1. Introduction

Wheat (*Triticum aestivum* L.) is one of the major cereal crop grown worldwide and stands next to rice (*Oryza sativa* L.) in India. It is the staple food and meets about 61 per cent of protein requirement in India (Sapkota *et al.*, 2014). The world wheat production was around 713.8 million tons (MT) in 2013-14, and its global production is estimated and forecasted for year 2014-15 and 2015-16 *i.e.* 723.1 and 726.2 MT, respectively. (International Grain Council, 2016). In India, the wheat production was around 95.85 MT in 2013-14, which is higher than a record production of 94.88 MT in 2011-12. India stood second in wheat production in the world during 2013-2014. In the year 2012-13, the area under wheat cultivation was 29.87 million hectares (m ha) approximately 24 per cent of the total area (Majumdar *et al.*, 2013). Agriculture and allied sectors contribute 18 per cent to GDP and grow by 3.7 per cent (2013-14). The wheat production in India has increased significantly from 75.81 MT in 2006-07 to an all-time record of 95.85 MT in 2013-14.

Although, India witnessed the high record of wheat producing of in the past three years during *Rabi* seasons, but there was a decline in production from 95.85 MT (2013-14) to 90.78 MT (2014-15, 3rd advance estimate) due to unexpected weather conditions in the major wheat growing regions of India during February-March 2015. This hampered wheat production by 5.29 per cent in comparison to previous year record production (Annual report, 2014-15). The productivity of wheat, which was 2602 kg ha\(^{-1}\) in 2004-05, has increased to 3177 kg ha\(^{-1}\) in 2012-13, with major increase in the states of Haryana, Punjab and Uttar Pradesh, however, higher area coverage was reported from Madhya Pradesh in recent years. India’s share in global wheat production was 13.1 per cent in the year 2013-14 (GOI, 2015).

Although the existing production is sufficient to meet the wheat demand of India, but the country has to enhance the wheat production to 105 MT by 2025 to meet of the demand of growing population (Prasad, 2011). As the land is limited, there is need to increase wheat production per unit area. The production data for wheat in India show no
significant increase in productivity over the last ten years (2000-2010) (Fertilizer Statistics, 2010–11). Various factors have been attributed for stagnating wheat yields in North-West (NW) India such as late planting, unsuitable rice and wheat establishment, inadequate and imbalance nutrient management, and degrading soil health. Besides limitation of irrigation water, cost of fuel, climate change are likely to further affect the productivity of wheat (Saharawat et al., 2010; Gathala et al., 2011). Increased use of machinery and fuel for repeated tillage operations emits large amount of greenhouse gases (GHGs) into the atmosphere. The use of blanket nutrient in India has led to low nutrient use efficiency, lower profits and environmental risks. In Indo-Gangetic Plains (IGP) farmers often apply more than recommended doses of fertilizer N and P, but ignore sufficient application of potassium and other secondary and micronutrients (Singh et al., 2005; Sapkota et al., 2014).

Wheat, paddy and maize provide just over 50 per cent of the world’s plant-derived food and out of other grain, wheat is the most widely grown crop and is occupies around 17 percent of the total cultivated land in the world. It is the staple food for 35% of the world’s population, and provides more calories and protein diet than any other crop. In Asia, wheat production is more than half of the developing world’s wheat (IDRC, 2015).

In the high-yielding wheat production systems in NW Indo-Gangetic Plains of India, intensive tillage or conventional tillage and blanket fertilizer application have led to high production costs, decreased nutrient use efficiency, lower profits and significant environmental externalities especially when united with removal or in-situ burning of crop residues and unscientific cropping sequence and irrigation have steadily degraded soil health (Saharawat et al., 2011). The NW Indo-Gangetic Plains of India is characterized as small farm holding size, highly populated, poor access to new technologies, fluctuated wheat growing season, rain dependent agro-ecology and frequent climatic aberration.

