)	23.20 (4.82)	50.30	51.80	51.05	1.87	1.98	1.93
C.D ($P \leq 0.05$)	**0.023**	**0.016**	**0.019**	**0.168**	**0.098**	**0.133**	**0.017**	**0.017**	**0.017**

*Figures in parenthesis are square root transformed means

Table-16 : **Carbon detail of Kale and French bean grown in organically amended soils**

Treatment	Carbon content of Kale						Carbon content of French bean					
	Root carbon (%)			Shoot carbon (%)			Root carbon (%)			Shoot carbon (%)		
	2011	2012	Pooled	2011	2012	Pooled	2012	2013	Pooled	2012	2013	Pooled
T_1	0.73 (0.85)	1.60 (1.26)	1.16 (1.08)	1.30 (1.14)	1.76 1.14)	1.53 (1.24)	2.70 (1.64)	2.80 (1.81)	2.75 (1.66)	38.70	39.17	38.93
T_2	3.33 (1.82)	3.63 (1.90)	3.48 (1.87)	3.30 (1.81)	3.80 (1.94)	3.55 (1.88)	5.30 (2.30)	6.30 (1.73)	5.80 (2.41)	43.30	43.83	43.56
T_3	9.33 (3.05)	10.16 (3.18)	9.74 (3.12)	9.33 (3.05)	9.53 (3.08)	9.43 (3.07)	8.70 (2.95)	9.40 (1.94)	9.05 (3.01)	45.30	46.30	45.80
T_4	2.73 (1.65)	3.60 (1.89)	3.16 (1.78)	1.33 (1.15)	1.76 (1.32)	1.54 (1.24)	5.30 (2.30)	6.03 (2.33)	5.66 (2.38)	43.30	43.43	43.36
T_5	7.43 (2.72)	8.80 (2.96)	8.11 (2.85)	5.30 (2.30)	5.80 (2.40)	5.55 (2.36)	8.70 (2.95)	9.40 (2.33)	9.05 (3.01)	45.23	46.30	45.76
T_6	3.30 (1.81)	4.23 (2.05)	3.76 (1.94)	5.26 (2.29)	5.80 (2.40)	5.53 (2.35)	6.70 (2.58)	7.40 (2.01)	7.05 (2.66)	45.30	45.77	45.53
T_7	10.43 (3.23)	11.83 (3.44	11.13 (3.34)	9.30 (3.05)	9.80 (3.13)	9.55 (3.09)	13.30 (3.64)	14.30 (2.09)	13.80 (3.71)	45.30	46.33	45.81
T_8	10.70 (3.27)	11.60 (3.40	11.15 (3.34)	9.76 (3.12)	10.80 (3.28)	10.28 (3.21)	18.70 (4.34)	19.40 (2.27)	19.05 (4.36)	49.30	49.83	49.56
T_9	10.73 (3.27)	11.56 (3.40)	11.14 (3.34)	9.20 (3.03)	10.20 (3.19)	9.70 (3.11)	16.70 (4.08)	17.40 (1.94)	17.05 (4.13)	47.30	47.80	47.55
T_{10}	11.86 (3.44)	13.26 (3.64)	12.56 (3.54)	10.13 (3.18)	11.10 (3.33)	10.61 (3.26)	22.70 (4.76)	23.70 (2.25)	23.20 (4.82)	50.30	51.80	51.05
C.D ($P \leq 0.05$)	**0.015**	**0.028**	**0.022**	**0.034**	**0.027**	**0.030**	**0.023**	**0.016**	**0.019**	**0.168**	**0.098**	**0.133**

*Figures in parenthesis are square root transformed means

case of French beans significantly high value of 1.87, 1.98 and 1.93 cm^2/g was noticed in T_{10} during 2011, 2012 and pooled data, respectively and significantly low value of 0.49 and 0.54 cm^2/g was recorded in T_1 during 2012 and pooled data and T_2 recorded lowest leaf area ratio of 0.16 cm^2/g during 2013.

4.7.4 Total nitrogen (%)

A perusal of the data presented in Tables-14 shows significant influence of different organic amendments on total nitrogen of leaf in Kale. It is inferred from the results that in Kale significantly high total nitrogen of 3.23, 4.73 and 3.98% during 2011, 2012 and pooled data respectively was recorded in T_5 and significantly low total nitrogen of 1.54 and 2.29% during 2011 and pooled data was observed in T_8 and during 2012, T_{10} recorded lowest of 2.80%. In French beans high of 3.36, 5.26 and 4.31% was noticed during 2012, 2013 and pooled data and the lowest of 2.05 and 1.78% was recorded in T_8 during 2013 and pooled data, respectively. However, lowest total nitrogen of 1.03% was observed in T_{10} during 2012 (Table-17).

4.7.5 Number of nodules/plant

The data pertaining to the impact of organic amendments on number of nodules/plant in French beans has been presented in Table-17. T_5 recorded highest number of nodules of 30.20, 32.40 and 31.30 during 2012, 2013 and pooled data, respectively which are statistically significant as compared to other treatments. The significantly low number of nodules of 22.80 and 23.95 was recorded in T_8 during 2012 and pooled data, respectively, however, T_{10} recorded lowest of 25.00 during 2013.

