Introduction
Green revolution had increased the agricultural productivity to a great extent by the increased use of high yielding crop varieties, use of heavy farm equipments, synthetic fertilizers, pesticide application, improved irrigation, better soil management and massive conversion of forest to agricultural lands (Tilman et al., 2002; Kassam and Hodgkin, 2009; Gomiero, 2011). But there is a growing concern that intensive agricultural practices promote large scale ecosystem degradation and loss of productivity. Adverse environmental effects include deforestation, soil degradation, large scale green house gas emissions, accumulation of pesticides and chemical fertilizers, pollution of ground water, decreased water table due to excessive irrigation (Tilman et al., 2002; Foley et al., 2011). The international fertilizer industry association (IFA) Agriculture Committee, projected that the global fertilizer consumption is expected to grow, and it will reach 199.4 million metric tonnes (Mt) nutrients in 2019 (Heffer and Prud’homme, 2015). The projected increase will be at the rate of 1.3, 2.1 and 2.4% for nitrogen, phosphorus and potassium respectively. In reality, an intensive agricultural practice is thought to be the major cause of loss of global biodiversity. Traditional agricultural practices like organic farming, that considerably reduce the input of chemical fertilizers, pesticides, energy and mechanic stress, help us in mitigating the negative effects of intensive agricultural practices and simultaneously boost the sustainable agriculture production (Gomiero et al., 2011). However, we have an insufficient understanding about the challenges, advantages and constraints of low-input farming (Tscharntke et al., 2012) and the viability of organic farming (Wu and Sardo, 2010).

World total population is currently around 7 billion and this is projected to increase to approximately 8 billion people until the year 2025 and 9 billion by 2050. Considering the increase in worldwide population with the increase in environmental damage due to ever increasing industrialization, it is clear that in coming next 50 years it will be a daunting task to feed the existing population, a problem that will increase with time. Therefore, to feed the ever increasing population, there is a need for tremendous increase in agricultural productivity in a sustainable and environmentally friendly manner. To produce more food, the world will require a variety of different strategies and approaches which must include sustainable and environmentally friendly biological solution (Glick, 2014). The effective use of PGPR in agriculture in an integrated manner is an attractive technology to address these problems.
Therefore, various strategies and approaches are required to meet the food demand. The long term and sustainable agricultural productivity requirement must include sustainable and environmental friendly biological solution. One of the most promising approach recommended by various scientists is based on exploiting the role of soil microbial communities for sustainable and healthy crop production. The role of soil microorganisms in agriculture mainly by improving availability of plant nutrients and plant health as well as soil quality is well known (Barea et al., 2013, Lugtenberg, 2015). Among soil microbes, the role of root associated microbiome in nutrient supply and plant protection have to be optimized (Raaijmakers and Lugtenberg, 2013).

Among the diverse soil microflora, plant growth promoting rhizobacteria (PGPR) mark an important role in enhancing plant growth through a range of beneficial effect both by direct and indirect mechanisms (Glick, 2012). Generally, PGPR promote plant growth directly by facilitating resource acquisition (nitrogen, phosphorus and essential minerals) or modulating plant hormone levels. Indirectly, rhizobacteria promote plant growth by reducing the population of phytopathogens, production of antibiotics, cell wall degrading enzymes, induced systemic resistance and competition for colonization sites on plants (Bhattacharyya and Jha, 2012; Glick, 2012).

The colonization of the adjacent volume of soil under the influence of root is known as rhizosphere colonization. Rhizosphere colonization not only works as a fundamental step in the pathogenesis of soil microbes but also play an important role in the employment of microorganisms for beneficial purposes (Benizeri et al., 2001). PGPR normally promotes the plant growth by establishing themselves on plant root and suppressing the colonization or eliminating the pathogenic microorganisms (Schroth and Hancock, 1982; Beneduzi et al., 2012). The competitive exclusion of deleterious rhizosphere organisms is directly linked to the ability to successfully colonize a root surface. However, disease suppressive mechanisms were shown by plant growth promoting rhizobacteria is of no use until these microbes successfully colonize and established themselves on root surface (Nautiyal, 1997; Meena, 2014). Bacterial root colonization is primarily influenced by the presence of the specific character of bacteria necessary for adherence and subsequent colonization. Moreover, several biotic and abiotic factors also play significant role in bacteria-plant root interaction and colonization. When an organism colonizes a root, factors like water content, temperature, pH, soil characteristics, composition of root exudates, mineral
contents and other microorganisms may influenced the process of root colonization. However, plants are the major determinant of the structure of microbial diversity (Dakora and Phillips, 2002; Philippot et al., 2013). Recent studies on the root-microbe interaction have indicated that rhizobacteria can establish in the root zone and form biofilm and biofilm like structure. Such phenomena are considered as survival strategy by the rhizobacteria which provide protection to stress condition (Timmusk and Nevo, 2011).

