2. REVIEW OF LITERATURE

India is mainly an agriculture country with the predominant occupation for most of the Indian. The backbone of Indian economy with unique characteristics where over 250 different crops are being cultivated in its varied agroclimatic regions. The agriculture and allied sector contributed approximately 13.95 % of India’s GDP (Govt. of India, Annual report, 2015). The total geographical area of the country is about 328.7 million hectares of which 140.8 million hectares reported as net sown area and 19.2 million hectares as the gross cropped area.

2.1. Historical perspective challenges of traditional and modern agriculture

2.1.1. Historical Perspective of Indian Agriculture

Organic agriculture in India has its roots in traditional agricultural practices that evolved in more than 0.5 million villages and numerical countless farming communities over the millennium (Howard, 1931; Deshmukh, 2015). In India, traditional agriculture 'Organic Farming' is getting popularity in recent times, but it was initiated dates back to the Neolithic age. The farmers of ancient India are known to have evolved a nature-friendly farming system. The organic inputs Gunapachalam, machapani etc., are illustrated in ancient literatures of India like Rigveda, Ramayana, Mahabharata, Kautilya Arthasashthra etc. (Bhattacharya and Chakrabarty, 2005). The first ‘scientific’ approach to organic farming can be quoted back to the Vedas of the ‘Later Vedic Period’, around 1000 BC to 600 BC. The ‘Vrkshayurveda’ (Science of plants), the ‘Krishisastra’ (Science of agriculture) and the ‘Mrgayurveda’ (Animal Science) are the main works. Here agriculture was not developed just as a production system but as a culture (Mahale, 2002)
2.1.2. Challenges in Traditional Agriculture

The traditional agricultural practice involving the use of seeds whose genetic makeup goes back to thousands of years (Parayil, 1992). Traditional technologies also include wooden ploughs, waterwheels and bullock carts, with energy required for all agriculture activities provided by animals and humans. Finally, traditional agriculture is largely dependent on the vagaries of monsoon rains.

Throughout the early agricultural era, plant disease management approaches were extremely limited and hence lead to low yields and the general lack of significant food reserves. Once disease epidemics occurred food shortages could easily develop resulting in disastrous effects on human society - such as the Irish Famine caused by potato late blight in the 1840s and the 1943 Bengal famine caused by rice brown spot (Bourke, 1964; Padmanabhan, 1973; Strange and Scott, 2005).

2.1.3. Green Revolution and Modern Agriculture

During the colonial period large parts of land were converted into the production of cash crops such as indigo, coffee, tea and the poppy to produce opium (Brown, 1993). The colonial period (1900-1947) was characterized by insignificant growth in food production and frequent famines. During the 1930s in India, government’s non-intervention policy was adopted and as a consequence agriculture prices were collapsed and lead to huge increase in peasants’ indebtedness and malnutrition, rural poverty and Bengal famine of 1943, which claimed 4 million lives (Saminathan, 2010; Siddiqui, 2014, 2015). The former prime minister of India Jawaharlal Nehru had made a remark soon after independence in 1947, ‘everything else can wait, but not agriculture’. Agriculture should be given priority. This led to meet the above challenges, an Intensive Agriculture District Programme (IADP) and
high yielding programme was started in the early 1960 so as to maximize the yield of rice and wheat in districts where irrigation water was available (Saminathan, 2010).

2.1.3.1. Advantages of Green Revolution

The green revolution contributed to the Indian economy by providing food self-sufficiency and improved rural welfare. Moreover, it has observed considerable increase in the production of oil seeds through “Yellow Revolution”, milk (White Revolution) and fish (Blue Revolution) and fruit and vegetable revolution (Golden Revolution) (Borthakur and Singh, 2013). The green revolution improved the economic situation of farmers, getting better yield, control of many insects and pest, employing 2 to 3 crop rotation, scientific methods applied as per nutritional requirement of soil, high yielding seed varieties were developed with better yield and disease fighting capability.

The rapid increase in agricultural output resulting from green revolution came from an impressive increase in yields per hectare (Pingali, 2012). Between 1960 and 2000, yields for all crops in developing countries rose 208 % for wheat, 109 % for rice, 157 % for maize, 78 % for potatoes and 36 % for cassava (FAO, 2004; Pingali, 2012). World food and feed prices would be 35-65 % higher and average caloric availability would have declined by 11-13 % (Evenson and Rosegrant, 2003). The green revolution has successfully increased crop yields by adopting intensive production practices, including genetic crop improvement, the use of massive chemical inputs such as fertilizers and pesticides and practices of intensive tillage. Despite the early benefits, green revolution became apparent that there were many negative impacts such as monocropping, non-judicial use of fertilizer and pesticide
which led to genetic erosion, soil degradation and pesticide residues in crop products and thus lead to less productivity (Pawan, 2001).

2.1.3.2. Challenges in green revolution

The green revolution brought an impressive gain in food production but also led with an insufficient concern for sustainability. Dependence on chemical fertilizers for future agricultural growth would mean further loss in soil quality, possibilities of water contamination with nitrogenous fertilizers & pesticides and unsustainable burden on the fiscal system (Mazid and Khan, 2014).

Monoculture method of cropping system has resulted in low water tables and depleted essential nutrients in the soil for crop growth. Green revolution techniques sparked a vicious cycle in which farmers were forced to spend more and more money on chemicals to counteract what monoculture and heavy fertilizer applications have done to their land (Laidlaw, 2008).

In modern agriculture, due to maximum usage of chemical fertilizers and harmful pesticides on the crops, sustainability of the agriculture systems collapsed, cost of cultivation soared at a high rate, income of farmers stagnated and food security and safety became an overwhelming challenge. Indiscriminate and imbalanced use of chemical fertilizers, especially urea, along with chemical pesticides and unavailability of organic manures has led to soil degradation and reduction in crop yield (Pathak and Ram, 2013; Mazid and Khan, 2014).

2.1.3.2.1. Soil degradation

Soil degradation is a global problem, which was quite severe especially in the tropics and sub-tropics (Plate 1a). The degradation has decreased the soil ecosystem
services by 60 % between 1950 and 2010 (Leon and Osorio, 2014). The soil degradation process is expected to further destroy the capacity to supply nutrients except for what is supplied externally through inorganic inputs. Degradation of the soil resource will also limit soil water availability, which will limit food production in spite of added nutrients (Hatfield, 2012). The soil degradation can be physical (e.g., decline in structure, crusting, compaction, erosion, anaerobiosis, water imbalance), chemical (e.g., acidification, salinization, elemental imbalance comprising of toxicity or deficiency, nutrient deficiency), biological (depletion of soil carbon pool, reduction in soil biodiversity, decline in microbial carbon biomass) and or ecological (e.g., disruption in elemental cycling, decline in carbon sink capacity) (Lal, 2015). The soil degradation leads to reduction in soil nutrients processes.

Annually, India is losing nearly 0.8 million tones of nitrogen, 1.8 millions tones of phosphorus and 26.3 million tons of potassium (Anonymous, 2011) through agricultural malpractices. Soil organic carbon content in most of the Indian soils has been reduced to > 0.5 %. The green revolution is exhibiting second generation problem owing to over exploitation and mis management of soil. Under these situations, maintenance of soil fertility and crop productivity are the major limitations in agriculture (Pathak and Ram, 2013).