Table-17 : Total nitrogen of pods and number of nodules of French beans as affected by organic amendments

Treatment	Total nitrogen of pods (%)			No. of nodules/plant		
	2012	2013	Pooled	2012	2013	Pooled
T_1	1.34	3.24	2.29	24.10	26.03	25.06
T_2	2.15	3.25	2.70	23.70	26.60	25.15
T_3	2.38	4.28	3.33	28.00	29.50	28.75
T_4	2.01	4.05	3.03	27.00	29.00	28.00
T_5	3.36	5.26	4.31	30.20	32.40	31.30
T_6	2.46	3.56	3.01	26.80	28.00	27.40
T_7	2.40	4.30	3.35	29.20	31.50	30.35
T_8	1.51	2.05	1.78	22.80	25.10	23.95
T_9	1.51	2.61	2.06	24.60	25.30	24.95
T_{10}	1.03	3.00	2.01	23.00	25.00	24.00
C.D ($P \leq 0.05$)	**0.017**	**0.017**	**0.017**	**1.106**	**0.84**	**0.847**

Muffle Furnace

Plate-6 : Determination of carbon content (%) by Ash method

Vacuum desiccator

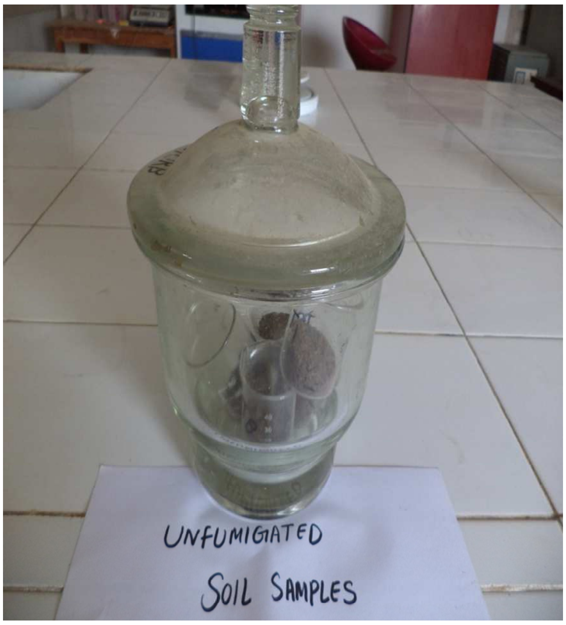

Plate-7 : **Determination of soil microbial biomass carbon by chloroform fumigation extraction method**

Chapter – 5

DISCUSSION

The present investigation entitled "Impact of organic amendments on soil carbon sequestration and biomass carbon allocation of crops" was conducted for two consecutive *Rabi* seasons of 2011 and 2012 and *Kharief* seasons of 2012 and 2013 at Seed Multiplication Unit, Shuhama, SKUAST-Kashmir. This chapter has been devoted to examine the results of current study based on the logical arguments in the light of the scientific evidences available in the literature. The results have been proved by establishing the cause and effect relationship between them to derive out the fruitful conclusions.

Soil plays significant role in global carbon cycle. It was estimated that soils have contributed as much as 55 to 78 billion tonnes of carbon to the total atmospheric CO_2 (Kimble *et al.*, 2002). The total soil carbon consists of the soil organic carbon and inorganic carbon, estimated to be approximately over 2250 billion tons in the top 1meter depth (Batjes, 1999). A key process in many unsustainable agricultural systems is degradation of soils through loss of soil organic carbon (SOC). With cultivation, soils may lose 50% or more of their organic carbon content, depending on soil conditions and agricultural practices. Sequestration of soil organic carbon from plant biomass is a key sequestration pathway in agriculture; offering an offset strategy (i.e.,mitigation) for agriculture's other greenhouse gas emissions. Soil carbon sequestration is also important at the farm level to build soil fertility, protect soil from compaction and nurtural soil biodiversity. In addition to its vital role of mitigating greenhouse gas emissions, soil carbon sequestration provides many other significant off-farm benefits to society (Franzluebbers, 2007).

The present study reveals that pH of the soil under the cultivation of Kale and French beans showed the decrease in all the treatments. The lowest value is recorded in T_{10} treatment with the application of 100% Vermicompost and highest in T_1 (RFD). Decrease in the pH could be attributed to the acidifying effect of urea and organic acids produced during the course of decomposition of organic amendments. Compost manure application lower the pH which may be due to the accumulation of organic acids from microbial metabolism or from the production of fulvic and humic acids decomposition (Albanell *et al.*, 1988). These results are in the agreement with the findings of (Srikanth *et al.*, 2000) who reported decrease in pH of the soils treated with enriched compost after harvest of Ragi and Cowpea. Similar results were reported by Gopinath *et al.* (2009) in his experiments with Capsicum cultivated in open field. Organic amendments had a greater effect on the soil pH than the inorganic fertilizer (Savalva *et al.*, 2003). The addition of vermicompost in soil results decrease of soil pH in tomato (*Lycopersicum esculentum*) (Azarmi *et al.*, 2008). The decrease in pH of the soil by about one unit from the initial value could be related to the decomposition and mineralization of organic matter (Kannan *et al.*, 2013). Deshpande and Devasenapathy (2010) also reported that application of vermicompost decreased the soil pH. The decrease in pH of the soil could be due to release of organic matter and this could help in the reduction of alkalinity of soils (Ganiger *et al.*, 2012).

