American-Eurasian Journal of Sustainable Agriculture, 5(3): 344-349, 2011
ISSN 1995-0748

ORIGINAL ARTICLES

Effect of Plant Growth Promoting Bacteria on Crop Growth

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ABSTRACT

PGPRs can affect plant growth, directly or indirectly. Direct promotion of plant growth may be exerted through several mechanisms, such as biological nitrogen fixation synthesis of siderophores, compounds that chelate iron from soil, making it available to the plant solubilization of minerals such as phosphorous, or synthesis of plant hormones, such as auxins, gibberellins or plant hormone regulators, such as ACC deaminase, an enzyme that decreases endogenous concentrations of ethylene. The indirect promotion of plant growth occurs when bacteria lessen or prevent the deleterious effects of phytopathogenic organisms. All these mechanisms suppose a direct contact between bacteria and the root surface or inner root tissues, a place where there is maximum bacterial activity due to the release of organic components from the roots.

Key word: Plant growth bacteria, ACC deaminase, plant hormone, growth.

Introduction

Different plant growth-promoting rhizosphere bacteria, including associative bacteria such as Azospirillum, Bacillus, Pseudomonas, Enterobacter group have been used for their beneficial effects on plant growth. (Kloepper and Beauchamp, 1992; A. bbaspoor *et al.*, 2009).

Many studies were done about the effects of PGPR bacteria over the growth and operation of agricultural plants. Studies show that PGPR bacteria can increase the plant growth under the different conditions (Tien *et al.*, 1979; Glick *et al.*, 1995) or in the pot environment condition where they can compete with normal population of soil microorganism; they improve plants yield by using various mechanisms (Polonenko *et al.*, 1987: Fuhrmann and Wollum, 1985).

Many studies in 1960s in China over the Plant growth promoting bacteria of Yield Increasing Bacteria (YIB) were being done. In this decade, YIB bacteria, is inoculated in 18 provinces in 3/3 million hectares over various plants in the field conditions, and the yield enhancement is reported in :wheat(8/5-16%), rice(8/1-16%), corn (7-11%), bean (7-16%), sugar beet (15-20%), Sorghum (5-10%), sweet potato(15-19%), Brassica Rapa (B. campestris)(11-18%), watermelon (16-18%), peanut(10-15%) and vegetable (13-35%) (Zahir *et al.*, 2004).

According to a study in Canada more than 4000 bacterial isolates which are separated from the plant Rhizosphere, are prepared. 222 isolates, increase the canola plant growth (Kloepper *et al.,* 1987). after choosing the active straits in the greenhouse experiment, the experiment was going on for more two years in the field and canola inoculation with the above strains in the field condition increase the germination and yield range up to 5-29% (Kloepper *et al.,* 1992).

Many researchers reported the effects of plant growth promoting bacteria inoculation on the wheat growth and yield was significant. (Parsaeimehr *et al.,* 2009) During a 7 years experiment, inoculation onto the above plant with B.cereus (83-10) and B.cereus (83-6) has been caused to increase the rapeseed yield up to 11/5 percent (Asghar *et al.,* 2002).

In the repetition of the above experiment, inoculation of Brassica cereus 83-10 strains with rapeseed plant does not increase the yield up to 17/2% as compared with the non-inoculation (Boelens *et al.,* 1993). In this experiment, the pods number and the 1000 kernel weight do not increase in comparison with the chek Xia *et al.*, reported that the repaired plant's growth promoting bacteria, usually increase germination and plant growth. Rapeseed inoculation with PGPR, is increased the oil amount (15/2%), root system activity and the nutritious elements gathering (Xia *et al.,* 1990). In a experiment it is reported that 35 PGPR increase the rapeseed yield 6-13%. Efficient PGPR are: P.putida, P.fluorescens, S.liquefaciens, Arthrobacter (Kloepper *et al.,* 1987). Root growth development is one of the most important signs of PGPR bacteria over the plants which attract many researchers attention. Root growth development, Lateral root proliferation and aberrant are effective in

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increasing the seedling's water and nutrient absorption and its proper settlement in the growth primary stages (Glick, 1995).

Chen *et al.,* 2001 separated some of the PGPR strain from the rapeseed root and Rhizosphere and added them to the sterilized pipette, then they inoculate the rapeseed with 5 strains of the above bacteria for 11 years, they saw the 11/5% development. The usage of the above strain improves the germination speed and plant growth.

Direct Promotion:

A-Biological Nitrogen Fixation:

Nowadays, in several cases, the plant interior has been found to host populations of endophytic bacteria, both N2-fixing and others, without showing any symptoms of disease.