About 146.82 Mha of the country's total land area is suffering from different kinds of land degradation, including water erosion (93.68 Mha), wind erosion (9.48 Mha), waterlogging (14.30 Mha), salinity or alkalinity (5.94 Mha), soil acidity (16.04 Mha) and other complex reasons (7.38 Mha) (Plate 1b).
2.1.3.2.2. Pesticide usage in Agriculture

The use of pesticides has emerged as one of the essential agro-inputs. In India, the utilization of pesticides began in 1948 with the import of DDT for malaria control and benzene hexachloride (BHC) for locust control (Gupta, 2004). Later, in 1949, the use of both pesticides (DDT and BHC) was broadened to the agriculture sector. India accounts for approximately 3% of total pesticide consumption in the world, however this is increasing at the rate of 2–5% per annum (Bhadbhade et al., 2002). Pesticide consumption has increased several hundred folds, from 154 MT in 1954 to 41,822 MT in 2009–2010. However, the domestic consumption of pesticides in India is low (0.5 kg ha\(^{-1}\)) compared to several other countries (Taiwan (17.0 kg ha\(^{-1}\)), China (14.0 kg ha\(^{-1}\)), Japan (12.0 kg ha\(^{-1}\)), Netherlands (9.4 kg ha\(^{-1}\)), USA (7.0 kg ha\(^{-1}\)) and United Kingdom (5.0 kg ha\(^{-1}\)) (Fig. 2.1) (Chauhan and Singhal, 2006). The worldwide consumption of pesticides is about 2 million tonnes per year. Globally, the pesticide covers only 25% of the cultivated land area. The 3 most commonly used pesticides such as HCH, DDT and malathion. In India, 80% of are in the form of insecticide, 15% are herbicide, 2% fungicide and less than 3% are others (De et al., 2014).

The arguments behind using pesticide are that with the intensive agriculture, the problems of insect pests and disease are taking complex shape and posing serious challenges (Bhattacharya, 2004). About 14000 people die every year in the third world countries due to pesticide poisoning. Large-scale death of birds is also reported every year (Bhattacharya and Chakraborty, 2005). Over-use of chemicals also generated many near-irreversible changes reducing farmland quality through soil compaction, reduced organic material, mineral imbalances, and heavy metal and pesticide residue contamination (Kosalec et al., 2009; Lu et al., 2015; Tripathy et al.,
Furthermore, this deterioration in farmland quality may further reduce host plant immunity against pathogen infection.

Therefore, feeding the growing world population under conditions of changing climate demands new and innovative solutions to complex problems of soil degradation, to enhance and maintain soil biological systems, and to recycle nutrients contained in manure sources around the world (Walthall et al., 2012).

2.2. Revival of Sustainable Farming

Excessive and inappropriate use of fertilizers and pesticides has polluted waterways, salt build up in soils, poisoned agricultural workers, and killed beneficial insects and wildlife (IFRI, 2013). The increased rate of fertilizer nitrogen may increase the yield but reduces the quality of the grains (Conry, 1995; Cassman et al., 1995). After this prolonged dependence on inorganic and mineral components for agriculture growth there has been an increasing demand for rethinking agricultural growth strategy. Agriculture sustainability (Pretty, 1998), soil degradation (soil productivity and soil structure), bio-diversity (CSE, 2000), impact on human health and on environment as a whole are the some of the concerns that are being raised for reviewing part of the agricultural growth potentials based on the current strategy. Therefore, farming systems that are both highly productive and minimize environmental harms are critically needed (Carr et al., 1995; Johnson et al., 1998; Jongbloed and Lenis, 1998; Shruti et al., 2014; Ponisio et al., 2015). Search for alternates with a focus on long-term sustainability of agriculture have been enhanced in the last decade. In developed countries, the initiatives towards greening agriculture have been prompted both by market attractiveness as well as by state support activities. Usage of bio-fertilizer & bio-pesticides, organic farming (Bernhard, 2001),
Biodynamic farming (Planning Commission, 2002) low input agriculture (http://www.ileia.org/), permaculture (Allan, 1991), sustainable agriculture (Pretty, 1998), integrated farming practices (integrated pest management and integrated nutrient management), are some of the practices that are being espoused by proponents both in developed and developing countries. All these practices have evolved as alternatives to chemical use in agriculture keeping in view the increasing demand for green agriculture products across the world (Paul, 2003).

2.3. Organic Agriculture

Organic agriculture is a production system, which avoids or largely excludes the use of synthetically produced fertilizers, pesticides, growth regulators and livestock feed additives instead relying on crop rotations, crop residues, animal manures, legumes, green manures, and aspects of biological pest control to maintain soil productivity and tilth, to supply plant nutrients and to control insects, weeds and other pests (Lampkin, 1990).

2.3.1. Concept of Organic Agriculture

Organic farming is a system which avoids or largely excludes the use of synthetic inputs such as chemical fertilizers, pesticides, hormones, feed additives etc and to maximum extent rely upon crop rotation, crop residues, animal manures, off farm organic wastes, mineral grade rock additives and biological system of nutrient mobilization and plant protection (Banerjee, 2010). The organic farming today is not traditional agriculture. The principles governing organic farming are more scientific than even the principles followed in modern agriculture (Banerjee, 2010). There are different types of organic farming but conceptual idea is same (Fig.2.2).
2.3.2. International Status of Organic Agriculture

The survey on certified organic agriculture world-wide shows (data end of 2014) that 43.7 million hectares of agricultural land are managed organically by 2.3 million producers (FiBL-IFOAM, 2015). The regions with the largest areas of organically managed agricultural land are Oceania (17.3 million hectares or 40 % of the global organic farmland), Europe (11.5 million hectares or 27 % of the global organic farmland) and Latin America (6.6 million hectares or 15 %) (Fig. 2.3). On a global level, the organic agricultural land area increased by 0.5 million hectares compared with 2013. The countries with the most organic agricultural land are Australia (17.1 million hectares), Argentina (3.1 million hectares) and the United States (2.2 million hectares). The highest shares of organic agricultural land are in the Falkland Islands (36.3 %), Liechtenstein (30.9 percent), and Austria (19.4 %). The countries with the highest numbers of producers are India, Uganda and Mexico (FiBL-IFOAM, 2015).

2.3.3. Status of Organic Agriculture in India

In India, about 528,171 hectare area is under organic farming from which 44,926 number of farms under organic certification (Ramesh et al., 2010). With growing awareness and high market demand, India exported 585,907 tonnes of organic products worth of Rs. 301 million which has been documented by APEDA 2016 (www.apeda.com/organic.htm).