The study reveals that electrical conductivity showed significant increase with the application of 100% VC (T_{10}) followed by T_8 (100% FYM) in soils under cultivation of Kale and French beans. Electrical conductivity is a soil parameter that indicates indirectly the total concentration of soluble salts and is a direct measurement of salinity. Although EC of the soil increased in different treatments but the actual values did not cross the critical limit of 4.0 dS m^{-1}. The possible explanation for increasing EC may be due to the large quantities of soluble salts and HCO^{-3} contained in the manure compost (Wong *et al.*, 1999). Similar results have been reported by (Sarwar *et al.*, 2003; Niklasch and Joergensen, 2001; Selvakumari *et al.*, 2000) which indicates that EC increases in acidic as well as alkaline soils when organic materials of different nature are applied to the soil.

The decomposition of organic materials release acids or acid forming compounds that react with the sparingly soluble salts already present in the soil and either convert them into soluble salts or at least increase their solubility. Hence, the EC of soil was increased e.g., $CaCO_3$ (ever present in the soils of arid and semi-arid regions) may be converted to $CaHCO_3$ or even to Na_2CO_3 which are more soluble forms. However, the quantum of increase will depend how much quantity of the acids or acid forming substances is produced which will in turn relay upon the amount of the organic materials applied. A trend of general increase in EC of normal soil was observed after rice and wheat crops by application of sole compost or in combination with chemical fertilizer (Sarwar *et al*., 2008). The electrical conductivity, representing salt content, increased linearly in response to increasing concentrations of pig manure vermicomposts in planting media mixtures (Atiyeh *et al.*, 2001). Klock (1997) also reported that electrical conductivity of planting media substituted with vermicomposts increased in the range of 1.3 to 2.8 times over those untreated control.

Our present study revealed that cation exchange capacity (CEC) had significantly increased in all the ten different treatments under Kale and French beans, particularly in T_{10} with 100% vermicompost followed by T_8 (100% FYM). In addition to the presence of higher amount of humus, presence of clay loam, soil have helped in boosting the cation exchange capacity. Organic amendments added to silt loam soil improves soil structure, especially the formation of macro-aggregates. Soil organic matter also binds plant micronutrients like iron, aluminum, zinc, copper and manganese by chelation — a chemical association of organic matter when fresh organic matter is added to the soil, microbes release long-chain sugars or polysaccharides and make them available for plant uptake relatively quickly. These polysaccharides promote formation of large or macro-aggregates. Increase in available cations in vermicompost are related to the greater amounts of plant tissues that provide a larger surface area for cation exchange (Lee, 1995). Savalva *et al.* (2003) also reported that cation exchange capacity increases with an increase in pH from 5 to 7. CEC is greater in soils with greater amount of organic matter and clay. (Parthasarathi *et al.*, 2008) reported increased CEC in vermicompost plots mainly due to humic substances in the vermicompost. This observation falls in line with Vasanthi and Kumarasamy (1999) who found significant increase in CEC of the soil treated with vermicompost application. Same findings have been reported by Benedito, 2002 and Zink and Allen, 1998.

Among different treatments under cultivation of Kale and French beans T_{10} (100% VC) treatment recorded maximum soil moisture followed by T_8 (100% FYM). The improvement in soil moisture in response to the addition of organic matter is due to improved soil structure and water stable aggregates, as well as increasing the total number of storage pores which is attributed to the action of polysaccharides and fulvic acid components of organic matter. The consequence of increased water infiltration combined with a higher organic matter content is increased soil water storage. Especially in the top soil, where the organic matter content is greater, more water can be stored (Tadesse *et al.*, 2013). Boateng *et al.*, 2006 also reported that organic amendments with its high organic carbon content, adds organic matter to the soil. Organic matter has the ability to retain appreciable amounts of soil moisture, hence, probably the rise in level of moisture content of soil upon application of the manure. The increased soil moisture in vermicompost and vermicompost plus NPK treated plots was due to increased porosity and decreased bulk density of the soil due to vermicompost application and these in turn provide greater aeration and better drainage (Parthasarathi *et al.*, 2008). The soil moisture which depends on micro porosity of soil, varied significantly with application of organic nutrients. Further, the high humus content along with increased surface area and favourable aggregates might had resulted in increased soil moisture in the treatments where organics were components of nutrient sources compared to reduced soil moisture in inorganic fertilizer treatments (Ganiger *et al.*, 2012). These results are in the conformity with the results of Maheswarappa *et al.* (1999) who reported that vermicompost application increased soil porosity and soil moisture to a greater extent after growing of East Indian Galangal. Manures contain high amount of organic matter which increase the moisture retention of the soil and improve dissolutions of nutrients particularly phosphorus (Choudhary *et al*., 2013). It is in close conformity with the findings of Munirathnam *et al.* (2004) in Foxtail millet and Yadav (2001) in cowpea.