The major wheat producing states are Uttar Pradesh, Punjab, Haryana, Madhya Pradesh, Rajasthan, Bihar, Maharashtra and Gujarat. Haryana state is part of NW Indo-Gangetic Plains of India, and it is the next wheat producing state after Punjab and which produces
more than 116 lakh metric tons of wheat annually. Wheat is the main crop of Haryana, which is grown in more than 25 Lakh hectares out of over 35 lakh hectares of cultivated land. The most popularly grown variety of *Triticum aestivum* were HD 2967, DWR 17, and PBW 343, which was grown in districts like Karnal, Rohtak, Gurgaon, and Hissar.

**Conventional Agricultural Practices**

Conventional tillage means tillage operation performed with a moldboard plough (full inversion of soil) or with a disc plough (inversion and mixing of soil) followed by several passes of levelling harrow. These conventional agricultural practices of cultivation of cereals cropping system is input intensive, deteriorates soil health and is less profitable (Singh *et al.*, 2016). There is a need to develop new or more sustainable management practices that should be compatible with emerging crop rotation dogma and can meet the consumer or industrial requirements. All of this has to be accomplished within a scenario of decreasing farmland available for crop production due to rapid urbanization and industrialization. Nowadays, farmers have come to understand that agriculture should not only be high yielding, but also be sustainable (Verhulst *et al.*, 2010) and are worried about the environmental sustainability of their crop production systems combined with ever-increasing production costs. The imbalance and inadequate use of nutrients can decrease the nutrient use efficiency and profitability along with increase environmental risks. This further increases the agriculture’s share to total amount of GHGs emissions. Therefore, conventional agricultural practices of wheat production need refinement for minimal emissions of greenhouse gases (GHGs) through efficient use of land, labour, nutrient, water and other agro-chemicals.

The rice-wheat (R-W) cropping system of NW India is the dominant system, occupies about 10.5 million ha and contributes to about 40% of the country’s food grain basket (Saharawat *et al.*, 2010). During green revolution era, particularly in NW India, the productivity of R-W remarkably increased along with the adoption of high yielding varieties (HYV) and improved crop management practices. Recommendation are being made that R-W productivity is plateauing because of exhausted natural resources, including the effects of adverse changes in climatic aberration (Laik *et al.*, 2014). Thus,
the region’s food security is constantly threatened and the emerging challenges of post green revolution agriculture bear additional difficulties. Global environmental changes have further complicated the already fragile and vulnerable food security in South Asia (Fischer et al., 2011).

In the R-W system, rice is grown by transplanting seedlings into puddled (conventional wet-tillage) soil and is continuously flooded during the rainy summer (kharif) from June to October and followed by wheat during the winter (rabi) from November to March/April. In general, conventionally rice-planting increases input cost and delays the sowing of succeeding wheat that involves wet and dry tillage and a fallow period between the harvest of wheat and planting of rice. A yield decline of 8–9% has been observed in wheat when grown after puddled rice compared to non-puddled rice (Gathala et al., 2011a; Kumar and Ladha, 2011). The conventional land preparation for wheat involves intensive tillage that lead to a long shift and delayed wheat planting, with a yield loss of 15-60 kg ha⁻¹ day⁻¹, if delayed nearby mid-November (Pathak et al., 2003).

Generally, rice and wheat is harvested by large combine harvester in northwestern IGP (Gajri et al., 2002). During subsequent harvest, rice residue is partial/fully burnt. This would otherwise need extra tillage, which results in 2-3 weeks delay in wheat sowing to avoid N deficiency due to N immobilisation (Thuy et al., 2008). Conversely, the wheat residue is removed to use for livestock feed and sometimes partly burnt (Gajri et al., 2002). These conventional agricultural practices resulted in a loss of C and various other nutrients such as N, P, K etc. It also negatively affects the sustainability of the agricultural production (Guo et al., 2015, Parihar et al., 2016b) and biological activity of soil due to the emission of greenhouse gases (GHGs) (Gathala et al., 2013). In winter, shorter growing period coupled with delayed wheat planting due to above said factors results in overlapping of grain filling stage with high temperature (terminal heat) that in turn lead to huge yield loss. Therefore, in the current scenario it is important to focus on soil health and system sustainability of rice-wheat rotation system.