Currently, India ranks 33rd in terms of total land under organic cultivation and 88th position for agricultural land under organic crops to total farming area. The major crops under organic farming in India are rice, wheat, pulses, spices, beverages, fruits vegetables, oil seeds etc. (Surekha et al., 2010).
2.3.4. Scientific impact of Organic Agriculture

2.3.4.1. Impact of Organic Manures on Soil Health

A growing number of studies show that organic farming leads to higher soil quality and more biological activity in soil than conventional farming (Reganold, 1988; Alföldi et al., 1993; Drinkwater et al., 1995; Droogers and Bouma, 1996; Cabilovski et al., 2014). These organic farming systems have also been shown to use fertilisers and energy more efficiently than conventionally managed systems (Mäder et al., 2002) and to be just as economically viable as conventional farms (Reganold et al., 1993; Reganold and Palmer, 1995). Application of vermicompost prevents the soil degradation, improves water infiltration and moisture holding capacity, stabilizes the soil pH and reduces the incidence of nematodes (Tharmaraj et al., 2011). Reduction of bulk density could be due to higher organic matter content of soil added through FYM which improved the physical condition of soil (Singh et al., 2016). Krishnakumar et al. (2007) stated that application of 90 kg N ha⁻¹ through FYM + neem cake improved the soil physical fertility as measured by bulk density (1.24 Mg m⁻³), water holding capacity (51.2 %), hydraulic conductivity (6.3 cm hr⁻¹) and pore space (56.9 %). Green manure application followed by vermicompost + Trichoderma had significantly higher available N & P than FYM combination treatments (Tripathi and Verma, 2008). Poultry manure is rich in essential plant nutrients and it decomposes very quickly and adds organic matter in the soil (Shelke et al., 2001; Deshpande et al., 2007).

The microbial population and enzymic activity were increased by application of various organic manures such as FYM, poultry manure and green manures (Sesbania rostrata Sesbania aculeate), were extensively studied by Kenchaiah
The high organic carbon content in soil applied with poultry manure and has increased the bacterial, fungal and actinomycetes population (Boomiraj, 2003; Somasundaram, 2003). Decomposition of organic matter added through FYM application increased the available nitrogen, microbial activity of the soil due to decomposition of organic matter by mineralization (Singh et al., 1996).

### 2.3.4.2. Impact of Organic Manures on Seed Germination

Organic manures are the richest source of primary, secondary and micronutrient and also provide plant growth regulating substances. The highest germination percentage was observed in vermicompost application of the seedlings. The application of recommended doses of organic manures, inorganic fertilizers and biofertilizers increased the seed germination percentage (Vaithiyanathan and Sundaramoorthy, 2016). Similarly, increase in germination percentage was recorded in rice sweet flag (Kalyanasundaram et al., 2008), Zea mays (Wu et al., 2005), Abelmoschus esculentus (Gupta et al., 2008) and Triticum aestivum (Ram et al., 2014).

### 2.3.4.3. Organic approaches for Plant Disease Management

Healthy soils are the key to sustainable agriculture including plant disease management through their impact on pathogen density particularly of soil-borne diseases (Magdoff, 2001; Janvier et al. 2007). Agricultural management strategies can have a major impact on soil quality (Bancal et al., 2008; Larkin, 2015; Van Bruggen et al., 2015) with consequent effects on disease incidence (Welbaum et al., 2004; Bonilla et al., 2012; Page et al. 2013; Chun et al., 2016).
The use of natural pesticides is an agroecological practice that replaces synthetic pesticide use. Natural pesticides, often also called botanical pesticides or botanicals, have a high potential as an alternative to synthetic pesticides and their associated negative effects. Among botanical pesticides, for example, pesticides which are derived from the seeds of the trees, plant essential oils, pyrethrum extracted from flowers, crude aqueous extracts of plants and extracts of trees (Mordue and Nisbet, 2000; Coulibaly et al., 2002; Charleston et al., 2005; Sinzogan et al., 2006; Batish et al., 2008; Isman, 2006 and 2008; Regnault and Philogène 2008). In addition to botanical pesticides, biopesticides are also used. This includes the application of bacteria and fungi that can control deleterious organisms (Whipps, 2001; Vessey, 2003). Biopesticides impact pests by antibiosis, competition, induction of plant resistance mechanisms, inactivation of pathogen germination, and/or degradation of the pathogenicity of the pathogens (Whipps, 2001; Ariena et al., 2016).

2.3.4.4. Weed management in Organic Farming

Organic farming promotes weed suppression (Pallavi and Swastika, 2016). In organic farming rotation of annual crops (Anonymous, 2009) is done which means that a single crop cannot be grown in the same place without a different, intervening crop. Organic crop rotations frequently involve crops with dissimilar life cycles to discourage weeds associated with a particular crop. Research is going on to develop methods to suppress the growth or germination of common weeds (Kremer and Li, 2003). Practices used to control weeds (Szykitka, 2004; Brese, 2015; Pallavi and Swastika, 2016) are:

- Tillage - Turning over the soil between crops to incorporate crop residues; remove existing weed and prepare a seedbed for planting
- Mowing and cutting - Removing tops of weeds
- Thermal weeding – Killing weeds by using heat.
- Mulching - Blocking weed growth with plastic films
- Introducing Fish - Some farmers introduce fish to wet paddy fields to eat both weeds and insects.
- Using stale seed beds to destroy weeds before planting.

In addition, some allelopathic plants like sunflower, rye and sorghum have the ability to produce chemical compounds which negatively influence the growth and development of weeds, pests, or diseases (Weston, 1996; Tabaglio et al., 2008; Kruidhof et al., 2008; De Albuquerque et al., 2011). Allopathic plants inhibit weed seed germination and/or development due to the release of root exudates (De Albuquerque et al., 2011).

2.3.4.5. Impact of organic farming on growth, yield and quality of crops

The superiority of FYM and poultry manure is due to the release of aliphatic and aromatic hydroxyl acids, humates and lignins (Ram Singh et al., 1985). And also ammonical nitrogen supplied from poultry manure in early stage of crop growth resulted in better growth and development of the crop. Organic sources influenced the dry matter accumulation pattern in the growth stages of rice (Ofiri et al., 2005).

Application of poultry manure and FYM increases the yield attributes of rice (Channabasavanna and Biradar, 2001). A similar result was reported by Prasad et al. (1999). The significant increase in grain yield was supported by higher number of panicle bearing tillers, straight ear heads and 1000 grain weight, which was observed more in organic manure applied plot as compared to inorganic fertilizer. Higher number of effective tillers, panicle length and filled grains were noticed in all the
vermicompost applied treatment than FYM application (Barik et al., 2006). The observations on panicle length shows that the highest panicle length was recorded with the application of glyricidia 10 t ha\(^{-1}\) (Yadav et al., 2008). Natarjan et al. (2008) reported that higher rice grain yield was obtained with FYM + neem cake compared to that of recommended dose of fertilizers.

Prabhu et al. (2000) reported significantly higher yield of coriander with 25 % recommended dose of fertilizer + FYM @ 10 t ha\(^{-1}\) + Azospirillum + VAM over other combination of nutrient sources. The similar results were obtained by Mehta et al. (2016). Increase in grain yield due to the addition of poultry manure had been reported by Vasanthi and Kumaraswamy (2000), Channabasavanna (2002), Adeniyan and Ojeniyi (2003) and Luikham et al. (2003).

Mehta (2016) reported that, antioxidants and antioxidant enzymes revealed that activities of these molecules were improved by foliar application of farm yard manure. Corn production using locally available compost materials improves the yield 9 Mg ha\(^{-1}\) within 3-5 years.

Cooked rice grains from organic farming showed higher elongation and width expansion ratio and lower gruel solid loss and grain hardness compare to chemical farming (Nguyen et al., 2002; Harish and Devasenapathy, 2010; Kaur et al., 2015).