The study also reveals that application of T_{10} (100% VC) resulted in lowest bulk density in soils under cultivation of Kale and French beans and maximum in T_1 (RFD). Reduced bulk density indicates better aeration and drainage besides good soil physical condition that would help in better root penetration and proliferation necessary for vigorous growth and subsequent high yield of crops. The reduction in bulk density by organics may be due to the improvement of aggregation and structure which has direct influence on the bulk density of the soil. Similar observations were reported by Vasanthi and Kumarasamy (1999) who found a significant reduction in the bulk density of soil treated with vermicompost. The least reduction in bulk density among the ten treatments was observed in soils treated with only NPK. Manure and vermicompost significantly increased soil organic carbon (SOC) and decreased bulk density over time (Saha *et al*., 2008; Bhaskaran *et al*., 2009). Studies have observed lower soil bulk density and improved soil porosity as a consequence of organic fertilizer application (Agbede *et al*., 2008; Hati *et al*., 2006). Sarkar *et al.* (2003) reported decrease in soil bulk density, especially at 0-15 cm depth, when organic fertilizers were applied, although the decrease of soil bulk density was less when organic and inorganic fertilizers were combined. Results showed that application of 15 t FYM/ha significantly increased soil organic matter and available water holding capacity but decreased the soil bulk density, creating a good soil condition for enhanced growth of the rice crop (Tadesse *et al*., 2013). Soil bulk density was reduced due to application of organic manure having the minimum value. The higher bulk density in control and in only fertilizer treated plots may be due to very low organic matter content in soil and formation of compact layer (Islam *et al*., 2011). Mathur (1997) also observed that soil treated with organic matter showed lower bulk density. the addition of organic amendment (at least 33% for sandy loam and 50% for clay loam) to a compacted soil reduced bulk density **(**Rivenshield and Bassuk, 2007). According to Brady (1996), organic matter is the major component that stimulates the formation and stabilization of granular and crumb type of aggregates. As organic residue decompose organic acids, sugars, mucilaginous substances and other viscous microbial byproducts are evolved which, along with associated fungi and bacteria, encourage the crumb formation and net effect of these activities will decrease bulk density and increase porosity as reported by (Loganathan, 1990).

The present study reveals that T_{10} (100% VC) showed increase in organic carbon and soil carbon storage in soils under the cultivation of Kale and French beans followed by T_8 (100% FYM) and minimum in T_1 (RFD). The rapid build up of organic carbon in the soil may be due to higher level of organic matter, organic carbon, microbial and enzyme activities, (Tomati and Galli, 1995; Arancon *et al*., 2008) and due to the action of mineralization and slow release of N and fixation and accumulation of organic N in the soil. The build up of organic carbon helps in retention of soil moisture and acts as buffer to the soil and also increases the infiltration rate (Ganiger *et al*., 2012). The results are in conformity with that of Saha *et al.* (2008) who reported that the addition of cattle manure and vermicompost to the soil after three years increased organic carbon (54% and 52%, respectively). (Parthasarathi *et al*., 2008; Hapse, 1993; Vasanthi and Kumarswamy, 1996) reported that organic carbon had been phenomenally enhanced in all soil types treated with vermicompost and vermicompost plus NPK. The soil organic carbon content increased by 8.0, 9.6, 12.9 and 19.3 % in wheat straw, vermicompost, FYM and poultry manure treated soils, respectively, as compared to control (no manure). Organic carbon build up was maximum in organic manure amended soils during 15 to 60 days after incorporation and thereafter declining trend was observed. Compost produces significantly greater increases in soil organic carbon and some plant nutrients (García-Gil *et al.*, 2000; Bulluck *et al.*, 2002; Nardi *et al.*, 2004; Weber *et al.*, 2007).

Application of organic amendments to rice and wheat increased organic carbon status of soil (Chettri *et al.*, 2003). Similarly, Rogasik *et al.* (2004), Khursheed *et al.* (2013), Kannan *et al.* (2013), Katyal (2000) indicated that combination of organic and mineral fertilizes increased soil organic carbon content compared to exclusive mineral fertilizers. The results corroborate the findings of Manna *et al.* (2006), Ghosh *et al.* (2009), Kaschl *et al.* (2002), Babalad (1999), Manjappa (1999) who found a positive correlation between the addition of compost and soil organic carbon contents. The application of organic amendments increased the organic carbon content of the soil and thereby increasing the microbial counts and microbial biomass carbon (Nakhro and Dkhar, 2010).

