Chapter 7
General Discussion

Soil is among most precious and key components of life that benefits everyone directly or indirectly. Soil is vital component in functioning of terrestrial ecosystems which provides a habitat for diverse soil fauna and interacting populations of soil organisms, accounts for various processes and a critical link in carbon sequestration to mitigate climate change. On the other hand, human activities may change the condition and nature of soil which might disturb its functioning as human beings are the managers for soil itself. Thus, functioning of soil ecosystems especially of terrestrial ecosystems is depending on how soil used for what purpose.

Terrestrial soil ecosystem consists from various components such as physical, chemical and biological components. All components are interlinked with tight functional phenomenons. Biological components makeup a large part itself to working continues for long lasting life support system without which no one domain of soil could be in proper function. Thus, biological composite system is only the part on which all functionalities are dependent. Apart from biological components, soil microarthropods are as important as for their functional capacity have a big chart and hence they fully seldom appreciated. Among all soil microarthropods, Collembola might indirectly benefit plants through an enhancement of mycorrhizal functioning and indirect multi-trophic links to foliar-feeding insect herbivores. Soil decomposition and mineralization both count as additive functions provide by soil microarthropods which might be consider as plant promoter functions.

7.1 Seasonal variation of soil microarthropods

A large number of studies have documented that present global climatic change has significant consequences for flora, fauna and ecosystem processes worldwide (Graham & Grimm 1990, Walther et al. 2002, Parmesan & Yohe 2003, Weltzin et al. 2003), they may be temporal or seasonal. Seasonal changes of the soil are mostly relative humidity and temperature dependent that they earnestly affect soil microarthropods populations. In the same way, we have reported in this investigation
that the diversity of soil microarthropods found quietly dependent on soil environmental conditions with time as a function of climate. Therefore, climatic manipulations such as seasonal interference can be performed as main affective measures and indicators of diversity patterns for soil microarthropods. The brief correspondence results were noted as discussed below.

Soil microarthropods are the important biotic components of soil ecosystem, represents a picture of ecological change all the time (day/night, weather/season/years etc.) and the necessity for competence in species determination of very diverse soil fauna may depend on seasonal patterns or on climatic interference. Thus, soil microarthropods are highly variable biological components. Consequently in soil microarthropods, the species diversity index was characterized by different dynamics. This is because of due to different species count in different sites as well as in different time that was found. In other words, the peak population varied from site to site being minimum in pre monsoon (summer months) and maximum population during winter and spring months. Thus, diversity index value was differentially significant in different sites. This confirms the habitat heterogeneity hypothesis (Hypothesis III).

The habitat heterogeneity hypothesis states more complex of habitat means higher species diversity along with sufficient population which shape the community structure highly reliable as it has been inadvertently found true for the richness and diversity of the soil microarthropods species in this study. On the other hand, seasonal variation critically affects the population of soil microarthropods.

Apterygotes, Pterygotes and Acarina (mites) formed a core of population of animal species who are primary residents of soil. The moderate population of collembolans obtained in the samples of MOS and UAS, which can be attributed to the total absence of litter. Similarly, Ford (1937) has emphasized on the influence of presence or absence of grasses on the fluctuation in the populations of Collembolan and Acarina. In the present study, less population of Collembola and Acarina (mites) found in summer that may be because of intense heat and loss of moisture. The present observation related to the effect of vegetation on soil denizens is supported by
Strickland (1947) as stated that vegetation has greater influence on the soil inhabiting insect population than the soil type.

The population of Collembolans, Dipterans and Acarina (mites) can be said to be a poor population in tropical and subtropical areas as compared to a temperate region. The meager number of the forms specifically Collembolans and Acarina (mites) obtained in UAS in the present study can be attributed to the facts that the paucity of humus in tropics resulting in a smaller population microarthropods in soil. Hale (1966) also observed same findings, strengthened the case and stated that habitat has a pronounced effect on the life of Collembolans.

Agricultural sites (both AQS & APS) support the most diversified groups of soil microarthropods (Collembolans and mites); their interrelationship assumes the significance of great ecological importance. On the other hand, decrease of these groups in MOS and UAS may be attributed due to predation as Collembolans, Termites, Prostigmate and Mesoatigmate Mites face the predation risk from adults/larvae of Scarabidae (Coleoptera) which also have a trend of increase along with these groups. Apart from soil microarthropods, Collembolans, Prostigmates and Mesostigmate Mites are prone to the predation of Japyx and Gamasides also which are predatory in habit. These two groups show a similar trend of increase during summer and mostly in Monsoon in which the collembolans flourish (MOS & UAS).

This assumption is supported by Joose (1981) who emphasized that in a more stable and favourable environment, biotic factors play a more direct role. A higher predation risk as he observed in the case of Orchesella cinecta and an interspecific competition between two or more species of Collembola. These abundant soil microarthropods have been observed as a source of food for the members of Coleoptera and Hymenoptera as they not only prey on these microarthropods and plant materials but also dead ones as postulated (Raw 1956).