*Conservation Agriculture (CA) Practices*
To meet the ever increasing food grain demand, there is a need of crop intensification while increasing resource-use efficiency and reducing the environmental footprint (Ladha et al., 2009). Achieving this will require a holistic system approach or alternative technology, incorporating the principles of conservation agriculture (CA), and efficient crop rotation (Balasubramanian et al., 2012). During the last few years, several component technologies of CA-based resource-conserving technologies (RCT) together with other best management practices (BMP) offer particular opportunities in the NW-IGP (Ladha et al., 2009; Jat et al., 2013). The farmers of the region immediately need technologies that have twin benefits of reducing input cost while enhancing productivity and income on sustainable basis. The technologies like zero/reduced tillage that are widely adopted in the NW-IGP appear to be transferable to the Eastern-IGP after evaluation and modifications parallel with the field machinery revolution (Jat et al., 2013). Zero-tillage is well identified as zero-till, no-till, direct seeding and direct drilling (Erenstein et al., 2008). Zero-tillage is currently practiced in around 155 m ha (10.9 % of crop land) worldwide in more than 50 countries, however CA is practiced in 124 M ha and the area is expanding rapidly (Derpsch et al., 2010; Sharma et al., 2015). Currently, CA in the R-W cropping system is being practiced on more than 5 M ha in IGP of South Asia. In India, wheat cultivation through CA is being practiced in the rice-wheat double cropping system and promoted in the NW states i.e. Punjab, Haryana, Bihar and Uttar Pradesh, and is being rapidly adopted by the farmers due to realization of its benefits towards reducing production cost and enhancing soil productivity and sustainability.

An alternative technology of current farmer’s practices, the conservation agriculture (CA) is a system based management optimization involving three principles (Fig. 1.1), i.e.

(i) a paradigm shift from intensive tillage to zero or reduced tillage (means minimum mechanical soil disturbance),

(ii) establishment of permanent organic soil cover (means crop residue retention), and

(iii) Economically viable crop rotation (means diversified crop rotation) that accompaniment reduced tillage and residue retention and benefits breaking cycles of pest and diseases (FAO, 2015).
Experimental evidence from various agricultural production environments suggests that CA based management can have immediate reduced production costs, reduced erosion, sustain rice, maize and wheat yield, improved water productivity, increased nutrient use efficiency, adaptation to climatic change, long-term benefits, higher soil organic matter contents, improved physical, chemical, biological soil quality and increase farmer income (Kienzler et al., 2012; Gathala et al., 2013; Jat et al., 2014; Guo et al., 2015; Hafeez-ur-Rehman et al., 2015; Parihar et al., 2016a, 2016b) and more sustainable farming practices. A number of scientists and institutions have been promoting CA technology with the expectation that it can help reconcile with these competing objectives and contribute to sustainable intensification (Hobbs et al., 2008; FAO, 2015).

Conservation agriculture enhances number of microbes in soil and biological activities of soil like microbial biomass carbon (MBC), potentially mineralizable nitrogen (PMN), enzyme dehydrogenase and phosphatase activity etc. Microbes play an important role in nutrient transformation in soil through different reactions and excretion of enzymes like enzyme phosphatase. Phosphatase catalyses the hydrolysis of esters and anhydrides of phosphoric acid and thus its activity indicated the mineralization potential of organic phosphorous in soils (Dick and Tabatabai, 1993). The measurement of dehydrogenase
activity in soil is a good overall indicator of microbial activity and has been used as an indicator of soil fertility (Roldan et al., 2003; Bhaduri et al., 2013). Fertilizer application with reduced and no-till seeding requires careful attention in order to optimize fertilizer use efficiency by crops, favorable soil structure enhances the process of mineralization and root growth, which is helpful for nutrient uptake (Pietola, 2005). Fixation of applied inorganic fertilizers results in lowering nutrient use efficiency and significant economic loss, as it is common in conventional farmer’s practices (Syers et al., 2008). Among all the plant nutrients, nitrogen (N), phosphorous (P) and potassium (K) are important nutrients that are recycled through crop residues under CA. There is an important and critical relationship, which exists between nitrogen and crop residues. Crop residue could significantly improve the supply of soil nitrogen and phosphorus by reducing their losses and may control soil erosion and runoff (Xu et al., 2006). Tillage, crop residues and nitrogen have critical effects on plant growth and yield. Surface accumulation of crop residues with zero tillage improves soil physical properties and increase crop yields. Straw mulch with zero-tillage is one of the important agronomic practices in conserving the soil moisture and modifying soil physical environment to maximize crop yield and enhance water use efficiency (Zhang et al., 2007; Chakraborty et al., 2008). Vanlauwe et al., (2014) has advocated that a fourth principle like the appropriate use of fertilizer to enhance crop productivity be required to define Conservation Agriculture in sub-Saharan Africa (SSA). In contradiction of fourth principles of CA, Sommer et al., (2014) argued that fourth principle will created more confusion rather than clarity and is thus not required to define CA. Further research should focus on defining appropriate fertilizer practices for CA since fertilizer use efficiency should be affect by the other three principles of CA.