Biofilms are assemblages of microorganism adhered to each other and/or to a surface and embedded in a matrix of exopolymers (Branda et al., 2005; Vlamakis et al., 2013). These biofilms work as microniches, which are entirely different from their surrounding environment and stimulates the microbes to work as a family not possible in planktonic state or outside biofilms. The list of the possible effect of biofilms on bacterial ecology and biology, such as protection from desiccation, salinity, UV exposures, acid exposures, metal toxicity, predation and bactericides, enhancement of genetic exchange and of synergistic interactions is impressive (Hall-Stoodley et al., 2004; Vlamakis et al., 2013). Biofilms might also foster the expression of density-dependent phenotypes. Induction of the expression of certain bacterial genes in a density-dependent manner is known to require the accumulation of diffusible molecules such as acyl homoserine lactones via process called quorum sensing (Li and Tian, 2012).

Research on microbial biofilms is proceeding extensively in many fronts in medical, environmental and food industry (Hall-Stoodley et al., 2004; Van Houdt and Michiels, 2010). Biofilm formation have been extensively demonstrated by bacteria on various biotic and abiotic surfaces such as mineral crystals, corrosion particles, clay, silt particles, living cells/tissues of human, animals and plants etc. However, biofilm research associated with plant surfaces and its understanding is still poor. This is probably due to the complexity of microbes in the soil-root association and difficulties in studying the mixed biofilm under natural/ simulated models (Burmolle et al., 2014). However in last one decade many researchers have explored the beneficial biofilm associated with plants (Timmusk et al., 2005; Vlamakis et al., 2013). It has been demonstrated that beneficial biofilm associated with plant root could be exploited to enhance plant protection and growth promotion even under stress conditions (Timmusk et al., 2014). Since the microbial physiology in the biofilm form is different compared to planktonic mode of growth, it is of paramount
importance to assess the biofilm forming potential of PGPR *in vitro* and under soil-root system to explore the role in effective root colonization and benefits to plants in a sustained and consistent manner. Commercially, many crops were intentionally inoculated with different rhizobacteria in crop production (biofertilizer) and protection (biocontrol). PGPR are supposed to establish and maintain a minimum threshold population size in the rhizosphere in order to impart their beneficial effects. The major limitation of such microbial inoculants is their inconsistency in their performance, which is due to various biotic and abiotic factors including poor root colonization.

Efforts have been made to developed biofilmed biofertiliser to enhance survival and cell density of inoculants under field conditions. It has been suggested that indigenous rhizobacteria exhibiting multiple PGP traits and tolerance of environmental conditions may be more suited and adapted to local ecological conditions (Ahmad *et al.*, 2008a). However, no systemic efforts have been made from India to explore the role of biofilm formation in root colonization under natural condition. Therefore, it is hypothesized that indigenous isolates of plant growth promoting rhizobacteria capable of forming strong biofilm may be more effective in root colonization and may promote plant growth effectively under field condition.

Considering the importance of biofilm formation by PGPR on plant surface and its beneficial impact, the present study has been planned with followings aims and objectives.

I. To isolate and identify the selected rhizobacteria for their biofilm forming ability *in vitro*.

II. To assess the tolerance among isolated bacteria to salt, antibiotics, and heavy metals.

III. Detection and quantitative estimation of plant growth promoting (PGP) activities of test bacteria.

IV. To assess the root colonization by selected biofilm forming rhizobacteria having multiple PGP traits.

V. Performance of efficient root colonizing bacterial strains on plant growth and yield characteristics under control and field conditions.