The study also reveals increase in soil microbial biomass in all treatments under cultivation of Kale and French beans with the maximum in T_{10} (100% VC) followed by T_8 (100% FYM) and lowest in T_1 (RFD). Increased microbial biomass carbon content recorded in the organically treated plot maybe due to the suitable conditions for microbial growth (Nakhro and Dkhar, 2010). Leita *et al.* (1999) indicated that soils treated with FYM and composts showed a significant increase in total organic carbon and biomass carbon in response to the increasing amounts of organic carbon added. A positive effect of organic fertilizers on the microbial biomass nitrogen and the carbon content in the soil was also observed and reported by Cerny *et al.* (2008). The significant increase in microbial biomass carbon (MBC) with application of organic amendments along with inorganic fertilizer probably resulted from a more conducive environment for microbial growth (Grego *et al.*, 1998). Stimulation of microbial biomass and activities by organic carbon inputs has been well documented (Chowdhary *et al.*, 2000; Garcia Gil *et al.*, 2000; Peacock *et al.*, 2001). Rasmussen *et al.* (1998) reported that addition of organics caused a substantial increase in the MBC in soil.

Similar results are reported by Ghosh *et al*. (2010) and Ge *et al*. (2011). Microbial biomass levels are typically higher when legume cover crops are included in the rotation than when fields are left fallow between cash crops (Lupwayi *et al*., 1999).

In present study T_5 treatment (50% RFD + 50% PM) showed highest increase followed by T_7 (50% RFD + 50% VC) in available NPK in soils under cultivation of Kale and French beans. The plots receiving 50 %NPK through inorganic fertilizers and remaining 50% RDN through poultry manure (PM) registered the highest available N, P and K status in the soil and it was closely followed by the plots receiving 50% RDNPK through inorganic fertilizers and remaining 50% RDN through VC but was markedly higher than those of the plots receiving 100% RDNPK through only inorganic fertilizers during all the three years. Application of 100% RDN through organic manures only (PM, VC and FYM) also significantly enhanced the available N, P and K status of soil over its initial values. Application of 100% RDNPK through only inorganic fertilizers also increased the available N, P and K status in the soil over its initial values. The increase in soil N and P after PM application might be due to the direct addition of N and P through decomposition of the PM added to the soil. A large portion of the N in poultry manure is in organic fractions but 20 to 40 per cent of the total N is inorganic (Willrich *et al.*, 1974; Sims, 1987). The improvement in the soil available P with PM addition could be attributed to many factors, such as the addition of P through PM and retardation of soil P fixation by organic anions formed during PM decomposition. Kumar *et al*. (2012) also reported increase in available NPK through inorganic fertilizers and organic sources particularly PM or VC. Similar favourable effect of inorganic fertilizers and organic manures on increasing the available N, P and K contents in soil have been noticed by Kumar *et al.* (2008), Baishya (2009), Ghosh *et al.* (2004), Adeoye *et al*. (2011), Alabadan *et al*. (2009), Choudharya and Kumar (2013). Similar results were also obtained by (Devi and Agarwal, 1999) in sunflower.

The study also reveals that all the growth parameters i.e plant height, plant spread number of leaves, number of pods, number of branches of Kale showed maximum value in T_5 (50% RFD + 50% PM) followed by T_7 (50% RFD + 50% VC) and T_5 followed by T_4 (75% RFD + 25% PM) in French beans .This may be due fact that these organic manures supplies direct available nutrients such as nitrogen to the plants and these organic manures improves the proportion of water stable aggregates of the soil. Poultry manure is a good source of nutrients for crops, in this manure, 60 per cent of the nitrogen is present as uric acid (Srivastava, 1998). The uric acid readily changes into ammonical form of nitrogen. Therefore, it is of great value in soil fertility maintenance. The average nutrient content in poultry manure is 3.03 per cent N, 2.63 per cent P_2O_5 and 1.4 per cent K_2O (Malone *et al*., 1992). Higher plant growth as a result of organic amendment application maybe associated with the fact that the materials release considerable amount of nutrients especially nitrogen for plant use, this is essential for chlorophyll and protoplasm formation. The cementing action of polysacchrides and other organic compounds released during the decomposition of organic matters, thus leading to taller plants, increased number of leaves in Cowpea (Adeoye *et al*., 2011). The improvement in crop parameters is associated with the increase in NPK levels in the soil as affirmed by Reyhan and Amiraslani (2006). Channabasanagowda *et al.* (2008) also reported that vermicompost application @ 3.8 t per ha and poultry manure @ 2.45 t per ha recorded higher plant height and number of leaves per plant in boro rice. These results are in akin with Kale *et al.* (1994) in groundnut and Rajavel (2002) in cowpea. Babu *et al.* (2001) also reported that Plant height was significantly influenced by the application of organic manure and chemical fertilizers. Similar results also reported by Rajni *et al.* (2001),Singh *et al.* (1999), Hossain *et al.* (1997), Sharma and Mitra (1991).

Islam *et al*. (2011) also reported that the chemical fertilizers along with PM had a marked influence on the number of leaves/plant in raddish and spinach. Ullah *et al*. (2008) reported the maximum branching with combined application of manures and fertilizers. These results were in conformity with the findings of Rahman *et al.* (1998). Similar results were reported by Jablonska (1990) and Hosmani (1993) in tomato, eggplant, pepper and chilli. Talashilkar *et al*. (1997) observed that application of poultry manure recorded higher dry pod yield of groundnut. The increased pod formation may be attributed due to better plant development through efficient utilization of soil resources by the plant, where primary growth elements were available in sufficient amount (Naeem *et al*., 2006) in mungbean.