These bacteria, and also fungi, are called endophytes, and it has been suggested that in Some cases they have a beneficial effect on plant growth (Kloepper and Beauchamp, 1992). In recent years various novel endophytic nitrogen-fixing bacteria have been discovered, such as *Acetobacter diazotrophicus* (Cavalcante and Döbereiner, 1988), *Herbaspirillum seropedicae* (Baldani *et al.,* 1986a), and *"Pseudomonas" Rubrisubalbicans*, now established as a second species of *Herbaspirillum* (Baldani *et al.,* 1996), *Azoarcus* spp. (Reinhold-Hurek *et al.,* 1993) and *Alcaligenes faecalis* (Zhou and You, 1988; You and Zhou, 1989). Also, some strains of *Azospirillum brasilense* have been found to colonize the plant interior (Schloter *et al.,* 1994). Among the various N2-fixing endophytic bacteria, two types have been suggested to classify these bacteria: the obligate endophytes *A. diazotrophicus*, which cannot survive in the soil, and the facultative ones that include the *Azospirillum* group (Baldani *et al.,* 1997). Another new group of endophytic bacteria has been described recently that now includes threespecies. The genera *Burkholderia* posses three diazotrophic species: *B. vietnamiensis* (Gillis *et al.,* 1995), *B. brasilensis* (Baldani, 1996; Hartmann *et al.,* 1995) and the new group isolated only from sugarcane that tentatively has been called *B. tropicalis* (in preparation). To this list we can expect a further inclusion of a new group of *Herbaspirillum* isolated from *Miscanthus* spp., *Spartina pectinata* and *Pennisetum purpureum,* described by Kirchhof *et al.,* (1997) and also a new *Acetobacter* species has been proposed after the isolation of several strains from coffee plants (Jimenez-Salgado *et al.,* 1997).

Zhang *et al.,* 1996 recognized the species of PGPR bacteria, which increased the growth of Legumes plant, root development and nitrogen fixation especially in the temperature lower than the optimized condition of the Rzts-Root Zone temperature.

B-Synthesis of Siderophores:

Siderophores are chelating molecules with iron binding groups that are produced by most microorganisms to scavenge and acquire iron when it is scarce.iron is present in organisms as a constituent of many metabolically significant compounds,such as cytochromr,which functions in the redox reactions that occur in mitochondria and chloroplasts,and is required for normal cellular functioning.iron is most commonly present in soils in the fe^{3+}state contained in clays,oxides,and hydroxides,a form in which it is extremely insoluble. (Vessey, 2003) the concentration of iron in the soil solution under aerobic con ditions is pH-dependent with a 1000 fold decrease for every unit increase in PH. The solubility of common Fe minerals to increase availability of this vital nutrient,organisms would often be iron deficient.pseudomonas are among the most widely studied of Glick, 2003 reported that E.coli bacteria and P.putida GR 12-2 strain have this ability to develop the root length of canola seedlings under the gnotobiotic conditions. Of course they related this ability to the ACC-D Aminaz enzyme.

In a report, Glick *et al.,* (1995) measured the 11 pseudomonas strains ability in increasing the canola root length under the gnotobiotic conditions. Canola root length and stem increased in wet and dry case with P.putida GR 12-2 inocul.

C-Solubilization of Minerals:

Several studies clearly showed the effect of PGPR on growth of different crops at different climates, soils and temperatures (Ruppel, 1987; D. Obereiner, 1992; Boelens *et al.,* 1993; H. Oflich and K. Uhn, 1996; Javed and Arshad, 1997). Rhizosphere bacteria *Pseudomonas spp., Azospirillum spp., Pantoea spp., Agrobacterium spp.*, increased plant growth and nutrient uptake of maize, wheat and legumes in moderate climates (Ruppel, 1987; H. Oflich and K. Uhn, 1996; H. Oflich *et al.,* 1994). Inoculation of maize and wheat with Azotobacter and Azospirillum increased plant growth, nutrient uptake and yield in warm climates (Okon, 1991; Boddey and D.obereiner, 1995).

In a research Carletti *et al.,* (1994), separated 111 bacteria from the cultivated plants Rhizosphere in the field and chose a collection of 9 PGPR as bacteria which solve phosphate.

Isolates of bacteria which solve phosphate were: Bacillus, B.megaterium, B.polymyxa, B.sphaerricus, B.thuringiensis and Xanthomonas maltophilia. These bacteria are tested from the point of view of the growth and yield of rapeseed plant. Some of these Rhizosphere bacteria increase the height, shoot and pod yield, significantly, because of the inoculation with B.thuringiensis. Pod weight and seed function are also increased. X.maltophila strain is also increase the plant height but none of the isolates could not increase the phosphate absorption.

D-Synthesis of Plant Hormones:

There are several possible mechanisms to explain positive bacteria/plant interactions, such as their interaction with pathogens or through stimulating systemic resistance of the plant to pathogens (McInroy and Kloepper, 1994).

In a research, Brown *et al.,* in (1968) connect the benefits of Azotobacter Chroococcum over the tomato plant growth to the plant hormones like IAA and Gibberellins. Many years later some researchers reported the same results from their researches.