The collembolans due to their vertical distributions are present in high proportion in the upper most soil apart from total population of soil microarthropods. Kaczmarek (1993) also stated that more than 90% of Collembola inhabit the top 10 cm of soil. Thus, soil cores of 10 cm depth were considered to be sufficient soil
samples for most of the soil microarthropods population. There are global reports about the decline in the number of collembolans with the depth by Poole (1959), Davis (1963), Christenson (1964), Mc Millan (1969), Chaudhury and Roy (1970), Takeda (1976), Darlong and Alfred (1982), and Mallow et al. (1985).

Haarlov (1960) observed a correlation between the size of collembolan forms and their distribution according to depth and indicated that with increasing depth there was reduction in the soil pore space due to which the larger forms were unable to penetrate to the deeper layer. Further in this operation the depth distribution was related to feeding, temperature and humidity relationships of the individual species concerned.

Acarina (mites) was represented by all the three suborders in moderate numbers throughout the investigation period in UAS. The moderate population of mites leads to a conclusion that the site is unarable therefore, devoid of vegetation, moisture and organic matter. The presence of Dipterans and Coleopterans larvae also add to their low population, as they feed on the mites. The only reason which favors the presence of mites is that the site was undisturbed that there is no tillage, no manuring, no ploughing or chemical spraying. Multiple peaks are very rare in soil mites. Most genera of mites have only one peak which coincides with same time of the year (Badejo 1990).

Apterygotes population showed very interesting and fluctuating pattern specifically Collembola population in all the study sites. The order was represented by all the five families but family Isotomidae showed remarkable peaks in the months of January, February and March (in case of AQS & APS mostly), consecutively for two years and very meager population in rest of the months at 5 cm and 10 cm respectively (in case of MOS & UAS). The probable reasons for such population could be due to edaphic factors as well as some biotic factors. Seasonal distribution of collembolans reveals that different species reach maximum and minimum number at different times of the year in different sites which was also noted by Hale (1966). Collembolans avoid desiccation by migrating from the place for sometimes, hence in dry months the population of Collembolans is very low because in the absence of
vegetation there was no shade and high atmospheric temperature reduces the soil surface.

The patterns of response of ecosystem functioning seasonally or periodically altered the diversity will likely depend on the patterns of loss of diversity of soil microarthropods because of gradual losses of soil microarthropods species as abiotic conditions begin to exceed tolerance limits could result in random losses of functional ability of soil. This is because of functional ability of soil is generally dependent on functional groups and these functional groups or domains highly interlinked to each other that is the natural way which is mostly depend on their competence as well as on their survival capacity. Thus, exceed conditions of harsh climate in seasonal patterns may detrimental for the survival and rich diversity of soil microarthropods.

In this investigation there were two decisive factors those found responsible mostly for population fluctuation of soil microarthropods, the first one is combination of soil temperature with relative humidity and another is low soil moisture. These factors are also vital for plant growth as well as in conditioning for better management of soil to farm in any way. Thus, soil humidity is a limiting factor that must be recognized as an important factor if there is normal temperature and stable soil moisture conditions. Higher soil temperature with relative humidity always detrimental to rich soil microarthropods populations. However these all factors are the function of climatic variability which mostly depends on seasonal duration. Hence, seasonal interference is critically affecting the population of soil microarthropods.

Further from the view of management perspective, maintaining agricultural vegetation or ground cover may be important for sustaining all over the diversity of soil microarthropods, because the maintenance of such agricultural habitats can provide overwintering refuge sites for many predatory microarthropods species. More interestingly, each soil microarthropods species is a part of a greater assemblage and if lost, the complexities and abundances of other soil organisms will likely affect very soon. Some microarthropods are considered to be the ‘keystone species’ because the loss of their critical ecological functions is argued to cause the failure of wider ecosystem. For example, the valuable role of the termites as converters of cellulose in tropical soils suggests that they form keystone group in soil structuring. Thus, benefits
from such microarthropods are more than economic or environmental. Hence, characteristics of certain microarthropods in soil make them useful models for understanding biological processes in general as well as spatial.

Populations of collembolans among soil microarthropods much more importance however declined during the specific seasonal time of sampling period (July–September, in some cases and April–June, in most of the cases), but mite populations generally increased during July-September. These trends are clear in managed sites but less apparent in the samples from natural and less managed site, where population sizes were smaller or remarkably less (approximately 50% or more difference) reported. However, this is some implicative nature of diversity of microarthropods in soil complex that cannot be concluded in a significant manner without a long term investigation. Hence, it may argued that cultivation of crops in native agricultural soil results in a number of changes in community structure and activity of indigenous soil microarthropods which could beneficial to growth and productive strategies in some instances for our agricultural landscapes. This matter can be truly seen from the results of this study, because most cultivated sites (agricultural sites, AQS & APS) were rich in soil microarthropods diversity as compare to uncultivated site (UAS). In case of both well managed agricultural sites (AQS & APS), the population differences were small between the sites and within the two consecutive years. However, such small differences in variation are not something to worry about.

