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YIELD RESPONSE OF FIVE MAIZE HYBRIDS TO INOCULATION WITH RHIZOBACTERIA

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Abstract
The biofertilizers are found positive contribution to soil fertility, resulting in an increase in crop yield without causing any environmental, water or soil pollution hazards. Nitrogen fixing and phosphorus solubilizing bacteria play an important role in nitrogen mobilization and phosphorus solubilization for the benefit of plant growth. A field experiment to study yield response of maize to inoculation with rhizobacteria, was conducted during 2013 at experimental field of Institute of Field and Vegetable Crops in Novi Sad. The maize hybrids (NS 3014, NS 4015, NS 5043, NS 6010 and NS 6030) were used in the study. The field experiment was laid out in randomized complete block design with four treatments (control and 3 inoculations) and four replications. Inoculation was done with *Pseudomonas* PS2, *Bacillus* Q7 and their mixture with *Azotobacter chroococcum* (Q7 + PS2 + AC). Application method was incorporation immidiately before planting with liquid culture of strains (1 l + 300 l H2O ha-1). The results showed significant increase in maize yield with inoculation treatments. The best effect on maize yield was achieved with mixture of strains (19.7%). Significantly higher yield was obtained for hybrids NS6010 and NS 6030. The highest increase in yield of maize was achieved with hybrid NS 6030 (32.2%). Statistically significant differences in comparison to the control were obtained on treatments with Q7 and PS2 + Q7 + AC.

Key words: *Azotobacter*, *Bacillus*, *Pseudomonas*, yield.

Introduction

Maize is one of the most important cereal crops in the world. In 2010, this crop was grown in an area of nearly 162 million ha and occupied second place in overall production (http://faostat.fao.org). In Serbia, maize is grown on about 1 200 000 ha and the total grain production is between 4 and 7 million tons per year. The grain yield of maize dependson the genetic potential of a hybrid, soil characteristics, agrotechnical measures and climatic factors (Jocković *et al*., 2010; Đalović, 2014).

Microbial inoculants are highly ranked among promising alternatives for reducing global fertilizer inputs into agroecosystems. Their use has been steadily growing through the last decade. some microbial inoculants are able to improve nutrient availability and plant uptake capability, thereby reducing nutrient inputs and increasing the use efficiency of applied chemical fertilizers. Single or mixed inoculant formulations containing plant growth promoting bacteria (PGPB) stimulate plant growth by diverse mechanisms, which include biological nitrogen fixation, synthesis of hormones and a variety of other molecules, phosphate solubilization and biological control of pathogens.

Maize (*Zea mays* L.) is widely used for human and animal food and is a staple in many developing world communities where small increases in productivity without increasing production costs represent significant gains in food security. Thus, new technologies promoting the effectiveness of bioinoculants based on endophythyc diazotrophic microbes (such as plant growth promoting bacteria (PGPB) are of compelling social environmental reelvance).

Significant increases in growth and yield of agronomical important crops in response to inoculation with PGPR have been reported by Asghar *et al*. (2002), Bashan *et al*. (2004) and Biswas *et al*. (2000). *Azospirillum*, *Pseudomonas* and *Azotobacter* strains could affect seed germination and seedling growth (Shaukat *et al*. 2006). Kloepper *et al*. (1992) has been shown that wheat yield increased up to 30% with *Azotobacter* inoculation and up to 43% with *Bacillus* inoculation. Strains of *Pseudomonas putida* and *Pseudomonas fluorescens* could increase root and shoot elongation in canola (Glick *et al*. 1997) as well as wheat and potato (De Freitas and Germida, 1992; Frommel *et al*., 1993). Thus it has been shown that *Azospirillum* and Pseudomonas had the potential for agricultural exploatation and could use as natural fertilizers (Bashan *et al*., 1989; Cakmakci *et al*., 2006).

The main objestive of this research was to determine the effect og PGPR strains on yield of five maize hybrids.