Among the plant growth promoting bacteria, Pseudomonas fluorescens is the most important one since it has the ability to produce a vast domain of plant growth controller, iron collecting and absorbing complex, organic acids production like Saksynyk acid and Lactic acid and finally controlling the plant pathogenic factors. Some of Pseudomonas strains ability on resources of increased solubility of insoluble phosphate and non-absorbent organic phosphates, for plants this helps to increase the nutrition absorption especially phosphorus in terms of nutritional deficiency. Pseudomonas strains have more efficiency because of the root colonization among the growth promoting bacteria. In a research, after cotton plant inoculation with P.fluorescens bacteria, the 8-40% increase in the growth has been reported.

Zahir *et al.,* (1998) reported the 19/8% increase of corn seed yield after the inoculation onto the Pseudomonas and Azotobacter bacteria.

Also in a research, Javed *et al.,* reported the increase of 18/9% from the corn seed yield after inoculation with Pseudomonas.

Carletti *et al.,* (1994) reported the increase of dry shoot system weight in pepper after the inoculation with Pseudomonas.

In the same form, Carletti *et al.,* (1994), also reported the 81% increase of dry shoot system weight in tomato after inoculation with Pseudomonas.15/3% increase in the seed yield in the Revolutionary wheat figure and 18/5% in the LU265 figure is reported after inoculation with Pseudomonas. In the separated experiment Khalid *et al.,* (2004) reported more than 20%development in wheat seed yield because of Pseudomonas inoculation.

Many reports show the positive influence of various P. fluorescent strains over the canola plant.many reported showed that the rapeseed root's dry weight, is increased after inoculation with P.putid (Am_2) up to the 25/5%.In the other side, researchers reported the 57% increase in rapeseed yield after inoculation with P.putida and P.fluorecens.

Kloepper *et al.,* (1992) in the other experiment showed that the root colonization bacteria inoculation like Pseudomonas with rapeseed after 12 days cultivation, is the 123% increase factor in germination and 79% increase in the bud dry weight. A significant increase is observed in the germination speed.

Francois (1994) in an experiment evaluated the P.putida GR 12-2 strain growth stimulation under the gnotobiotic conditions and reported that rapeseed inoculation with the above bacteria significantly increased the root length and the stem weight in comparison with the check.

Production of plant growth regulators such as auxin, cytokinin and gibberellin by inoculation with PGPR has also been suggested as a possible mechanism of action affecting plant growth. Numerous studies have shown improvement in plant growth and development in response to seed or root inoculation with various microbial inoculants capable of producing plant growth regulators (Zahir *et al.,* 2004).

Hall *et al.,* (1994) designed an experiment to study the PGPR effects on the length of the various plant roots. Canola, lettuce, tomato, wheat, ,grain, oats seed with wild strain of P.putida and Mutant which doesn't have the ACC-D Aminas enzyme were inoculated. They reported the increase in root length of seeds which inoculated by wild strain. Inoculation of the rapeseed (canola) strain, Brassica Compestris with P.putida GR 12-2 bacteria increased the root length, dry weight and aerial organ in sterile condition, control without bacteria.The result of this experiment proved that P. fluorescent strain increased the rapeseed (canola) growth even in condition without pathogenic factors.

In the sterile condition, Glick, 2003 observed the enhance in the plant ethylene and stop the root growth during the canola inoculation seed with P.putida GR 12-2 Mutant strain which has the ability to produce high amount of IA. In this research Inhibitory effects of too much Auxin hormone over the ACC-D Aminas activity as an effective factor in inhibiting the root growth.

There are many evidences base upon the Rhizosphere bacteria ability in producing the secretion controller materials like Auxin and their influence over the morphology, nutrition and plant growth. In most of the observed studies, in which the growth controller especially IAA, influence most of the root system like primary root growth, side root and Piliferous layer formation (Glick, 1995). In a research Saravanakumar *et al.,* (2007), reported that Pseudomonas were abundant among the other microorganism of Auxin producers. Salisbury 1994 proved the direct influence of produced Auxin and Cytokinines by PGPR over the canola and millet plant growth.

In the research, Asghar *et al.,* (2002) show the high and significant correlation between the Auxin hormone and seed yield(r=0/77), pod number(r=0/78), Tiller (r=0/77) in the canola plant in vitro.

Li *et al.,* 2000 in a research investigated the IAA various amount over the growth and development of root system of canola by using seven P.putida GR 12-2 Mutant strains. Of course Mutant strains from the view point of Siderophore production, ACC-D Aminas activity and growth speed are the same as the wild strain.

Among these seven Mutant strains, just one strain that had the ability to produce IAA 4 times more than the wild strain, hindered the canola root growth, but the other six strains did not have any differences with stimulation and root system development. Mutant strains with the IAA high amount production ability, increased the ACC amount up to the point that bacterial ACC-D Aminas could not hydrolyze ACC and decrease the Ethylene level, so the synthesized IAA, hindered the growth and the development of root system of the host plant (Noal *et al.,* 1996).

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