Soil ecosystem services are reliant upon soil microarthropods mediated functions at very fine local scales. These functions are referred to as the indirect value of soil microarthropods diversity and include soil formation and nutrient recycling. Thus, this study indicates that soil microarthropods can increase the translocation of organic matter, which canalizes other processes in the soil. These fundamental processes facilitate soil services that still benefit for humans as a source of primary production, agricultural productivity and regulatory services including carbon sequestration and control of greenhouse gas fluxes.

Soil in low organic carbon possibly due to high temperature in summers and good aeration in the soil which increased the rate of oxidation of organic matter by
which minimum quantity of soil organic carbon released. However in winters, the soil organic carbon increased tremendously which may be due to decreased rate of oxidation and aeration that might increased the rate of decomposition of organic matter in the soil. This is beneficial however in Summer, the critical approach of soil organic carbon is somewhat detrimental both for soil microarthropods populations and soil productivity. On the other hand, soil organic carbon is the main source of soil nutrients as well as for plant growth. The food stored by plant as a result of their fruits or crops harvested in the form of carbohydrate mainly in which carbon is the main part of these. Thus, soil organic amendments must be added to reform the soil health and to buildup the organic constituents in which soil microarthropods can survive better and might be contribute soil activities preferentially.

Collembolans showed relatively high response to changes in soil environmental and seasonal conditions which were confirmed from the observations of this study (seasonal and temporal changes in density and abundance (Table 4.1 – 4.5), and mean ± SD (Table 4.6 - 4.9). However, consistently high community similarity within the sites (in MOS and UAS mostly) during two years of this study period which suggests a remarkable persistence of some components of soil microarthropods assemblages. The approximate similar observations have been recorded in case of Acarina (mites) which found in the same line of Collembola populations between the sites and within the sites studied. Acarina (mites) populations always found meager compare to Collembola population in all four study sites. Although, this study provides evidence substantial ecosystem level (site wise) implications of changes of soil microarthropods populations in varied manner but moreover, correlations between edaphic and soil matrix factors with reference to soil microarthropods point out to the overarching impact of such varied factors and this might be imply to our better understanding in further research.

7.2 Impact of edaphic factors on diversity of soil microarthropods

In general, soil quality is the capacity of a specific kind of soil to function within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality and support human health and habitation. It can be evaluated through chemical-physical properties and biological indicators. The
soil contains various physical, chemical and biological features which play great influences on the vitality of the microarthropods. Soil organic matter plays an important role to determine the character of the soil. Soil rich in organic matter are generally rich in nutrients. Organic matter is the chief source of minerals return to the soil. It has greater water holding capacity. Soil organic matter is the reservoir of the nitrogen; it furnishes large deposition of phosphate and potash and relates to some extent of micro climatic changes in soil temperature.

Temperature varies over the earth’s surface and it exhibits as a gradient effect on every living being which can be suit or modify with their environmental conditions. Actually, increase or decrease in temperature regimes is directly depend on amount of radiations entering on earth’s surface or habitat concerned. Each and every habitat is also regulated by extent of vegetation cover. Thus, vegetation cover may directly or indirectly affect the temperature at local or regional scale though micro-environmentally.

Temperature also fluctuates over different time scales notably seasonally or diurnally within decomposer habitats and these major fluctuations might modify several other factors in soil environment. Consequently diurnal fluctuations of temperature showed marked variations on top soil (0-10 cm depth). Thus, the effect of temperature is directly proportional to transfer of heat energy (radiation energy) in top soil profile. Hence, it is probable that in nature, there is a continuous spectrum of overlapping temperature. However for a mixed community such as soil microarthropods, the high level of activity may expected over the range of temperature at which much of community members adapt to corresponding temperature limits that may apply to promote microarthropods activity and can influence the survival and population of soil microarthropods. Thus, population fluctuation of soil microarthropods may directly influenced by soil temperature.

Bowen (1991) has underscored the curious fact that, soil temperature had received relatively little attention from scientists, even though it is of fundamental importance to plant productivity. With the realization, soil temperatures may raise as a part of anthropogenic global change, there is renewed interest in studying the mechanisms and effects of terrestrial ecosystem responses to changes in soil.
temperature (Billings et al. 1982; Rosenzweig and Hillel 2000). However, this area of investigation is still much under represented. In any consideration of soil temperature, we must be cognizant that it continually interacts with biotic and abiotic components of the soil–plant system in both space and time (Pregitzer et al. 2000). For example, not only soil temperature influence the rate constants of chemical reactions, water content, and nutrient transport in soil, but it simultaneously affects plant physiological aspects of ions uptake, root growth, and the composition as well as function of soil microbial communities.

