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Effects of Biofertilizer Application on Growth and Yield of corn (Zea mays L.) : A Review

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ABSTRACT

Maize (Zea mays L.) is the third most important globally cereal crop (after wheat and rice), it is grown throughout a wide range of climates. Plant-growth-promoting rhizobacteria (PGPR) are bacteria with plant-growth-stimulating activity, which may result from different mechanisms, such as the production of plant-stimulating growth substances (phytohormones) or the suppression of minor plant pathogens by various mechanisms. These effects are mainly derived from morphological and physiological changes of the inoculated plant roots, leading to an enhancement of water and mineral uptake. Plant growth-promoting rhizobacteria (PGPR) are considered to have a beneficial effect on host plants. Today the use of chemical fertilizers to the problems of society has imposed. However, the important role of biological fertilizer in the food plants supply and reduce the environmental impact has been proved. Considering that, one the goals of producing is access to healthy seed and seed quality and high production capacity. The effects of PGPRs on plant growth and productivity are either direct (e.g. biological N fixation, S oxidation or P solubilization, increasing nutrient availability) or indirect ‘‘catalytic’’ actions . There are some evidence that plant growth and yield increase may be stimulated by plant growth promoting bacteria due to their ability of N2-fixing, phosphate solubilizing and production of plant growth hormones. It is documented that some plant-growth promoting rhizobacteria (PGPR) enhance plant salt tolerance.

Keywords : Zea Mays L., Plant-Growth-Promoting Rhizobacteria (PGPR), Biological Fertilizers

I. INTRODUCTION

Maize (Zea mays L.) is the third most important globally cereal crop (after wheat and rice), it is grown throughout a wide range of climates. A major shift in global cereal demand is underway and by 2020 the demand for maize in developing countries is expected to exceed the demand of both wheat and rice (Pingali and Pandey, 2001). During the last four production seasons (2010 - 2014), the average world maize areas were about 176.19 million hectares producing 930.13 million metric tons with average yield estimated at 5.78 ton per hectare (FAO, 2014). corn (Zea mays) among the crops, is an important in temperate climatic region, because of the increasing demand for food and livestock feed. Nitrogen and phosphorus are essential nutrients for plant growth and development in corn (Wua et al., 2005). The biological fertilizers and plant residues included all products that are made by microorganisms activity.The soil bacteria such as Azotobacter and Azospirillum are some of these microorganisms. These bacteria help to preserve the health of the plants by controlling the pathogenic agents indirectly as growth is improved (Kennedy et al., 2004.). Utilization of microorganisms in agriculture requires an evaluation of environmental risks associated with the introduction of indigenous or nonindigenous microorganisms into the plant rhizosphere for different purposes. Furthermore, the successful establishment of introduced microorganisms in the rhizosphere depends on the ability of the bacterium to colonize roots and to compete with the indigenous microbiota (Cello et al., 1997). Use of these microorganisms as environment friendly biofertilizer helps to reduce the much expensive phosphatic fertilizers. Phosphorus biofertilizers could help to increase the availability of accumulated phosphate (by solubilization), efficiency of biological nitrogen fixation and increase the availability of Fe, Zn etc., through production of plant growth promoting substances (Kucey, 1989). Increased root, shoot weight with dual inoculation in maize have been reported by (Chabot et al ., 1993), while grain yields of the different maize genotypes treated with Azospirillum spp. Seed inoculation with Rhizobium, phosphorus solubilizing bacteria, and organic amendment increased seed production of the crop (Panwar et al ., 2006). Increasing yield was attributed to the plant growth promoting substances by root colonizing bacteria more than the biological nitrogen fixation, (Lin et al ., 1983) stated that yield increased due to promoting root growth which in turn enhancing nutrients and water uptake from the soil. There were positive and synergistic interactions between factors like interactions between mycorrhizal inoculation and phosphate biofertilizer on N concentration and phosphate biofertilizer and vermicompost on P concentration (Darzi et al ., 2009). Plants in nature interact with several beneficial soil microorganisms, which improve plant stress tolerance (Aroca and Ruiz-Lozano 2009a; Ryan et al., 2009). Among such microorganisms, plant-growth-promoting rhizobacteria (PGPR) are one of the most studied (Dimkpa et al. 2009; Lugtenberg and Kamilova, 2009). PGPR can be classified as extracellular bacteria (existing in the rhizosphere, on the rhizoplane, or in spaces between cells) and intracellular bacteria (mainly N^2 fixing bacteria) (Gray and Smith, 2005). The action mechanisms of PGPR can be divided also into direct and indirect ones. Direct mechanisms include N^2 fixation, soil mineral solubilization, production of plant-growth-promoting substances (auxins, cytokinins or gibberellins), and reduction of ethylene levels, among others. Indirect mechanisms include favoring colonization by other beneficial soil microorganisms, as mycorrhizal fungi, and repressing the growth of plant pathogenic microorganisms (Vessey, 2003; Lugtenberg and Kamilova, 2009).