In the present study yield of Kale and French beans was recorded highest in T_5 treatment (50% RFD + 50% PM). The increase in yield could be attributed to the fact that nutrients were more readily available when organic and inorganic fertilizers were combined. The beneficial effects of organic manures are manifested through increase in soil organic matter and humus over the period. Soil organic matter and humus acts in several ways; it serves as slow release source of plant nutrients to the crops and increases water holding capacity to maintain the water regime of the soil and acts as a buffer against change in soil pH (Upadhayay and Singh, 2003). Fuchs *et al*. (1970) reported that nutrients from mineral fertilizers enhance the establishment of crops while those from mineralization of organic manures promoted yield when both fertilizers were combined. Titiloye (1982) reported that the most satisfactory method of increasing maize yield was by judicious combination of organic wastes and inorganic fertilizers. Makinde *et al.* (2007) reported increased melon growth and optimum yield with organo-mineral fertilizer at 4 t/ha. Kumar *et al*. (2012) reported that 50% of the recommended dose of NPK through inorganic + 50% recommended dose of nitrogen (RDN) through organic manures (FYM, PM or VC) or 100% recommended dose of NPK through inorganic fertilizers alone favourably influenced the tuber yield, nutrient uptake, soil fertility and paid higher returns compared to other treatments. Similar results were reported by Kumar *et al.* (2008 and 2011) and Das *et al.* (2009).

The study also reveals that above and belowground biomass production was highest in treatment T_4 (75% RFD + 25% PM) in Kale and T_3 (50% RFD + 50% FYM) in French beans which is attributed to improvement in nutrient content and uptake because organic manures, not only supply macronutrients but also meet the requirements of micronutrients, besides improving soil health. These findings are in line with Singh *et al.* (2001b) who revealed that application of 80 kg N per ha through poultry manure or substituting 75 per cent N through poultry manure and 25 per cent N through urea to wheat gave the highest root and shoot biomass and obtained highest number of plants per meter row (62.73) and highest seed yield (15.37 q/ha) as compared to control (49.37 and 10.00 q/ha, respectively). Boateng *et al.* (2006) also reported that Poultry manure treatments produced higher values for height, leaf area index and above ground biomass in maize. Application of manure significantly increased root and shoot dry weights, leaf area in maize (Adeyemo and Agele, 2010). Maerere *et al.* (2001) also reported that root dry weight increases with increasing poultry manure application rate in Amaranthus (*Amaranthus cruentus* L.). Ouda and Mahadeen (2008) also reported increase in fresh and dry weights of broccoli by application of 60 and 80 kg organic manure with 60 kg inorganic fertilizer. Hossain *et al.* (2012) reported increase in dry weights of root and shoot. In maize with the application of poultry manure alone and with 25% NPK + 75% PM. Similar results are reported by Ogundare *et al.* (2012) in maize.

The present study reveals the maximim root mass ratio in T_5 (50% RFD + 50% PM) and shoot mass ratio in T_4 (75% RFD + 25% PM) in both Kale and French beans respectively. It could be attributed to different mineralization rates and nutrient availability in the two soil amendment systems at different growth stages of the plant. Poultry manure plays a direct role in plant growth as a source of all necessary macro and micronutrients in available forms during mineralization, improving the physical and physiological properties of soils. These favourable conditions create better nutrients absorption and favour the growth and development of root system which in true reflects better vegetative growth, photosynthetic activity and dry matter accumulation (Abou El-Magd *et al*., 2006).

The present study also reveals the maximim shoot root ratio in both Kale and French beans in T_5 (50% RFD + 50% PM). It can be attributed to the fact that Poultry manure is an excellent organic fertilizer, as it contains high nitrogen, phosphorus, potassium and other essential nutrients. In contrast to chemical fertilizer, it adds organic matter to soil which improves soil structures, nutrient retention, aeration, soil moisture holding capacity and water infiltration. The S:R also tends to decrease with decreasing soil N availability (Troughton, 1982). The supply of macronutrients other than the N can effect shoot root ratio. Reports are consistent that S:R decreases when the growth is limited by P or S supply (Adalsteinsson and Jensen, 1988; Clarkson *et al*., 1989; Fredeen *et al*., 1989; Rufty *et al*., 1990; Zsoldos *et al*., 1990; Ingestad and Agren, 1991; Cakmak *et al*., 1994).

The maximum root and shoot carbon and leaf area ratio was recorded in T_{10} (100% VC) followed by T_8 (100% FYM) and lowest in T_1 (RFD) in both Kale and French beans which can be attributed to the reason that in contrast to chemical fertilizer, vermicompost adds organic matter to soil which improves soil structures, nutrient retention, aeration, soil moisture holding capacity and water infiltration.