The population of soil microarthropods in Indian agricultural soils rarely studied mostly in North Indian region. However, soil microarthropods are the inter mediator for soil functioning, soil productivity and soil health altogether. Although, occurrence and diversity of soil microarthropods is mostly depend on several edaphic and soil bio-geo-chemical factors like soil temperature, soil moisture, soil pH value, organic matter and organic carbon contents present in the soil and potash, phosphate as well as available soil nitrogen in varied concentrations etc. It is generally due to the tropical nature of our environment and thus soils are mostly disturbed due to its varied pH values. Thus, it is in the line of this study that predominance of soil microarthropods in neutral-alkaline soil found in most of the cases (AQS, APS, MOS and 1st year of UAS) whereas acidic soils mostly showed the negative response except a single case in IInd year of UAS (Table 5.6).

The interaction between drought and nitrogen enrichment may be the consequent measure which directly affect performance of soil ecosystem. This is due to that soil moisture content strongly controls Nitrogen availability in soils. Therefore, more stable soil moisture conditions found in AQS and APS sites prefer to the higher concentrations of available nitrogen in soil which has ultimately influenced the populations of soil microarthropods. However, there has been substantial variation recorded in soil microarthropods populations between the sites and within the sites studied.

Soil microarthropods are an important component of agro-ecosystems, contributing significantly to soil faunal biodiversity and soil functioning. However, seasonal patterns, temporal population dynamics, and significant roles of these soil
microarthropods in improvement of soil structures and functions are influenced by many factors. The activity and diversity of soil microarthropods in different soil habitats are regulated by a number of abiotic and biotic factors. Among these soil factors, edaphic factors influence the diversity and abundance of soil microarthropods in agro-ecosystems. Soil temperature, soil pH, and soil moisture contents affect the rate of physiological activity, nutrition, and habitats of all soil microarthropods, directly and indirectly. These factors are in turn determined by epigaeic variables such as rainfall, etc. (Killham 1994).

Several reports are available which elaborate the effect of abiotic or edaphic factors on the distribution and abundance of soil fauna in site-specific ecosystems. Most of these studies are on edaphic factors including soil type, soil pH (Hagvar and Abrahamsen 1980; Klausman 2006; Rentao et al. 2013), soil moisture (Wallwork 1970; Usher 1976; Badejo 1982; Steinberger et al. 1984; Kamill et al. 1985; Vannier 1987; Whitford 1989; Asikkidis and Stamou 1991; Bean et al. 1994; Ali-Shtayeh and Salahat 2010), soil temperature (Usher 1976; Whitford 1989; Asikkidis and Stamou 1991; Cancela Da Fonseca 1995; Sulkava and Huhta 2003; Cakir and Makineci 2013), soil organic matter (Fujikawa 1970; Santos et al. 1978; Anderson 1988; Scheu and Schulz 1996; Ponce et al. 2011), rainfall (Yang and Tang 2004; Anu et al. 2009), vegetation (Speight and Lawton 1976), and crop type (Robertson et al. 2012). Thus, there is an ample scope of investigation on the edaphic factors in context of soil microarthropods populations to envisage the challenges of climatic interference due to which populations of soil microarthropods fluctuate in a highly varied manner.

Many physical, chemical, and biological processes that occur in soil are influenced by temperature. Increasing temperature enhances mineralization of soil organic matter or decomposition of plant residues by increasing rates of physiological reactions and by accelerating diffusion of soluble components/substrates in soil. An increase in temperature can also induce a shift in composition of soil microarthropods community because of their highly response to changes in micro-climatic conditions in their habitats. However, the relationship between temperature and biologically mediated processes are more complicate because of soil complexity with its micro- and macro-aggregates embedded within a solid, liquid and gaseous matrix. Thus, in
view of these aforesaid lines and on the basis of observations of this study, it may
state that temperature is a highly affective measure than the other edaphic factors.

Terrestrial ecosystem mostly native soil agricultural systems processes directly
relate to water contents (soil moisture) available in the soil which more dependent on
dry and wet periods of weather. Thus, soil moisture and temperature both are the
critical climatic factors regulating soil biological activity. As soils dry, moisture is
more controlling of biological processes than soil temperature because biological
processes need more preferentially water contents than compared to temperature.
However temperature is much more critical use for all biological activities. According
to the observations of this study, Soil moisture mostly found statistically positive
significant to soil microarthropods populations. Thus, soil moisture content is the
precursor in influencing the population of soil microarthropods.

Predicted longer drought intervals between rainfall events will increase
drought stress for crops while changes in the amount and timing of rainfall will affect
yields and biomass production of crops (Eitzinger et al. 2001, Alexandrov et al. 2002
and Thaler et al. 2008). These changes in vegetation structure and quality of soil will
also affect the associated arthropods (Andow 1991). Moreover, it has also been shown
that changes in magnitude and variability of rainfall events are likely to be more
important for arthropods than changes in annual amounts of rainfall (Curry 1994,
Speight et al. 2008, Singer and Parmesan 2010). This study also corroborates the same
findings as per the above mentioned studies.