### 2.3.4.6. Economic benefit of organic agriculture

This growing demand for green agriculture products is both a constraint as well as window of opportunity not only for the agriculturists but also for producers, suppliers and traders of agriculture inputs (fertilizer, pesticide, etc.) and outputs (www.etagriculture.com/). Organic farming sector seems labor and knowledge-intensive while conventional farming is requires more energy and
manufactured inputs (Halberg, 2006). Organic farms have been found to be as profitable as conventional farms. Markets and supermarkets sell organic food at higher prices and gain more profits than non-organic food (Crowder and Reganold, 2015). Application of green manure along with poultry manure significantly increased the grain and straw yield of rice and higher gross and net return by reducing the cost of cultivation (Harish and Devasenapathy, 2010). Similarly, Adhikari (2011) revealed that organic farming is more cost effective than conventional one and, can yield higher than the average. The higher productivity of organic rice than the national and regional average proved that the organic rice production is a viable option for the sustainable food production and food security. The B:C ratio of organic rice production was found to be 1.15.

In this chapter, an attempt has been made to review the salient research findings on biodynamic manures characterization and effect of organic and biodynamic manures on crop growth, yield and quality of crops under relevant headings.

2.4. Biodynamic agriculture

2.4.1. Biodynamic agriculture definition and concepts

The biodynamic practices include a series of well–known organic farming techniques to improve soil fertility (i.e. rotations) and total exclusion of any kinds of chemical fertilizers and pesticides (Di Silvestro, 2012). Biodynamic agriculture has many similarities to other organic agricultural systems and relies heavily on composted farmyard manure (FYM) as a fertilizer. While embracing many of the traditional approaches of organic production, such as crop rotations and soil building regimes using compost, biodynamic farmers see their farms as resembling an actual
living organism or individual entity (Koepf, 1989; Koepf et al., 1990; Sattler and Wistinghausen, 1992; Beismann, 1997; Vereijken et al., 1997).

Additionally, biodynamic farming utilizes field sprays and compost preparations consisting of specific minerals or plants treated or fermented with animal organs, water and/or soil (Steiner, 1924). Since biodynamic preparations are added to composting organic material in very low doses of a few grams per ton of compost material, the primary purpose of these preparations is not to add nutrients, but to stimulate the processes of nutrient and energy cycling, hasten decomposition and to improve soil and crop quality (Koepf, 1993).

Generally, biodynamic compost additives are made from six different plant species (Steiner, 1924): flowers of yarrow (*Achillea millefolium* L.), chamomile (*Matricaria chamomilla* L.), dandelion (*Taraxacum officinale* Web.) and valerian (*Valeriana officinalis* L.), bark of oak (*Quercus robur* L.) and whole plant of stinging nettle (*Urtica dioica* L.) (Table 2.1). Several studies demonstrated that biodynamically treated composts maintained a significantly higher temperature throughout the composting period, suggesting more thermophilic microbial activity and/or faster development of compost with biodynamic treatment (Wistinghausen, 1984; Koepf, 1989; Carpenter-Boggs et al., 2000b).

Biodynamic agriculture is based on the anthroposophical concept of Rudolf Steiner, it is the oldest form of organic farming with a history of more than 80 years and still has considerable importance (Koepf et al., 1990; Podolsky, 2000; Turinek et al., 2009). It is characterized by the unique use of compost and field preparations to stimulate the nutrient transformation processes (Zaller and Köpke, 2004).
2.4.2. Difference between organic and biodynamic agriculture

Basically, the only difference between organic and biodynamic agriculture falls in application of BD preparation (Carpenter-Boggs et al., 2000a; Giannattasio et al., 2013; Scott, 2013). BD manure applied in minute doses like homeopathy (Demeter Association, 2013). Besides the preparations, there are other differences between organic and biodynamic farming (Table 2.2). Rudolf Steiner’s concept of a healthy agriculture took into account not only crop rotations, sound stocking rates, and organic manuring, but also cosmic factors, namely the influence of the moon and planets (Reganold, 1995).

2.4.3. International status of Biodynamic agriculture

The concept of biodynamic agriculture has spread around the world and is widely being practiced in Europe, North America, Asia and Australia (Paull, 2011). Germany accounts for 45.1 % of the total biodynamic areas, followed by Italy and India. The leading three countries totally account for 56.3 % of the world’s biodynamic hectares (Paull, 2011). Since the introduction of biodynamic farming in the early 1920’s by Rudolf Steiner, the practice has continued to develop and cultivate leading to the operation of over 4,200 biodynamic farms worldwide (Moore, 2010). According to the certifier Demeter–International (2016), an area of 164.323 ha and 4.96 farms across 62 countries is cropped under biodynamic conditions. Besides number of biodynamic agriculture, several long-term trials have been effected with the inclusion of the BD farming method and/or BD preparations (Table 2.3).
2.4.4. Indian scenario of biodynamic agriculture

Rathore et al. (2014) cited that the biodynamic movement started in India in the early 1990’s. Amongst the first initiatives were the Shri A. M. M. Murugappa Chettiar Research Centre in Chennai, T.G.K. Meon in Madhya Pradesh, Kurinji farms near Kodaikanal, the maikaal cotton project in Madhya Pradesh and the tea projects in Darjeeling. In India, there are more than not formally certified and producing a broad range of crops including fruits, vegetables, grains, coffee, tea and spices. The research institution and other training institution listed in Table 2.4.

2.5. Scientific impact of Biodynamic Agriculture

2.5.1. Production and characterization of BD 500 and BD 501

The two BD field sprays BD 500 and BD 501 are believed to work synergistically, with BD 500 mainly improving the overall soil fertility and BD 501 being active in enhancing the plant physiological response to the light radiation (Koepf et al., 1976; Bhattacharya and Ghosh, 2014; Rathore et al., 2014). The BD 500 consists of cow manure placed in a cow horn that is left to ferment while buried under the soil for six months throughout autumn and winter, whereas BD 501 is made of powdered quartz packed in a cow horn that is also buried under the soil for six months, but over spring and summer. Besides these peculiar production methods, the effects of BD field spray preparations appear to rely on very low amounts for either soil or plant applications. The actual quantities for BD 500 and 501 are based on the early recommendations by Steiner (1924) and are commonly applied as water solutions of 150 and 3 g ha\(^{-1}\), respectively (Koepf et al., 1976). Perumal and Vatsala (2002) found that, the mud horn manure and cow horn manure were equally comparable and reported to be of same quality.
Spaccini et al., (2012) investigated the molecular composition of preparation 500 by both solid-state NMR spectroscopy and thermochemolysis, found the product enriched in bio labile components compared with the cow dung, thus becoming potentially conducive to biostimulation of microorganisms and plants.

In comparison with initial manure, earlier reports suggested that BD 500 had lower values of pH, CO₂ respiration, and C:N ratio, higher nitrate content, and reduced losses of organic matter (Brinton, 1997) (Fig. 2.4).

Giannattasio et al. (2013) characterized the bacterial and fungal communities of BD 500 using ARISA (Automated rRNA Intergenic Spacer Analysis) fingerprints. BD 500 was found to harbor a bacterial community of 2.38 × 10⁸ CFU g⁻¹ dry weight dominated by gram positives bacteria with minor instances of Actinobacteria and Gamma proteobacteria. The culturable fraction was dominated by Bacillus species.

Recently, Radha and Rao et al. (2014) found that BD 500 showed high counts of Lactobacilli (10⁹ ml⁻¹) and yeasts (10⁴ ml⁻¹). L. xylanilyticus and B. licheniformis strains in BD 500 synthesis IAA and B. licheniformis exhibited antagonism to the plant pathogen.