The present study reveals the maximum leaf area ratio in T_{10} (100% VC) followed by T_8 (100% FYM) and lowest in T_1 (RFD) in both Kale and French beans which can be attributed to the reason that nitrogen being a constituent of protoplasm can show favourable effect on chlorophyll content of leaves which might have resulted in increased synthesis of carbohydrates (Tisdale *et al*., 1985).

Plant height, leaf area and dry matter production are the growth attributes which significantly affect the dry weight of leaves and shoots. These results are in consonance with the findings of Maitra *et al*. (1998) in Ashwagandha, Mansour (2002) and Hussein (2003) in Senna, Selvaraj *et al*. (2003) in Rosemary and Thyme.

The present study also reveals the highest number of nodules in French beans in T_5 (50% RFD + 50% PM) followed by T_7 (50% RFD + 50% VC) which can be due to the reason that the organic manures including Poultry manure significantly influence the chemical properties of the soil and improve the Nitrogen, Phosphorus and Potassium levels of the soil. This is in confirmation with the findings of Madukwe *et al*. (2008) also reported high nodulation in the cowpea varieties with the application of poultry manure.

The present study also reveals the maximum total nitrogen in both Kale (leaf) and French beans (pod) in T_5 (50% RFD + 50% PM) followed by T_7 (50% RFD + 50% VC). A higher value of leaf N content could be attributed to the ability of organic manure to supply nutrients throughout due to mineralization and improvement of the physical and chemical properties of the soil and the ability of organic fertilizer to release nutrients gradually throughout the growing season. Ouda and Mahadeen (2008) reported highest leaf N content (3.87%) produced when the greatest dose of both organic manure and inorganic fertilizer was applied. Similar results were obtained by Wong (1990); Abdelrazzag (2002) and Magnusson (2002) on several vegetable crops. Ojeniyi *et al.* (2013**)** also reported that leaf concentrations of N and P increased progressively as the application rate of PM increased from 0 to 10.0 t in Cocoyam (*Xanthosoma saggitifolium*).

Chapter – 6

SUMMARY AND CONCLUSION

The present investigation entitled "Impact of organic amendments on soil carbon sequestration and biomass carbon allocation of crops" was carried out during 2011, 2012 and 2013 at Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Shalimar, Srinagar (J&K). The findings of present study are summarized below :

- pH of soil of soil after harvest of Kale and French beans was recorded in neutral range under T_{10} (100% VC) whereas highest values were recorded in T_1 (RFD). Various physico-chemical parameters viz., electrical conductivity, cation exchange capacity and moisture of soil under both Kale and French beans were significantly high with the application of 100% VC followed by 100% FYM and lowest values were recorded in T_1 (RFD) under both test crops.
- Available nitrogen, phosphorus and potassium in soils under cultivation of Kale and French beans were significantly high in the plots treated with 50% PM + 50% RFD followed by 50% VC + 50% RFD.
- Various parameters of soil carbon storage viz., organic carbon, soil carbon pool and soil microbial biomass carbon were significantly highest in T_{10} (100% VC) treatment followed by T_8 (100% FYM) in both Kale and French beans. However significantly lowest values were recorded in T_1 (RFD) treatment.
- In soil under both Kale and French beans significantly highest bulk density was obtained in T_1 (RFD) and significantly lowest values were recorded in T_{10} (100% VC) followed by T_8 (100% FYM).
- Various growth attributes and yield viz., plant height, plant spread, number of leaves/plant, number of branches/plant, number of pods/plant were

significantly high in Kale treated with 50% RFD + 50% PM followed by T_7 (50% RFD + 50% VC) and in French beans it was in T_5 (50% RFD + 50% PM) followed by T_4 (75% RFD + 25% PM).

- Aboveground and belowground biomass production in Kale was significantly high with the application of 75% RFD + 25% PM and in French beans it was in 50% RFD + 50% FYM.
- Root mass ratio and shoot root ratio in both Kale and French beans was significantly high with the application of 50% RFD + 50% PM. Shoot mass ratio was significantly high in T_4 (75% RFD + 25% PM) in both the test crops.
- Aboveground and below ground carbon content of Kale and French bean was significantly higher in T_{10} (100% VC) treatment followed by T_8 (100% FYM). Significantly lowest values were recorded in T_1 (RFD) in both the test crops. However, of the test crops significantly highest values for above and belowground carbon content were recorded in French beans.
- Leaf area ratio was significantly high in both Kale and French beans treated with 100% VC followed by 100% FYM. However significantly low values were recorded in RFD.
- Total nitrogen content of leaf in Kale and pods in French beans and number of nodules in French beans were recorded significantly high in T_5 (50% RFD + 50% PM) followed by T_7(50% RFD + 50% VC).

CONCLUSION AND RECOMMENDATIONS

From soil carbon sequestration point of view, in both the Kale and French beans the treatments T_{10} (100% VC) followed by T_8 (100% FYM) and T_9 (100%PM) increased the soil carbon storage and are statistically significant. Carbon storage was found to be high in French beans.Yield in Kale was found to be highest in treatment T_5 followed by T_7 and T_3 and in French beans the highest values were exhibited in treatments T_5 followed by T_4 and T_7.