Necessity of Bio-Fertilizers

Depleting feedstock/fossil fuels (energy crisis) and increasing cost of fertilizers. This is becoming unaffordable by small and marginal farmers, depleting soil fertility due to widening gap between nutrient removal and supplies, growing concern about environmental hazards, increasing threat to sustainable agriculture. Besides above facts, the long term use of biofertilizers is economical, eco-friendly, more efficient, productive and accessible to marginal and small farmers over chemical fertilizers (Subba Roa , 2001). Organic agriculture is one of the ways that can produce high quality crops (Higa, 1994). Phosphorus (P) is an essential macronutrient for plant growth. Despite phosphorus being widely and abundantly distributed in the soil in both its inorganic and organic forms, many soils throughout the world are deficient in phosphorus. Phosphorus can be tightly bound with calcium, iron, or aluminium, leading to precipitation of phosphorus (Li et al., 2003). Use of phosphorus fertilizers has become an expensive practice. The useof cheap, alternative sources of phosphorus, such as rock phosphate (RP) and microorganisms. Therefore, has received considerable attention in recent years (Rajan et al., 1996). Many bacteria (Rodriguez and Fraga, 1999) and fungi (Whitelaw, 2000) are able to improve plant growth by solubilising sparingly soluble inorganic and organic phosphates in the soil.

Biofertilizers tolerance to environmental stress

Abiotic and biotic stresses are the major constraints that are affecting the productivity of the crops. Many tools of modern science have been extensively applied for crop improvement under stress, of which PGPRs role as bio protectants has become paramount importance in this regard (Yang et al., 2009). PGPRs as biological agents proved to be one of the alternatives of chemical agents to provide resistance to against various pathogen attacks (Murphy et al., 2000). Apart from acting as growth-promoting ag ents they can provide resistance against pathogens by producing metabolites (Backman and Sikora, 2008). PGPR produce IAA which, in turn, induces the production of nitric Oxide (NO), which acts as a second messenger to trigger a complex signaling netw ork leading to improved root growth and developmental processes (Molina et al., 2007).

Early changes in root characteristics of maize by PGPR

Modifications on young maize root properties may also be observed as a consequence of seed plant growth promoting rhizobacteria (PGPR) inoculation. Azospirillum has been suggested to afect root growth during the initial plant development stages (Jacoud et al. 1999). El Zemrany e t al. (2006) studied the field survival of Azospirillum Lipoferum CRT1 and various agronomic efects of the inoculation with this PGPR strain on maize. They observed that the density of the inoculum on roots reached a maximum for plants at the five-leaf stage (35 days) and then decreased, which means that most subsequent effects could be initiated during this early period of maize growth.