On the basis of our observations, soil is continuously suffering from acidic
nature than alkaline which is highly remarkable to the long term functionality of soil
because most of the crops grow in alkaline soils. Acidic nature of soil is generally
detrimental to soil microarthropods diversity and abundance as well as for crops.
More or less acidic nature of soil in this study has been critically observed in study
sites (UAS, Table 5.5) in Ist year as well as in IInd year. The acidic nature of rain
water from precipitation which makes the soil acidic is negatively influence the
biological diversity of soil inhabitant microarthropods as recorded in this study. And
because of no management practices applied in this site thus acidic nature of soil did
not reduced by crop harvesting because vegetation might intern the nature of soil even acidic or alkali.

In fact, virtually all processes occurring in soil, from the weathering of primary minerals to plant nutrition and storage of organic carbon, are strongly influenced by soil temperature. In particular, acquisition of mineral nutrients by plants is governed by myriad chemical, physical, and biological processes that are all sensitive to temperature of soil. Therefore, soil temperature exerts a major influence on primary productivity in terrestrial ecosystems due to influence the diversity of soil microarthropods in varied nature which makes a functional attention for our future research.

The functional attentions of soil temperature must improved our knowledge that is truly depend on How much of the incoming solar radiation is absorbed by the soil depends in large part on its surface, which is a function of solar angle and the degree to which the soil is covered with vegetation concern and organic detritus part as a source of next cycle to soil function that has reserved for the functional scrutiny. However, this is a highly difficult challenging task yet necessary for the knowledge underneath functional property of soil before going to the productive approach of soil of a particular plant covered ecosystems.

Plants cover generally less amount of energy that comes from solar radiation. Thus, functional redundancy in this case is prominent because of less conform about its processing. Hence, it is truly surprising yet clear fact that, solar radiation and amount of energy scattered are responsible for the productive nature of an ecosystem and these two factors relatively processor of day-night length and seasonal cycles or periodical patterns. Thus, temperature is an ultimate source of productivity of soil ecosystems which might be extremely important to energy balance in nature.

As it is a clear fact about temperature affordability in soil functioning in terrestrial ecosystems, that the part of the insulating effect of vegetation is due to the buildup of a layer of organic detritus on the soil surface, which can decrease the amplitude of daily and seasonal temperature fluctuations. The insulating properties of litter stem from the relatively low thermal conductivity of organic matter compared to
mineral soil, and the large proportion (volumetric) of air spaces. Other than this, evapo-transpiration of water from the soil surface that balanced by irrigation time to time in vegetation concerned removes latent heat from soil, thereby cooling it. Thus, soil microarthropods diversity is influenced by the cover of vegetation.

On the other hand, hydrologic cycle is a very important driver of soil temperature. This is because of the diurnal and seasonal progression of soil temperature exhibits patterns characteristic of the prevailing climate. During a day in the growing season, soil temperature close to the surface is lowest between the hours of midnight and sunrise. As the solar angle increases, so too does the soil temperature reaching a peak at midday and declining thereafter. With increasing depth, soil temperature decreases and amplitude of daily signal diminishes. Peak temperature is reached progressively later in the day due to a time lag imposed by thermal conductivity inherent to the soil. At sufficient depth, diurnal temperature variation is completely dampened, and the temperature of the soil remains near that of mean annual air temperature (Strahler and Strahler 1983).

Oppose to it, in winter season, the soil temperature profile is inverted, the warmest soil being found at depth. Soil temperature decreases toward the surface, and the diurnal signal has very little amplitude. Over the year, soil temperature exhibits a pattern very similar to that of the diurnal signal. Lowest temperatures are reached in late winter, and rise rapidly during the spring as the cumulative heat sum increases with the changing season. Soil temperature peaks in late summer and declines for the remainder of the year. As with the diurnal signal, the annual peak temperature is reached progressively later in the year with increasing depth, and the amplitude of the seasonal signal decreases. Thus, soil temperature might be a major determinant of length of the growing season in most of terrestrial ecosystems.

In summary, soil temperature is one of the key factor regulating nutrient availability and uptake in terrestrial ecosystems. Changes in soil temperature can inextricably linked to changes in soil moisture at ecosystem level. Changes in soil moisture affects the plant growth and changes in plant growth with its symbiotic factors such as microbial function along with diversity of its mediators and precursor (grazers) such as soil microarthropods will be very tightly coupled to changes in soil
temperature and moisture in the future, and these ecological interactions will play critical roles in nutrient availability and may fruitfully related to net ecosystem productivity. Thus, soil invertebrates, mostly microarthropods are an integral part of soils and are important in determining the suitability of soils for the sustainable production of healthy crop.

Soil moisture and temperature both are the critical climatic factors which regulate soil biological activities. As soils dry, moisture is more controlling of biological processes than soil temperature because biological processes need more preferentially water contents than compare to temperature. However soil temperature is much more critical use for all biological activities without which some of the biological activities may disturbed or less frequently occur in the system concern especially in terrestrial ecosystems.