In light of above conclusion, it is recommended that for achieving high carbon sequestration in soils, the crops should be fertilized with 100% vermicompost and French bean crop is recommended for better carbon storage in crop. However, for obtaining high yield, combination of organic and inorganic fertilizers (50% RFD + 50% PM) is recommended. Further work needs to be carried out in different agro-climatic zones to arrive at final recommendation for the valley using different organic amendments.

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Appendix – I

Standard weekly meteorological data for 2011

Standard Meteorological week No.	Mean temperature (^oC)		Total rainfall (mm)	Relative humidity (%)
	Maximum	Minimum		
19	25.8	9.7	15.0	68
20	28.8	11.1	2.4	63
21	26.1	11.0	13.2	56
22	24.3	11.2	26.2	69
23	26.8	11.4	4.6	59
24	30.9	15.5	0.0	64
25	26.7	16.4	3.0	71
26	28.9	13.6	6.0	67
27	31.3	17.0	0.0	66
28	28.0	14.8	45.0	72
29	27.4	13.6	3.6	67
30	31.5	15.8	5.0	69
31	27.3	16.6	52.8	80
32	30.3	17.4	15.0	70
33	30.0	17.6	0.8	73
34	27.6	14.4	8.4	69
35	28.9	12.8	0.0	64
36	31.1	10.6	0.0	61
37	30.4	15.5	0.0	69
38	26.1	10.5	2.0	70
39	26.7	8.1	0.0	64
40	23.6	9.2	9.2	72
41	19.3	6.7	52.6	76
42	19.2	5.5	0.0	74
43	17.9	3.6	9.2	72
44	18.2	0.4	0.0	72

Source: Meteorological Observatory, Division of Agronomy, SKUAST-K, Shalimar

Appendix – II

Standard weekly meteorological data during the crop growing season (2012)

Standard meteorological week	Temperature (^oC)		Relative humidity (%)		Rainfall (mm)
	Maximum	Minimum	Maximum	Minimum	
18	21.07	6.30	79.14	52.00	8.10
19	23.14	9.61	83.57	62.43	11.70
20	22.36	8.93	79.86	58.71	12.00
21	21.57	9.51	83.86	62.57	16.60
22	29.93	9.64	70.57	47.57	3.40
23	23.93	10.83	81.29	59.86	8.40
24	27.21	11.60	80.14	46.29	1.60
25	30.29	14.79	77.57	41.71	0.00
26	28.64	14.07	79.00	47.57	10.80
27	32.79	17.53	75.00	42.71	1.00
28	28.36	16.21	82.43	62.57	18.60
29	30.86	15.64	82.29	47.86	3.40
30	32.43	17.14	82.86	43.29	9.20
31	30.21	18.93	83.71	55.14	29.00
32	29.36	16.47	83.43	55.86	4.80
33	29.29	18.37	85.43	55.57	23.60
34	32.07	19.30	82.29	47.57	1.80
35	31.64	16.47	77.43	49.86	1.00
36	24.57	16.87	89.86	68.00	49.20
37	26.71	16.13	93.14	72.29	24.80
38	25.14	11.11	88.71	64.29	12.40
39	26.64	8.57	90.00	56.43	0.00

Appendix – III

Standard weekly meteorological data during the crop growing season (2013)

Standard meteorological week	Temperature (^oC)		Relative humidity (%)		Rainfall (mm)
	Maximum	Minimum	Maximum	Minimum	
18	21.00	7.14	80.14	51.43	4.20
19	21.79	9.50	88.29	57.14	14.00
20	26.21	8.86	76.00	41.00	8.60
21	27.14	12.07	76.57	49.43	32.20
22	26.57	8.69	77.00	41.29	13.00
23	31.86	14.10	73.00	46.71	0.00
24	25.21	15.61	91.00	66.71	61.20
25	31.14	14.50	72.00	40.00	3.40
26	29.10	17.61	81.00	52.14	32.20
27	31.23	17.40	78.57	45.86	15.80
28	29.00	16.43	81.57	51.43	35.20
29	31.14	18.31	74.29	48.57	8.00
30	32.71	18.47	71.86	44.14	3.20
31	30.50	19.27	79.71	56.29	18.40
32	32.07	19.13	77.14	47.00	6.20
33	21.74	16.86	90.14	84.00	158.60
34	30.36	17.07	75.29	62.57	3.40
35	28.64	15.97	83.86	60.57	0.60
36	29.57	13.39	79.57	51.71	7.80
37	23.79	13.57	86.86	67.29	21.00
38	28.93	9.04	81.00	48.00	0.00
39	28.21	11.67	85.29	63.43	2.40

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CERTIFICATE

Certified that all the corrections/amendments as suggested by External Examiner Dr. Ashok Kumar Bhat, Coordinator School of Genomics Molecules and Microbiology, SKUAST-Jammu during Viva-Voce examination held on June 26, 2015 have been incorporated in the manuscript entitled **"Impact of organic amendments on soil carbon sequestration and biomass carbon allocation of crops"** submitted by **Ms. Gowhar Bashir (Regd. No. 2010-334-D)**.

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