The role of Azospirillum in sustainable production of maize

Azospirillum species occur in soil and are enriched in root surface of many different plants such as wheat, rice, maize and sugarcane (Elmerich et al., 1992). At present in some countries this bacteria is used in biological agri cultural production including cereals and vegetables (Hassouma et al., 1994). Azospirillum causes physiological and morphological changes of host plant roots. Major changes that were observed in inoculated roots with Azospirillum were increasing of cellular division at root and rising number of root hairs. Apparently inoculation allows plants to have a more balanced nutrition, and the absorption of nitrogen and other mineral nutrients (such as phosphorus, potassium, zinc and manganese) (Hassouma et al., 1994). Davaran Hagh et al. (2010) showed that the inoculation with Azospirillum increased the yield, percentage of nitrogen in grains, number of grains in a cob row, flag leaf area, ear length and number of grains in ear. they concluded that using 140 kg of nitrogen fertilizer per hectare and inoculation of maize seeds by Azospirillum could reduce the application of nitrogen fertilizer, increase the grain yield up to 30 percent and prevent pollution of environment by extended sustainable agriculture.

Using Biofertilizer to Improve Seed Germination of Maize

The application of bacteria (PGPB –plant growth promoting bacteria) as biofertilizer is increasing due to the low level of animal husbandry and the utilization of organic fertilizers. As a consequence, soils become poor in useful bacteria. PGPB indicate a group of bacteria actively colonizing plant roots, thus increasing the growth and yield of the plant (WU et al., 2005). The Azospirillum, Azotobacter, Bacillus, Pseudomonas, and Serratia genus belong to this group (Bashan et al., 2004). One of the ways to improve germination is to use seed priming. The major aim of seed priming is to par tially hydrate the seed to a point where the germination processes starts but does not finish. Several ways of seed priming exist, such as hydropriming, halopriming, osmopriming, thermopriming, solid matrix priming, and biopriming (Ashraf and Foolad, 2005). Based on a experiment , it was concluded that there is a positive effect of PGPB on germination, as well as it is supposed, that the applied biofertilizer treatments stimulated the germination and growth of maize by reason of excreting phytohormones and enhancing the nutrient mobilization from the seed. (Bákonyi et al., 2013).

Effect of Bio-Fertilizer on Growth and Yield of Maize

Plant growth-promoting rhizohacteria (PGPR) are able exit a beneficial upon plant growth. Nitrogen fixation and P.solubilization (Zaidi and Mohammad, 2006) production of antibiotic (Zahir et al., 2004) and increased rood dry weight are the principal mechanism for the PGPR. A number of different bacteria promote plant growth, including Azotobacter sp., Azospirillum sp., Pseudomones sp., Bacillus sp. Acetobacter sp (Turan et al., 2006). Bio fertilizer is defined as a substance, contains effective living microorganisms (EM) which colonizes the rhizosphere or the interior of the plant and promotes growth by increasing the supply or the availability of primary nutrient and/or growth stimulus to the target crop, when it is applied to seeds, plant surfaces and soil (Ahmad et al., 2006). Bio-fertilizers contain beneficial bacteria and fungi that improve soil chemical and biological characteristics, phosphate solutions and agricultural production (Yosefi et al., 2011). The efficiency of EM (Effective recommended Microorganisms) as a bio-fertilizer is attributed to its role in accelerating the mineralization processes of organic matter and helping the release of nutrients resulting in enhancing the utility values of soil organic matter contents and cations exchange capacity (Yadav, 1999. Therefore, bio-fertilizers are gaining importance as they are eco-friendly, nonhazardous and nontoxic products (Sharma and Dak, 2007). Significant differences among maize genotypes in yield and its components were frequently detected by many investigators (Idris and Mohammed, 2012). Moreover, several authors (Radwan et al., 2001). Suggested that hybrids produced more ear/plant, better ear characteristics, heavier weight of grains/plant and higher grain yield/hectare compared with the open pollinated varieties. Significant interactions between maize genotypes and N application were also detected by many authors' (El-Kalla et al., 2001).