Conservation agriculture should not be construed as a “silver bullet” towards achieving the agro-ecological, economical and social extents of sustainable agriculture production, but rather judged on merits in different environment conditions. There is no universal template for CA based management and production practice, and actual practices employed for CA always require a process of refinement and localization to optimize system performance in different environments (Giller et al., 2009; Kienzler et al., 2012).
Despite harmful effect (i.e. decline in soil health, high input cost, and low production, less profitable and unsustainable) of conventional agricultural practices on soil fertility, crop production and environment, an alternative technology conservation agriculture can improve crop production through enhancing soil fertility and environmental sustainability. However, interaction and evaluation of CA with many of environmental or edaphic factor is still awaited.

One of factor is related to water scarcity, like drought stress that is threatening wheat productivity worldwide. It hampers wheat performance at all growth stages, and is more critical during the flowering and grain-filling stage (terminal drought) and resulted in considerable yield losses. Modulation in the antioxidant defense system is one of the important strategies responsible for agricultural management for wheat production. The identification of stress level, a comprehensive characterization of biochemical and physiological attributes of wheat in different agricultural management helps to improve in understanding the effect of CA for its yield and grain quality. Abiotic stress promotes oxidative stress due to over-generation of reactive oxygen intermediates (ROIs) under different agricultural management, and the anti-oxidative defense system including both enzymatic and non-enzymatic components helps in ROI scavenging under stress. Of the enzymatic antioxidants - catalase (CAT), peroxidase (POX), superoxide dismutase (SOD), ascorbate peroxidase (APX) and glutathione reductase (GR) and non-enzymatic antioxidants - ascorbic acid, reduced glutathione, β-carotene is reported to accumulate in plants under stress to avoid oxidative damage (Farooq et al., 2009, 2011a, 2014). Proline (PRO) acts as a compatible osmolyte since it can accumulate to high concentrations without damaging cellular macromolecules. Proline can also serve as a nitrogen carbon source in the cell (Kumar et al., 2015a).

Lipoxygenase (LOX) isoenzyme is involved in physiological processes such as flowering (Ye et al., 2000), seed germination (Suzuki and Matsukura, 1997), pigment bleaching in wheat (Pastore et al., 2000), formation of flavour and fragrance in wheat products (Williams et al., 2000). During oxidative stress, lipoxygenase enzyme (LOX) catalyze the hydroperoxidation of polyunsaturated fatty acids and thus the first step in the synthesis of fatty acid metabolites in plants (Rosahl, 1996). Higher LOX enzyme activity
has been seen in wheat leaves growing in reduced tillage, high residue retention and rice-
wheat rotation. This could contribute to better survival and recuperative capacity and thus
could be an important trait to select for good aroma and grain quality (Kumar et al.,
2015b; Kumar et al., 2015d). In addition, the role of hydrogen peroxide (H$_2$O$_2$) in stress-
induced damage has long been known, but it is now accepted that H$_2$O$_2$ is an integral
component of cell signaling cascades (Mittler et al., 2002). The chlorophyll
quantification using a soil plant analysis development (SPAD) meter, can quickly and
reliably assess the N status of a crop based on leaf area (Bijay-Singh 2008). It has been
used for rice (Balasubramanian et al. 2000; Hussain et al. 2000), corn (Peterson et al.
1993) and wheat (Follett et al., 1992), successfully. Likewise, other biochemical
characters in wheat, carotenoids is an important antioxidant that limit the levels of free
radicals and reduce the activities of degradative enzymes, thus avoiding the ageing.
Carotenoids protect the seed from deterioration and thereby contribute to fast germination
process. These are vital part of the human diet as antioxidants and some of them serve as
precursors to vitamin A, which is required and involved in a wide range of biological
functions, including reproduction, growth, immunity, and metabolic control. Few of these
are related to their role in the prevention of certain chronic disorders such as cancer,
cardiovascular disease and osteoporosis, among others (Mellado-Ortega and Hornero-
Méndez, 2016)