Singh (2008) documented that biodynamic farmers rely on BD 501 to help stave off fungal disease, increase dry matter content of the fruit, and increase the fruit’s flavour, colour and postharvest quality. Pathak and Ram (2013) also reviewed about BD 501 keeps sugar sap levels high with the excess sugars exuded through the roots to feed beneficial bacteria and fungi and also improves protein and sugar (brix) level, metabolism, mechanical rigidity, growth, tolerance to environmental stresses (frost, drought, salinity, mineral toxicity and deficiency) and resistance to fungal attack. It also improves the taste, colour and aroma and shelf life of produce. For
maximum effect, the BD 501 should be applied once at the beginning of a plant’s life, at the four-leaf stage and again at the flowering stage or fruit maturation stage. BD 500 increases health fertility and life of soils by stimulating humus formation, increasing microbial life, earth warm activity; and promoting root growth (Perumal et al., 2001; Nelson, 2005).

2.5.2. Mode of action of Biodynamic manures

2.5.2.1. Mode of action of Cow horn manure (BD 500)

A more reasonable potential mode of action for the preparations may be through hormonal effect (Reeve et al., 2010). The BD 500 was found to contain high levels of cytokinins (Sterns, 1976). Another possible mode of action could be through bacterial regulation effects or it may contain signaling compounds. BD 500 manure enriched in biolabile components like aromatic lignin derivatives and hence, it potentially conducive to plant growth stimulation (Spaccini et al., 2012).

2.5.2.2. Mode of action of Cow horn silica (BD 501)

BD Preparations may suppress plant pathogenic organisms through competition, predation, antagonism of microbes in the preparations, or inhibitory compounds from the microorganisms. BD 501 can also induce “systemic resistance” in plants (Fig 2.5) (Carpenter-Boggs, 2011).

2.5.2.3. Mode of action of biodynamic preparations (BD 502- BD 507)

The each of BD preparations was rich in specific micronutrients and microbial load. The BD preparations act as microbial inoculants, which speed up the composting process (Rosal et al., 1995; Razvi and Kramer, 1996; Lei and Vander-Gheynst, 2000). These BD preparations (BD 502 - 507) utilized for BD
compost and CPP preparation. The unique BD compost preparations have also been the subject of a few studies, which have usually found them to cause slightly higher temperature, slightly faster decomposition, and retention of more of the initial nutrients (Heinze and Breda, 1978; Reeve et al., 2010). The microbial community between compost made with and without the BD compost preparations as well as in soils fertilized with BD compost vs. untreated compost was widely studied by Carpenter-Boggs et al. (2000a, 2000c)

2.5.2.4. Mode of action of Cow Pat Pit

Bacterial and other organism like actinomycetes population is higher in CPP due to their stimulation by the addition of calcium source (Radha and Rao, 2014). Stalin (2009) also reported that CPP manure contained the highest bacterial load (4.8 x 10^6 CFU g^-1).

2.5.3. Effect of biodynamic manures on soil properties

Biodynamic farmers use ‘preparations’ to improve soil and crop quality, including fermented herbs to inoculate manure and compost, and field sprays that are either made from cow manure and silica fermented in cow horns, or from special mixtures of cow manure with concentrated applications of herbs (Koepf et al., 1989).

2.5.3.1. Biodynamic manures on physical properties of soil

Ansari and Ismail (2008) explored the significance of BD 500 as compost inoculum in sodic soils. BD 500 caused a definite improvement in soil structure, humus formation, populations of microbes, earthworm activity, supporting deeper root penetration and strong, upright growth in plant. Biodynamic management could be another promising technology that could be employed in bioremediation process of
problematic soils. Foissner (1987) investigated and reported lower bulk density in biodynamic soil than the conventionally farmed soil. Likewise, Reganold et al., 1993 documented the biodynamically managed surface soils (0-10 cm), had significantly lower in bulk density (1.05 Mg m$^3$), easier penetrability, and thicker topsoil (22.8 cm) than their conventional soils. Levick (1992) also found that the biodynamically farmed soils had significantly higher water infiltration rates, porosity, organic C and soil respiration, and lower bulk density ad penetration resistance than the conventionally farmed soils. Long-term studies on biodynamic preparations show significant alterations in the soil pH, basal respiration and metabolic quotient (Zallar and Köpke, 2004).

Nevertheless, Droogers and Bouma (1996) found no significant differences between biodynamic and conventionally managed arable fields in physical parameters, but simulated crop yields were significantly greater from biodynamic fields because of improved soil structure and better water relations. Berner et al. (2008) reported that there were no interactions between the three factors tillage, fertilization and biodynamic preparations.

2.5.3.2. Biodynamic manures on chemical properties of soil

Soil organic matter content was found to be significantly higher on most of the biodynamic farms than on their conventional (Pettersson et al., 1992). The soil health can be improved by advocating biodynamic compost, BD 500 and CPP to the soil (Perumal and Vatsala, 2002; Perumal et al., 2003; Stalin, 2009). Pfeiffer (1983) stated that BD 500 in cow horn had increased levels of micronutrients like calcium, copper, magnesium, manganese thus stimulate soil micro-life with increase in micro flora and humus forming bacteria. Carpenter-Boggs et al. (1997, 2000c) found that
compost-fertilized soils supported greater dehydrogenase activity, more soil respiration 19.0 mL CO₂ g⁻¹ soil h⁻¹ in biodynamic compost plot where as in non-biodynamic compost treated plot receiving 16.2 mL CO₂ g⁻¹ soil h⁻¹ and had more MinC than non-compost plot soils. Compost may supply an additional source of labile C and other nutrients to the soil for microbial growth and activity. Similarly Abele, 1987; Pettersson et al. (1992) reported that biodynamically treated and organically fertilized plots generally was higher in microbial activity, enzyme activity (dehydrogenase and urease). Mäder et al. (2002) studied that difference in dehydrogenase, protease and phosphatase activities with respect to the farming systems in the biodynamic, organic and conventional agriculture long-term comparison trial, where highest values were measured for the biodynamic system.

Forman (1981) reported that plants grown in the biodynamic soil that had a significantly higher N content (0.22 %) and extractable P content (44.9 mg kg⁻¹) than plants grown in the conventional soil. Penfold et al. (1995) found that biodynamic management resulted in lower extractable P than conventional or organic management.

The response to added P and N did not differ between the conventional and biodynamic soils, although, plants in the biodynamic soils had a slower growth rate and a higher level of colonisation by VAM fungi due to lower initial soil P and N concentrations (Ryan and Ash, 1999). Heinze et al. (2010) biodynamic treatment showed significant differences for the total S content. Soils which had received high rates of composted FYM under biodynamic management resulted in enhanced net N release for crop growth (Palmer et al., 2007).
Condron et al. (2000), from their experiments that biodynamic farming may be unsustainable in New Zealand soil because nutrients removed in farm produce are not adequately replaced. Soil organic matter content and biological activity is generally higher under both types of organic system than under conventional systems. Trace element availability and use may limit the sustainability of organic systems. The DOK plots found to increase in total hydrolysable protein amino acids (Scheller and Raupp, 2005) and pH (Birkhofer et al., 2008) in the biodynamic plots when compared with the organic plots.

2.5.3.3. Biodynamic manures on microbial properties of soil

According to Oehl et al., 2004, microbial biomass nitrogen also differed significantly and was highest in the biodynamic system with 59% more than that in the conventional farming. Furthermore, the microbial biomass carbon was 35% higher in the biodynamic system, compared with the conventional farming. Organically and biodynamically managed soils had similar microbial status and were more biotically active than that did not receive organic fertilization (Carpenter-Boggs et al., 2000c).