Material and methods

The trial was conducted at Rimski Sancevi experimental field of Institute of Field and Vegetable Crops in Novi Sad. The experimental objects were five hybrids of maize (NS 3014, NS 4015, NS 5043, NS 6010 and NS 6030) developed at Institute and three treatments with microorganisms. Non inoculated treatment was control. Inoculation was done with *Pseudomonas* PS2, *Bacillus* Q7 and their mixture with *Azotobacter chroococcum* (Q7 + PS2 + AC). Application method was incorporation immediately before planting with liquid culture of strains (1 l + 300 l H_2O ha^{-1}). The experimental design was a randomized, complete block with four replications. Data were analyzed by the analysis of variance; LSD test were used to separate treatment means when there was a significant difference at the $P<0.05$ level. All analyses were conducted using the statistical software package STATISTICA 10.0 (StatSoft Inc. USA) (Mead *et al*., 1996).

Results and discussion

The results showed significant increase in maize yield with inoculation treatments (Table 1). The best effect of inoculation was achived with mixture of strains (PS2 + Q7 + AC). The highest yield was obtained with hybrids NS 6010 and NS 6030 on all examined treatments in comparison with control. The highest increase in yield of maize was achieved with hybrid NS 6030 (32.2%). Statistically significant differences in comparison to the control were obtained on treatments with Q7 and PS2 + Q7 + AC.

Table 1. Effect of inoculation with PGPR on maize yield

Treatment	**Hybrid**	**Yield (t ha^{-1})**
Control	NS 3014	6.23^{f}
	NS 4015	6.77^{ef}
	NS 5043	6.82^{ef}
	NS 6010	7.38^{cde}
	NS 6030	6.89^{def}
Treatment 1: *Pseudomonas* PS_2	NS 3014	6.32^{f}
	NS 4015	6.83^{ef}
	NS 5043	6.95^{def}
	NS 6010	7.56^{bcde}
	NS 6030	7.64^{bcde}
Treatment 2: *Bacillus* Q_7	NS 3014	6.98^{def}
	NS 4015	7.48^{cde}
	NS 5043	7.85^{bcd}
	NS 6010	8.19^{abc}
	NS 6030	8.29^{abc}
Treatment 3: $PS_2 + Q_7$ + AC *Pseudomonas + Bacillus + Azotobacter*	NS 3014	7.42^{cde}
	NS 4015	7.65^{bcde}
	NS 5043	8.13^{abc}
	NS 6010	8.49^{ab}
	NS 6030	9.11^{a}

Means with the same letter are not significantly different at the P = 0.05 level of significance

Co–inoculation (*Azotobacter*, *Bacillus*, *Pseudomonas*) had an advantage compared to single inoculation, which is similar in our results, while in case of single strains, better effects were achieved in *Pseudomonas* and *Azotobacter* treatments (Jarak *et al*., 2012). Hajnal-Jafari (2010) investigated the effect of co–inoculation of NS 640 maize hybrid on the grain yield and microbiological activity in the rhizosphere. The results obtained over the period of three years showed that the average grain yield amounted to when microbial inoculants were used, and that microbiological variants had a significant effect on the total number of microorganisms, number of aminoheterotrophs, free nitrogen–fixing bacteria and phosphorus–mobilizing bacteria. Mixture of biofertilizers, biostimulants and biopesticides (*A. chroococcum*, *A. vinelandi*, *A. lipoferum*, *B. megaterium* and *B. subtilis)* caused an increase in the yield of all three investigated maize hybrids (Govedarica *et al*., 2002). Results of Hamidi *et al*. (2009) revealed that co–inoculation with PGPR (*A. chroococcum*, *A. lipoferum*, *A. brasilense* and *P. fluorescens)* had the highest promoting effect on phenology and grain yield of maize hybrids. The best results on dry matter accumulation and yield of maize hybrids were obtained by the plots which seeds were inoculated with *Azotobacter* bacteria compared with *Azosprillium* and *Azotobacter* + *Azosprillium* priming (Sharifi *et al*., 2011). Findings of Umesha *et al*. (2014) have clearly showed that combined application of *Azotobacter chroococcum*, *Bacillus megaterium* and *Pseudomonas fluorescens* along with recommended dose of NPK and enriched compost has resulted in obtaining highest plant growth, crop yield and dry matter production of maize.

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