Research Gap

Due to wider adoption and popularity of conservation agriculture practices, the
quantification in CA’s research is future thrust, and there is an urgent need for basic,
strategic and adaptive research in contrasting soils with different edaphic and wheat
requirements. Systematic understanding of wheat behavior, physiology and adaptation to
drought stress and other limiting abiotic stress is required in CA (Hobbs et al., 2008;
Brouder and Gomez-Macpherson, 2014; Hafeez-ur-Rehman et al., 2015). Also, the
conventional agriculture is currently facing twin challenges of resource fatigue and
decelerating productivity growth of cereal crops in South Asia. Moreover, there exist a
huge yield gap mainly ‘management yield gaps’ ranging from 14 to 47% in wheat, 18 to
70% in rice and 36 to 77% in maize, respectively.
Therefore, a wide research gap is found in terms of physical, chemical and biological soil properties, crop physiology and behaviour, crop sustainability and yield in relation to availability of soil nutrient and its interaction with different tillage, residue management and diversified crop rotation practices. Still, physiological and biochemical alteration in wheat has not been reported in details in rice-wheat based cropping systems under conservation agriculture practices. Also, to the best of knowledge, there is lack of previous report about fractions of C, N, P, and K in soil associated with rice-wheat cropping system under conservation agriculture impacts, while it is of great important in predicting bioavailability, transformation rate and equilibrium of nutrients in soil. We propose a hypothesis that differences in the quality and/or quantity of soil and crop attributes, caused by different tillage, residue retention and crop rotation management practices in rice-wheat cropping system, will alter soil and crop characteristics. To test this hypothesis, we quantified and evaluated the contributions of conservation agriculture vs conventional agriculture to soil and crop attributes.

Thus, the proposed research would be beneficial for understanding the impact of conservation agriculture on various quantitative and qualitative parameters in wheat-based production of North-West Indo-Gangetic Plain of India with special reference to Haryana state.

**Objectives**

The present investigation has been undertaken to study some biochemical, qualitative and quantitative parameters in conservation agriculture based wheat production. The studies mainly include the effect of conservation agriculture practices on soil characteristics, crop yield attributing parameters, nutritional quality of grain, some biochemical, and physiological responses during grain filling period in wheat. Long-term study of cereal based cropping system with Cereal Systems Initiative for South Asia (CSISA) at ICAR - Central Soil Salinity Research Institute (CSSRI), Karnal, Haryana, India was conducted with the following (mid-term) major objectives:

- To assess different soil health indicators (physical, chemical and biological properties) during wheat crop under conservation agriculture based rice-wheat cropping system.
➢ To quantify the nutrient fraction status and availability in soil during wheat crop grown under different tillage, residue, and crop rotation management practices in rice-wheat cropping system.

➢ To monitor the antioxidant enzymes and other physiological attributes in wheat crop during grain filling stage under different tillage, residue retention and crop rotation management practices in rice-wheat cropping system.

➢ To evaluate concentration of N, P, K, Zn and Fe in grain and straw of wheat and N, P and K uptake by grain and straw at harvest under different tillage, residue retention and crop rotation management practices in rice-wheat cropping system.

➢ To quantify crop yield attributes of wheat under different tillage, residue retention and crop rotation management practices in rice-wheat cropping system.