The prepared FYM however did not affect soil microbial biomass, dehydrogenase activity and crop yields (Zaller and Köpke, 2004; Raupp and Oltmanns, 2006) in a long term field experiment comparing FYM in a crop rotation in two treatments with and without biodynamic preparations and inorganic fertilizer after 18 years found that (i) the organic C content was higher with manure than inorganic fertilization and (ii) the highest content was found in the treatment with biodynamic preparations.

The differences seen in microbial efficiencies, defined as dehydrogenase activity per unit carbon dioxide respiration, dehydrogenase activity per unit readily
mineralizable carbon, and respiration per unit microbial biomass (Reeve et al., 2005). A single report of greater dehydrogenase activity in biodynamically treated compost linked to greater microbial activity (Reeve et al., 2010) was the only significant difference among several tested parameters and whose potential significance was unexplained (Scott, 2013).

The diatom diversity tended to be higher in the biodynamic than conventional system. Redundancy analysis (RDA) suggested that diatom community structure differed between organic and the two conventional systems. Testate amoeba abundance was about five times higher in biodynamic than in conventional systems. (Heger et al., 2012).

Monika et al. (2015) reported that bacteria, actinomycetes and fungi population was significantly greater in the soil receiving organic nutrients and biodynamic preparations and also supported the highest dehydrogenase, phosphatase and arylsulfatase activity of soil.

The effects of organic farming and biodynamic farming on soil organic matter and soil biological properties have been most intensively investigated in DOK trial, highest levels of soil organic matter, microbial biomass and soil biological activities were usually observed in the biodynamic treatment (Fließbach and Mäder, 2000; Mäder et al. 2002; Chu et al., 2007; Fließbach et al. 2007; Esperschütz et al., 2007; Birkhofer et al. 2008). Several authors reviewed that, increase in organic carbon content was recorded in BD system than conventional systems (Droogers and Bouma, 1996; Perumal and Vatsala, 2002). The biodynamic preparations aided the manure decomposition, increases the soil microbial properties, plant growth promoting activity, crop yield and food quality (Perumal et al., 2001 and 2003; Perumal and Stalin, 2006).
An increase in microbial biomass was observed for wheat and amaranth crops following organic and biodynamic manure application (Ngosong et al., 2010). Similarly, an earlier study at the same site by Bachinger (1996) 15% and 31% more C organic content at cattle manure and cattle manure with biodynamic preparation plots, respectively, compared to conventional plots. This match to less oil organic C (-13%) and total N (-16%) at conventional plots was recorded in wheat field (Heinze et al., 2010). Biodynamic preparations increased solely the Cmic-to-Nmic (soil microbial biomass C to soil microbial biomass N) ratio by 7% in the 0 – 10 cm soil depth (Gadermaier et al., 2012). However, researchers have consistently found no differences in microbial activity (Heinze et al., 2010; Reeve et al., 2011), biomass, or fungal colonization (Heinze et al., 2010) in biodynamically treated soils compared with organically managed soils.

Monika et al., 2015 reported that the highest activity of different soil enzymes viz., dehydrogenase, acid, alkaline and total phosphatase; and aryl sulfatase was assessed to the tune of 1311.02 μg Tri Phenyl Formazan 24 h⁻¹ g⁻¹ soil at flowering in ‘spring’, 26.99 μg p-nitrophenol h⁻¹ g⁻¹ soil, 35.19 μg p-nitrophenol h⁻¹ g⁻¹ soil, 62.18 μg p-nitrophenol h⁻¹ g⁻¹ soil and 77.75 μg p-nitrophenol h⁻¹ g⁻¹ soil at harvest of ‘rabi’ crop, respectively receiving the organic nutrient package along with biodynamic sprays.

2.5.3.4. Biodynamic manures on earthworm population in soil

The more frequent cultivation crops in the crop rotation of biodynamic farms resulted in denser earthworm populations, slightly better aggregate stability, and a higher soil density (Maidl et al., 1988; Kirchmann, 1994). Reinken (1986) found higher organic matter levels and earthworm populations on biodynamically treated vegetable and apple plots than on conventionally plots. Reganold et al. (1993)
analyzed that biodynamically cultivated vegetable soil to have more than 8 times as many earthworms as the conventionally soil. Simultaneously, Levick (1992) found 12 - 84 times more earthworms on the biodynamic citrus farm and biodynamic pipfruit farm over the conventional counterparts.

The application of BD preparations with FYM led to significantly higher biomass and abundance of endogeic or anecic earthworms than in plots where non-prepared FYM was applied (Zallar and Kopke, 2004). Conversely, Pfiffner and Mader (1997) found more earthworms under organic than biodynamic management, and fewest in mineral-fertilized compost and also Carpenter-Boggs et al. (2000c), reported that earthworms were more abundant in compost-fertilized plots, especially in plots receiving non-biodynamic compost. Diversity and abundance of earthworm (Lumbricidae) (Pfiffner and Ma¨der, 1997) and carabid beetle (Carabidae) (Pfiffner and Niggli, 1996) rich in biodynamic soil. Tung and Fernandez (2007a) reported that earthworm populations were also greater than those under biodynamic treatment. Similarly; Foissner (1992) reported enhanced soil life in organically managed fields compared with those under biodynamic management.

2.5.3.5. Biodynamic manures on soil carbon sequestration

Ahrens (1984) found a significantly larger amount of carbon dioxide mineralized inoculating 1.5-3.0 % (dry matter basis) concentrations of biodynamic compounds (BD preparations). As a result of a larger C mineralization, lower C/N ratios and higher total N concentrations were determined in the straw amended with compost compounds after one year. In Switzerland, a long-term trial for a biodynamic system showed a stable carbon content, while a carbon loss of 15 % in 21 years was measured for the compared conventional systems (Fließbach et al., 2007).
The soil biological parameters tested indicated many differences between soils that had received compost additions and those that had not. Both biodynamic and non-biodynamic composts increased soil microbial biomass, respiration, dehydrogenase activity, MinC, biomass and qCO₂. No differences were found between soils fertilized with biodynamic vs. non-biodynamic compost. A plot receiving the biodynamic field sprays had more MinC than water sprayed soils. Therefore, C is usually a good indicator of microbial activity.

Turinek et al. (2010) reported that the ecological footprint of production systems for wheat and spelt show higher footprints in the field of machinery use impacts, mainly due to manure spreading, harrowing and the use of BD preparations with the BD system.

Heitkamp et al. (2011) observed that differences between BD+FYM and FYM treatments. BD+FYM treatments had significantly higher organic carbon contents compared to soils of the FYM Treatments. Contents of labile C (70–114 g (kg C org)⁻¹ turnover times 462 days) and labile N (35–49 g (kg N)⁻¹, turnover time of 153 days) were strongly related to the application rate and also to crop yields. Efficiency of C sequestration in a more stable form (intermediate pool) decreased with increasing rate.