Terrestrial ecosystem processes directly relate to water contents (soil moisture) available in the soil which more dependent on dry and wet periods of weather. Thus, soil moisture and temperature both are the critical climatic factors regulating soil biological activity. As soils dry, moisture is more controlling of biological processes than soil temperature because biological processes need more preferentially water contents than compare to temperature. However temperature is much more critical use for all biological activities. According to the observations of this study, Soil moisture mostly found statistically positive significant to soil microarthropods populations. Thus, soil moisture content is the precursor in influencing the population of soil microarthropods.

Many of the environmental constraints affect decomposition reactions as well as its rate by altering organic matter (substrate) concentrations at the site concerned. Soil in low organic carbon possibly due to high temperature in summers and good aeration in the soil which increased the rate of oxidation of organic matter by which minimum quantity of soil organic carbon released. However in winters, the soil organic carbon increased tremendously which may be due to decreased rate of oxidation and aeration that might increased the rate of decomposition of organic matter in the soil. These might be some possible points which have been observed and noted under this quantitative study of soil microarthropods diversity.
The availability of soil nutrients more or less affects the population of soil microarthropods. Therefore, it is observed in this study that increase concentration of organic carbon and nitrogen direct by influence on the distribution and fluctuation of soil microarthropods population densities. Available phosphorous shows strong influence on the soil microarthropods dynamics and it showed positive but insignificant relationship with population of microarthropods in all the study sites.

Soil matrix has been frequently demonstrated to influence the soil microarthropods populations. Among the soil matrix parameters, higher clay contents promote faster buildup of biological population of invertebrates mostly in alluvial soils. However, this has been attributed to a number of seasons including superior ability of clay content due to the increasing turnover of organic matter and organic carbon in soils. Therefore, soil microarthropods have been shown to alter the rates of substrate utilization and nutrient release. Thus, influencing of soil organic matter and soil organic carbon contents positively favors the soil microarthropods populations as observed in this study.

On the basis of our observations, it can be stated that soil is continuously suffering from acidic nature than alkaline which is highly remarkable to the long term functionality of soil because most of the crops can grow in alkaline soils. This may be due to acidic nature of rain water from precipitation which is making the soil acidic as it negatively influence the biological diversity of soil inhabiting microarthropods.

In conclusion, the temperature sensitivity to soil microarthropods is in general a function of soil temperature, moisture and other factors which affect the soil microarthropods population in a more cumulative way than in particular. The dependence of the temperature sensitivity on multiple factors has important implications for modeling the soil systems, responses to climatic changes and particularly the terrestrial carbon balance. Because of the effect of temperature and moisture on the temperature sensitivity which may increase less profoundly in response to global warming.
7.3 Impact of agricultural management practices on the diversity of soil microarthropods


A greater environmental heterogeneity below the soil surface provided by the plant roots would ensure a greater edaphic biological diversity and the existence of all the functional groups, especially those taxa which have no equivalent trophic role (Santiago et al. 2009). Thus, diversity could be increased by increasing competitive interactions between different functional attributes and ultimately biological diversity of soil microarthropods may increase due to better performing managements either organic or conventional.

As it clear that, temperature plays critical role in soil functioning in terrestrial ecosystems, the part of the insulating effect of vegetation is due to the buildup of a layer of organic detritus on the soil surface, which can decrease the amplitude of daily and seasonal temperature fluctuations. The insulating properties of litter stem from the relatively low thermal conductivity of organic matter compared to mineral soil, and the large proportion (volumetric) of air spaces. Other than this, evapo-transpiration of water from the soil surface that balanced by irrigation time to time in vegetation concerned removes latent heat from soil, thereby cooling it. Thus, soil microarthropods diversity is influenced by the cover of vegetation.

The organic farming system has been found as precursor thus influence to soil microarthropods diversity whereas conventional system of farming may be contradictory due to it is highly dependent on synthetic fertilizers, pesticides, and insecticides. This makes the small difference between population diversity of microarthropods in two study sites (AQS & APS). Therefore, difference between density and diversity of soil microarthropods between AQS and APS study sites could possible due to nature of soil ecosystem and its management types that were applied.
From the observations of this study, it can be concluded that the soil microarthropods population was found to be higher in agriculturally managed soil (AQS, APS and MOS) than that of un-arable soil (UAS). The probable reason for this observation could be attributed to the fact that the amount of Nutrients (NPK) in the agricultural soil was higher than that of un-arable soil. Agriculture ecosystem being a close canopy and having with minimum sunlight reaching the soil directly provides a favorable condition for rapid decomposition of the continuously falling leaves from the vegetation plants. This rapid decomposition unlocks the nutrients contained in leaves and returns it back quickly to the soils which are available for microarthropods to use. On the other hand un-arable ecosystem soil is more or less continually exposed to the elements of sun thereby making them dry which hinders the rapid decomposition of plant leaves as well as small biomass of the dead organisms, thus slowing the return of nutrients to the soil and limiting its availability to the soil microarthropods.

The central tenet of this thesis is seasonal variation of population of soil microarthropods and how edaphic factors affect on their populations which are integral part of agricultural soil ecosystems and soil quality therefore they are potentially useful as the diversity of soil microarthropods might impact on soil quality and interactions and functions of soil. Thus, the conservation of such soil microarthropods as well as management of agricultural ecosystems by modified methods should be reliable to their survival and to their rich diversity could influence and benefits the agricultural production in some instances.