The effects of different biofertilizer combinations on corn under drought stress condition

The use of bio stimulators in condition of environmental stress can decrease effects of stress and enhance soil water holding capacity, root growth and yield (Li and Ni, 1996). Drought is one of the most important abiotic stress factor (Bruce et al., 2002), which affects almost every aspects of plant growth (Aslam et al., 2006). Drought, or more generally, limited water availability is the main factor limiting crop production (Seghatoleslami et al., 2008). Drought is a permanent constraint to agricultural production in many developing countries, and an occasional cause of losses of agricultural production in developed ones (Ceccarelli and Grando, 1996). No exact figures on yield and economic losses in maize due to drought are available. In maize, grain yield reduction caused by drought ranges from 10 to 76% depending on the severity and stage of occurrence (Bolaoos et al., 1993). Sivasubramaniawn (1992) related the droughtresistance of plants to the chlorophyll stability index that has been employed to determine the thermo stability of chlorophyll. Obviously, combined application of organic fertilizer and urea fertilizer or combination urea fertilizer and polyamines significantly increased yield, vegetative growth and chlorophyll index (Zeid, 2008). Zarabi et al. (2011) showed that phosphatesolubilising microorganisms can positively have effect on the increase of plant growth and phosp horus absorption in maize plant, leading to plant tolerance improving under drought stress conditions.

Maize (Zea Mays L.) with PGPR under Salt Stress

Soil salinity decreases plant growth, reduces photosynthetic activity and results in nutrient imbalance in plants.It was reported that PGPR significantly increased shoot/root fresh weight, shoot/root dry weight, chlorophyll a, b and cartenoid contents of maize under salt stress. PGPR can induce plant tolerance to salinity by producing various hormones and enhancing the availability of nutrients from the soil matrix (Nadeem et al., 2006). Hasnain and Sabri (Hasnain and Sabri, 1996) reported that inoculation with Pseudomonas sp. stimulated plant growth by reduction of toxic ion uptake and production of stress-specific proteins in plant. PGPR strains can also produce exopolysaccharides (EPSs) to bind cations including sodium, thus help alleviating salt stress in plants grown under saline environment (Ashraf et al., 2004). The rhizosphere is the soil portion found around the root and under the influence of the root. It is the site with complex interaction between the root and associated microorganisms (Sylvia et al., 1998). The rhizosphere harbors a multitude of microorganisms that are affected by both abiotic and biotic stresses. Among these are the dominant rhizobacteria that prefer living in close vicinity to the root or on its surface and play a crucial role in soil health and plant growth (Roesch et al., 2008). It has been noted by many workers that Pseudomonas, Bacillus, Arthrobacter, Azospirillum, Klebsiella, and Enterobacter, isolated from the rhizosphere of various crops, showed synergistic effects on plant growth (Glick et al., 1995). Weller (Weller, 1988) reported that PGPR belong to several genera, e.g. Agrobacterium, Alcaligenes, Arthrobacter, Actinoplanes, Azotobacter, Bacillus, Pseudomonas sp., Rhizobium,Bradyrhiz obium, Erwinia, Enterobacter, Amorpho sporangium, Cellulomonas, Flavobacterium, Streptomycesand Xanthomonas. Plant biomass, carbohydrates, protein and chlorophyll content were reduced by saline stress, however application of PGPRs treatments improved them either in comparison to control samples or to untreated samples under saline stress. Lipids and antioxidant enzymes (catalase and peroxidase) increased as a response for saline stress as an indication of oxidative stress. Plant growth-promoting rhizobacteria treatment restored them to semi-normal levels. Sodium/ potassium balance was observed to be disturbed by saline stress through higher levels of $Na^+$and lowerlevels of K^+, but treating samples balance was clearly restored close to normal conditions especially in the root system (El-Ghany et al., 2015).

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