2.5.4. Effect of biodynamic agriculture on crop management

Rupela et al. 2003 reported that the microbial population in BD preparations was found to be substantial where bacteria population ranged from 3.45 to 8.59 log 10 g⁻¹. In addition, a population of fungi was found to be 5.30 and 4.26 log10 g⁻¹ in the preparations 502 and 506 respectively. Several bacterial and fungal strains showed a potential for suppressing fungal plant pathogens. The 1,443 colonies (ranging between 45 in BD 500 to 527 in BD 506) were observed from the nine samples, from
that 67 isolates, 17 suppressed disease causing fungi such as *R. bataticola, A. flavus, S. rolfsii* (Rupela et al., 2003). More of isolated microorganism groups from composted biodynamic manure exhibited antagonism towards *R. solani* and *P. ulitimum* than exhibited antagonism towards the pathogenic fungi *Verticillium longisporum* and *Aphanomyces euteiches* (Arora et al., 2005). Plant based different biodynamic liquid manures contained sufficient level of nutrients and pesticidal properties for better growth and development of plants (Ram et al., 2010).

Blieech et al. (2012) experiments results suggest that entomopathogenic Bacillus like *Brevibacillus brevis, Bacillus licheniformis* present locally in the biodynamic farm could be used in biological control of olive tree pests larvae of lepidopterans *Prays oleae* (Bernard) and *Palpita unionalis* (Hübner) and Coleopterans, *Hylesinus oleiperda* (F.) and *Phloeotribus scarabaeoides* (Bernard).

By adopting BD techniques Central Institute of Subtropical Horticulture, Lucknow has been demonstrated for management of phytophthora infection in Kagzi lime and Nagpur mandarin. Effective antagonists from BD liquid manure was evaluated against mango bacterial canker disease (*Xanthomonas campestris* Pv. *Mangiferaeindicae*) and found effective in reducing the disease (Kishun et al., 2003; Pathak and Ram, 2012). Pathak and Ram (2012) also reported spray of BD 501 brings immunity against fungal infection. BD liquid pesticides prepared from *Casurina* /horse tail leaves also provide tolerance to disease and Nettle leaf extract spray to control midge, leaf minor and mites etc. Biodynamic manure tree paste has been used for the controlling gummosis and dieback incidence in mango tree. Wheat quality (*Triticum aestivum*) (Langenkamper et al., 2006) and disease incidence *Fusarium* head blight (*Fusarium poae*), microdochium patch (*Microdochium nivale*) (Gunst et al., 2006) were unaffected in biodynamic plot.
2.5.5. Effect of Biodynamic agriculture on growth and physiology of crop plant

Tung and Fernandez (2007a) found that the shoot biomass at pod filling stage of biodynamics was higher by 24-28 % and crop growth rate as well for the two different soybean varieties. Antiradical activity is higher under biodynamic conditions. There is a good correlation between polyphenol and flavonoids content. As regards antiradical activity, the shape of the kinetic curves is quite similar in both biodynamic and conventional farming (Heimler et al., 2009). In several studies, biodynamic preparations have hormone-like effects on various crops (Stearn, 1976; Goldstein, 1979; Goldstein and Koepf, 1982; Fritz et al., 1997) and it can increase root growth (Goldstein, 1986; Bachinger, 1996).

Lytton-Hitchins et al. (1994) observed that biodynamic soil improved marginal root growth (7 %) than conventionally managed soil (2 %). The more favorable physical and chemical properties in the biodynamic, soil may be attributed to less grazing pressure.

Bindhu et al. (2013) reported that 3.5 kg biodynamic compost increases carbohydrates, reducing sugar, protein content, chlorophylls ‘a’, ‘b’ and total chlorophylls content of soyabean crop at different stages growth. Döring et al. (2015) reported that the physiological performance was significantly lower in the organic and the biodynamic systems, which may account for differences in growth and cluster weight and might therefore induce lower yields of the respective treatments.

Kjellenberg and Grandstedt (2005) after 33 years of research concluded that using of biodynamic preparations had positive influence on the accumulation of dry matter in cereal. Similarly, Jariene et al. (2015) found that highest content of dry matter was observed in ‘Vitelotte’ variety of coloured potato tubers (Solanum
When treated with BD 500 in combinations with BD 501 (27.69%). BD 501 had significant effect on the content of total phenolics (in all cultivars), total anthocyanins (in ‘Vitelotte’ and ‘Red Emmalie’) and leucoanthocyanins (in ‘Blue Congo’). Application of BD 500 in combination with BD 501 substantially increased the contents of total phenolics and total anthocyanins in all tested cultivars.

### 2.5.6. Effect of biodynamic agriculture on crop yield

Compared with organically managed systems, additions of biodynamic preparations did not affect yields of cover crops, sunflower (*Helianthus annuus*) (Berner *et al*., 2008) wheat, spelt crop (Sans *et al*., 2011) and forage grasses (Reeve *et al*., 2011)

The performance of were rice crop with two different varieties compared under organic and biodynamic; in Pego-Oliva marshland in the year of 2005 to 2009. Result of study found grain yield of rice (*Oryza sativa* L.) was similar under organic and biodynamic methods (Garcia, *et al*., 2011).

An experiment was carried out for 6 years near Elkhorn with five different treatments. The BD system resulted in 403 to 605 kg ha\(^{-1}\) more wheat grain than organic system and five years of maize crop trials showed average yields of 5.58, 6.71, 6.77, and 7.15 Mg ha\(^{-1}\) of grain for the conventional, organic, BD, and BD+ treatments, respectively. Yields from the conventional plots lagged behind the organic and biodynamic plots throughout the experiment (Goldstein and Barber, 2005). Carpenter-Boggs *et al*. (2000b) found no significant differences in yield of wheat and lentil in biodynamic and chemical system, although the yield of lentil per unit of plant biomass was higher in biodynamic.
In Slovenia, the wheat and spelt yield differences between production systems (control, biodynamic, integrate, conventional and organic systems) were insignificant. When compared to the conventional system, significantly higher efficiency (4.39, 3.08 and 3.03 times higher) was attained with the use of the control, organic and biodynamic farming systems for wheat production, respectively. Similarly for spelt production, the control, organic and biodynamic plots had a 4.77, 2.29 and 2.56 times higher efficiency of production when compared to conventional plots, respectively (Turinek et al., 2010).

Heitkamp (2011) also reported that yield of potatoes, winter rye, and clover significantly increased in proportion to the application rate of FYM, while BD had no effect in sandy soil. The experiment was conducted at Mekong Delta of Vietnam, revealed that seed yield of soybean from biodynamic, organic or chemical production practically the same and significantly higher by 50-66 % than that of the control (Tung and Fernandez, 2007b). In Germany the biodynamic sprays increased crop yields (cereals and vegetables) on years where yields were low (Raupp and Koenig, 1996).

Sharma et al. (2012) experiment revealed that the application of BD 500 and BD 501 along with either FYM @ 6 t ha\(^{-1}\) or vermicompost @ 2 t ha\(^{-1}\) recorded a significant increase of 20.56 and 12.85 % in seed yield of cumin over the application of FYM @ 6 t ha\(^{-1}\) and Vermicompost @ 2 t ha\(^{-1}\) alone, respectively.

Both organically grown rice and cabbage (\textit{Brassica oleracea} var. \textit{capitata}) were ranked higher in cost-effectiveness and consumer preference (Valdez and Fernandez, 2008; Bavec \textit{et al.}, 2012) than organic treatments with additional biodynamic preparations. Organically raised mangoes had significantly greater
phenolics, flavonoids, and antioxidant activity than those from biodynamic fields (Maciel et al., 2010), which may be of importance from a nutritional stand point.