The results of this study warn against less managed site as well as conventional agricultural habitat corridors which may be the current problem against farmers. Conventional agricultural farming or lower class management strategies such applied in MOS may loss diversity of soil microarthropods which might disrupt ecological niche and could detrimental to productivity of native agricultural soils. Thus, organic farming might be fruitful and might favours to soil microarthropods diversity however the populations of such soil microarthropods are highly sensitive to edaphic factors along with climatic interference.

Due to the complexity, nonlinearity and uncertainty of populations of soil microarthropods as observed in this study, it is tough to make clear-cut conclusion on
patterns of these soil microarthropods though seasonal or temporal. However, it has been cleared that agricultural management directly affect the population of soil microarthropods which has been recorded positively response with reference to soil microarthropods in both agriculturally managed sites (AQS & APS). This may be because of in agricultural managements, several organic or inorganic amendments have been added in these sites thus nutritional balance has been the source on which they occupy better niche than compare to less or un-managed sites (MOS & UAS) where no organic and inorganic amendment has been added due to which nutritional imbalance made, thus soil microarthropods have less survive in their habitats.

Soil microarthropods are important components of agro-ecosystems which contribute significantly to productivity and functioning of soils. However, seasonal patterns and population dynamics of soil microarthropods significantly affect the improvement of soil structures as well as functional potential of soil. On the other hand, soil edaphic factors also affect on soil microarthropods populations and their diversity in a varied nature. Thus, secondly the study has been carried out on the effect of edaphic factors on soil microarthropods population to clarify the affect of edaphic factors more depth and to use the populations of soil microarthropods.

Nevertheless, different soil microarthropods communities are likely active at temperatures change while individual species may differ in their optimal temperature response. The general activity response to temperature might be similar for many organisms. Very few soils maintain a uniform temperature in their upper layers. Variations may be either seasonal or diurnal. Because of the high specific heat of water, wet soils are less subjected to large diurnal temperature fluctuations than in dry soils. Among factors affecting, the rate of soil warming, intensity and reflectance of solar irradiation are critical. Thus, amplitude of the diurnal soil temperature variation may greatly dampen with soil profile depth. On the other hand, vegetation protect the soil surface to warm from direct solar radiation/sun light rays by which some reduce in soil temperature found in both agriculturally managed sites (AQS & APS) mostly in dry period (summer).

Oppose to this indication, vegetation keep warm the soil surface in winter by avoiding the cool air due to abundant crop plants. The cold interference of climatic
induced variations due to which survival conditions better adopted by soil microarthropods in winter. This has been observed in both agricultural management sites (AQS & APS) due to which the population of soil microarthropods always found higher in both of these study sites as compare to less (MOS) or non-managed (UAS) study sites.

Many of the environmental constraints affect decomposition reactions as well as its rate by altering organic matter (substrate) concentrations at the site concerned. In contrast, Wardle (1995) reports several cases in which conventional agricultural practices stimulate soil faunal diversity. This may be the part of reducing organic matter and soil organic carbon concentrations at the site concerned because soil organic matter and soil organic carbon both are main food/nutritional resources for most of the soil microarthropods. On the other hand, individual taxa may have multiple functions yet several taxa may appear to have similar functions. However, taxa may not necessarily be redundant because taxa performing the same function are often isolated spatially, temporally, or by microhabitat preference (Beare et al., 1995).

In agricultural lands, perennial vegetation has been shown to increase microbial diversity and activity and therefore, enhances nutrient cycling and possible allocation of more carbon into deeper horizons of soils (Millard and Singh 2009). Furthermore, perennial vegetation strips within agricultural fields may accumulate soil organic C relatively quickly because of runoff retardation, improved hydraulic properties, and nutrient deposition in the vegetative buffer strips (Udawatta et al. 2002, 2008; Udawatta and Jose 2011) compare to plantations in orchards or in un-arable fields. This may be the strong reason for higher population buildup of soil microarthropods as well as higher soil carbon contents observed in both agricultural sites (AQS and APS) compare to other two sites (MOS and UAS).

Regarding the methods of cultivation, management practices employed by the farmers, pedobiologist have reported that the population of soil microarthropods is comparable between manual and mechanical tillage, tillage and no tillage also. Mechanical tillage destroys the preexisting plant cover or vegetational ground cover which in turn can change the structure of the soil and soil associated animal population (Ghilarov 1973, Darlong and Alfred 1982). The abundant population of
mites showed that ploughing had not affected Orbatids, which can be explained with the beneficial effect of ploughing on soil structure. As there was enough use of inorganic fertilizers (APS which implied negatively on the population of Collembolans and other soil microarthropods.