The highest yield was recorded (7853 kg ha\(^{-1}\) in first year and 7278 kg ha\(^{-1}\) in second year) in the treatment where lemon grass (Cymbopogon citratus) was sown as per moon position with organic manure and agnihotra ash while lowest yield (2833 kg ha\(^{-1}\) in first year and 3193 kg ha\(^{-1}\) in second year) was obtained in control with sowing as per non moon position. It clearly indicates that biodynamic farming (Biodynamic Planting Calendar) has potential for improving the plant yield and oil content of lemon grass. (Punam et al., 2012).

Monika et al., 2015 documented that various organic and biodynamic nutrient management practices improved the yield of chickpea, vegetable pea, green gram and maize cobs. Highest yield to the tune of 1458 kg ha\(^{-1}\) of chickpea, 5250 kg ha\(^{-1}\) of vegetable pea green pods, during ‘rabi’ and 8740 + 2476 kg ha\(^{-1}\) of ‘spring’ crops (maize cobs + green gram) was recorded under treatment comprising the organic nutrient management, biodynamic preparations and ‘panchakavya. Viuda-Martos, et al. (2011), reported that the essential oil yield was 1.4 % for lavender (L. officinalis) collected from biodynamic agriculture field in NE, Cairo, Egypt.

About 80 % of the farmers maintained 12-18 species of crop during winter season, including: wheat, mustard, barley, field pea, red gram, chickpea, sugarcane, potato, coriander, spinach, chilli, tomato, soya, brinjal, garlic, onion, carrot, turnip, radish and berseem under biodynamic agriculture adaptation in hamlets of Azamgarh district of eastern Uttar Pradesh, India (Singh et al., 2014).
2.5.7. Effect of biodynamic agriculture on improving food quality

Biodynamic farm management practices reflect a desire to improve the healthiness of produce, which is believed to occur through harnessing biological processes and eliminating use of pesticides, herbicides, synthetic veterinary medicines and readily soluble fertilizers (Kirchmann, 1994). Some authors report an increase of storage life of crops under biodynamic production (Spieß et al., 1978; Granstedt and Kjellenberg, 2005) or minor differences in product quality (Penfold et al., 1995; Mäder et al., 2002), but results are not consistent. Di Silvestro (2012) reported wheat grain samples harvested at the three biodynamic farms presented significantly different BG levels, comprised between 0.47 g/100g DW (Collina) and 0.58 g/100g DW (Cenacchi).

Jayashree and Annamma (2006) reported that, biodynamic preparations had no spectacular effects on the characters studied, application of organic manures generally promoted fruit quality in chilli.

The circular paper chromatographic analysis of soybean seeds grown from chemical production system gave weaker patterns than those from organic and biodynamic; this be inferred to be having lower protein organization and enzyme activity and thus contributory or translated to poorer storability of seeds that went under the same treatment (Tung and Fernandez, 2007b).

Podolinsky (1990) reported that quality of product given biodynamics is superior and with very high life forces, there is anecdotal evidence that biodynamic foods are becoming more popular among consumers. (Harte-Davis, 2004; Nelson, 2005; Van Der Zee, 2005). No secondary data could be identified that indicates the past sales volume of biodynamic food products. Likewise, according to Fullmer
(2005), no studies have been implemented to determine the demographic characteristics of consumers of biodynamic food products. These are areas for potential future research, perhaps to be funded by the biodynamic trade association that is currently being formed in California. It is likely, however, that consumers of biodynamic food products are more affluent than average consumers. This is due to the high cost of biodynamic foods (Van Der Zee 2005).

Other positive effect of biodynamic farming on nutritional and keeping qualities of vegetables were also seen (Abele, 1978). A study on the consumption of Demeter certified food in a German monastery showed an improvement in health parameters as well as in the physical and emotional well-being of the participants (Huber et al., 2005). Some authors report an increase of storage life of crops under biodynamic production (Spieß, 1979) or minor differences in product quality (Penfold et al., 1995; Mäder et al., 2002; Granstedt and Kjellenberg, 2005), but results are not consistent.

The market for organic food is growing in worldwide (Hamm et al., 2004; Willer and Yussefi, 2006) because of consumers believes that these goods are healthy, safety and plus' in quality compared with food from conventional production. The organic method of cultivation contributes well for the environment and society (Torjsen et al., 2004; Siderer et al., 2005). Organic products need written certification that the product is made according to the standards of the organic agriculture. This certification has several roles. It allows the customer to distinguish between organic and conventional products. In order to ensure a product from organic or conventional origin was not been solved satisfactorily. There is no simple technique for differentiating plant products/ food stuffs from organic.
Most of the studies evaluated are physico-chemical investigations of concentrations of desirables and undesirable ingredients, pesticide residues and environmental contaminants as well as sensory tests and feeding experiments on animals. Despite difficulties in the compilation and generalization of results, some differences in quality between conventionally and organically produced foods or food produced with the aid of different fertilization systems was revealed through image forming techniques (Kahl et al., 2007). The several well trained specialists have been shown to be capable of evaluating crystallization pictures in such a way that they could identify them correctly as coming from different farming systems or different processing techniques (Balzer-Graf, 1991, 1994, 1996, 2001; Mäder et al., 1993; Alföldi et al., 1996; Granstedt & Kjellenberg, 1997; Weibel et al., 2001; Andersen, 2001).

This technique is simple and differentiates produces from organic and conventional. The plant products/foodstuffs have subjected to develop a particular pattern of images formed by the reaction of the food matrix with certain inorganic salts, which will indicate the food quality (Andersen, 2001; Kahl et al., 2003; 2007; Huber et al., 2010). The characteristic qualitative traits of the image result in typical and reproducible structures. Biocrystallization has been used in a series of comparative studies of cultivation methods (Pettersson, 1970; Lieblein, 1993; Weibel et al., 2000; Andersen, 2001). Steigbild and Circular Paper Chromatography also was performed (Zalecka, 2006) for parallel check. Menaka et al. (2005ab) studied the nutritional quality of organic, biodynamic and conventional food products through circular Paper chromatography, steigbild and biocrystalization method.
Rice is grown in diverse ecosystems. The system of rice cultivation varies depending on land situation, soil and water regimes. In India the systems of rice cultivation are wet, semi dry and dry. Rice occupies one-third of the world's total area planted to cereals and provides 35 to 60 % calories consumed by 2.7 billion people (Maclean et al., 2002). The rice requirement by the year 2025 would be around 125 mt (Kumar et al., 2009). In India, organic production is practiced in 2775 ha. The annual organic rice production in India is 3500 t. Total organic produces in India is around 14000 t and rice constitutes 24 per cent of the total organic produce (Harish and Devasenapathy, 2010). In the world it has been reported that there are 10000 varieties of rice and out of which the maximum number are in India. The country has exported 82,74,046.06 MT of organic rice to the world for the worth of Rs. 20,428.51 crores during the year 2014-15. Major Export Destinations are Bangladesh, Sri Lanka, Benin, Senegal and Nepal (APEDA, 2016).

From the above cited literatures, it may be concluded that the influence of organic manures on soil health and crop growth and yield was highly significant. Research works on biodynamic agriculture were done separately by many researchers. The research information on package development for specific crop is limited. Hence, with a view to evaluate field sprays BD 500 and BD 501 and developed biodynamic package for rice crop under two agro climatic zone, a research programme is proposed and carried out.