The role of soil microarthropods is directly affected by the management practices which employed by farmers as they need to create favourable conditions for soil life. There is strong contrast in the population dynamics of the field which are managed conventionally and non-conventionally. The conventional tillage practices, based on the use of hand hoes, plough - animal drawn and powered, and harrows are likely to destroy soil structure and make the soil vulnerable to compaction and erosion. Wheel traffic or pressure excreted on the soil surface by large animals, vehicles and people can cause soil compaction. Compaction occurs where moist or wet soil aggregates are pressed together and the pore space between them is reduced. Compaction changes soil structure reduces the size and continuity of pores, and increase soil bulk density. It reduces the capacity of the soil to hold water, when less water is available for plant growth it decreases soil organisms. Therefore, in our observations, we found that the tillage negatively significant with reference to the population of soil microarthropods in both agricultural sites (AQS & APS).

The natural predators such as the Mites, Coleopterans and Dipterans larvae and the decomposers such as collembolans are directly benefitted from no tillage. Therefore in contrast to ploughed systems, no tillage management leads to accumulation of plant residues on the soil surface which decreases the rate of decay of crop material and therefore, helps to maintain good soil organic matter levels. Therefore, soil microarthropods (principally mites and collembolans) are among the unseen faunal diversity in nearly all agricultural soils. Microarthropods participate in the complex food webs of soils but their importance is seldom appreciated. (Crosseley et al. 1992).

Agricultural intensification involves high input application to replenish soil fertility, especially the use of inorganic fertilizers, continued use of inorganic fertilizers has not only altered the soil pH, structure and texture but also disrupted the
niches for the microarthropods which as essential for nutrient recycling (Ponce et al. 2011 and Moreira et al 2006).

Agricultural system that uses organic amendments tends to enhance crop diversity and soil fauna biomass. The soil fauna biomass is mainly represented by the decomposer biota, which have a major role in regulating the structure and function of the agricultural ecosystems (Beare et al. 1997). Biological, chemical and physical properties of soil vary both in time and over space. This spatial characteristic of the soil resources is an important contributor to the communities because of better resource partitioning.

The diversity of life in soil known as soil biodiversity that is an important natural resource however, poorly understood mostly in terrestrial ecosystems. Soil biodiversity is comprised of soil organisms those spend all or a portion of their life cycles within the soil or on its immediate surface including surface litter and decaying logs. The beneficial effects of soil organisms specifically soil microarthropods on agricultural productivity can be attributed as – they participate in- organic matter decomposition and soil aggregation, and breakdown of toxic compounds, both metabolic by products of organisms and agrochemicals along with inorganic transformations that make available to nitrates, sulphates and phosphates as well as essential elements such as iron and manganese, and participate a strong role in nitrogen fixation into such forms which are useable by higher plants.

In agricultural ecosystems, soil microarthropods may be overshadowed by temperature, relative humidity and vegetation density as well as concurrence of weeds thus population of soil microarthropods may likely to much more affect than compare to un-arable site. In arable soils, microarthropods depend on the input of crop and root residues or organic manure for their food preferences because organic manures have imitative effect on microarthropods. Also amount and quality of organic input is decisively determined the growth and populations of soil microarthropods.

Soil microarthropods is a very peculiar and remarkable living community and they are the driving force of most terrestrial ecosystems, mostly in agricultural soil systems because of their capacity to control the pathogenic fungal and bacterial
populations in one hand, and the turnover and mineralization of soil organic matter, and release of soil organic carbon in another hand which is the fundamental component of soil productivity. In observations of this study, it has been noted that both soil organic matter and soil organic carbon found statistically positive significant with respect to the population of soil microarthropods in most of the sites studied. This is the good indication of this study thus soil of Aligarh area generally rich in these two component of soil which are the main constraints of soil productivity in agriculture.

Sustainability in agriculture is a complex concept and there is no common viewpoint or unanimity among researchers about its dimensions. Nonetheless various parameters for measuring agricultural sustainability have been proposed and studied. This thesis reviews some aspects of agricultural sustainability measures specifically on soil biological constraints such as soil microarthropods by referring to their seasonal variation, impact of edaphic factors on their populations and their interactions to vegetation change and management soil conditions which are discussed. There is need to consider the research on ecology and dynamics of soil microarthropods in progress of their sustainable approach at national level, regional level as well as farm level to cover all the situations and possibilities which may be socioeconomic and ecological importance. Therefore studies should be location specific or faunal group specific.

Clearly, the presence of important faunal species in the soil such as microarthropods may provides the information about its functional potential, where as actual soil functioning depends on various factors such as climatic conditions and soil complex medium along with microbial activities as well as microarthropods decomposing and recycling activities. The exact status of soil functioning may not be detect because it requires more investigation. Further investigation could be initialized on quality parameters of soil that may contribute to plant productivity and soil fertility. Collembola and its diversity patterns could be used as reliable bio-indicators for this approach. Thus, this ecological study on soil microarthropods may provide valuable information about diversity patterns though temporal or seasonal and interactions between biotic (soil microarthropods) and abiotic (soil edaphic) factors that can be used as an applied tool to maximize crop productivity and to minimize the use of synthetic amendments in soil of agricultural ecosystems.