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Plant Growth Promoting Rhizobacteria (PGPR) Reduces Application Rates of Fertilizers in Chili (*Capsicum frutescens* L.) Cultivation

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Abstract

The search for microorganisms that recover soil fertility and improve plant nourishment has persistent to interest responsiveness due to the increasing price of chemical fertilizers. The purpose of this experiment with chili were to determine (1) if reduced rates of fertilizer with PGPR will increase plant growth, development and yield which were comparable with recommended doses of the fertilizer and (2) the lowest level to which fertilizer could be reduced when PGPR were used. The microbial inoculants used in the experiment were a combination of plant growth-promoting rhizobacteria (PGPR), a formulated PGPR product. Results indicated that 75% ($N_{100\%}$ $P_{75\%}$ $K_{100\%}$+PGPR) of the suggested inorganic fertilizer rate with PGPR produced plant growth, enlargement and yield that were statistically comparable with 100% fertility without PGPR. When PGPR were used in combination with reduce level of fertilizer 75% of the recommended rate, the helpful effects were typically not reliable; however, PGPR were used with 80% fertilizer (NK recommended dose) regularly produced the same yield which were comparable with full fertilizer rate without inoculant.

Keywords: Capsicum; PGPR; Fertilizers; Growth; Yield

Introduction

Vegetables have a great importance in the world, among them chili is one of the most important vegetable crop belongs to Solanaceae family [1,2].

Most of the vegetables produced in Pakistan have a great value and high in production. Worldwide, chili production is about 24% and its 2nd leading area of production is Southern Europe. Chili is used as a medicinal plant, helpful in cancer treatment and used as an antioxidant [3].

By using some PGPR, phosphorous solubilization, nitrogen fixation and production of siderophores are the mechanism which stimulates plant growth and nutrients which are available to plants from the soil [4]. Competence of synthetic fertilizers is very low because plants uptake a very small percentage of applied nutrients [5]. For example, phosphorous is less available to plants because after adding to soil phosphorous (P) become precipitated [5]. Roots takes essential plant nutrients from the soil [6], Better root growth is thought to be necessary for improved plant growth. Root growth is stimulated by using many PGPR systems [7,8], by the production of phytohormones produced by plants or bacteria [8,9]. In field, if root growth stimulated by PGPR could be attained with good results, PGPR may be potential tools for availability of nutrient uptake.

Two main questions arise from few of the prior studies: Is it feasible to change the existing trend of applying full supply of chemical fertilizer by enriching reduced fertilizer with PGPR? Can the possible interest of PGPR in plant nutrient uptake be consumed by combining them with decrease levels of phosphorous? The general assumption is that PGPR or PGPR in combination with phosphorous will increase the proficiency of phosphorus and lead to use of phosphorous in reduced quantity.

The objectives in this current study were to resolve (1) if decreased rates of fertilizer pair with PGPR will increase plant growth, expansion and yield which were comparable with recommended doses of fertilizer and (2) the lowest level to which fertilizer could be reduced when PGPR were used. For the achievement of these objectives, experiments were planned using different levels of fertilizer with or without formulated PGPR product. The PGPR were formally disclosed to stimulate significant effects on plant growth, yield and root development [10-13].

Materials and Method

Experimental area

All analyses reported in this paper were conducted in the field at the vegetable research farm, Department of Horticulture, Faculty of Agricultural Sciences and Technology, Bahauddin Zakariya University, Multan during the years 2016 and 2017. The experimental site is situated at 30°25'75°N and 71°51'55E. During the year 2015-16, minimum monthly temperature (average) and maximum rainfalls happened during the entire cropping duration at different intervals. During the year 2016-17, average monthly temperature was greater and rainfall not ensued as compared to during the year 2015-16.

Source of plant growth promoting rhizobacteria

Plant growth-promoting rhizobacteria used in previous studies [12-14], i.e. the PGPR (Bio Power) was obtained from National Institute for Biotechnology and Genetic Engineering (NIBGE) Faisalabad, Pakistan.

Experiential design

The layout of the experimental design was a factorial arrangement randomized complete block design (RCBD) with 3 replications and 12 treatments included (1) $N_{100\%}$ $P_{100\%}$ $K_{100\%}$ (2) $N_{80\%}$ $P_{80\%}$ $K_{100\%}$ (3) $N_{75\%}$ $P_{75\%}$ $K_{100\%}$ (4) $N_{70\%}$ $P_{70\%}$ $K_{100\%}$ (5) $N_{60\%}$ $P_{60\%}$ $K_{100\%}$ (6) $N_{50\%}$ $P_{50\%}$ $K_{100\%}$ (7) $N_{100\%}$ $P_{100\%}$ $K_{100\%}$+PGPR (8) $N_{80\%}$ $P_{80\%}$ $K_{100\%}$+PGPR (9) $N_{75\%}$ $P_{75\%}$ $K_{100\%}$+PGPR (10) $N_{70\%}$ $P_{70\%}$ $K_{100\%}$+PGPR (11) $N_{60\%}$ $P_{60\%}$ $K_{100\%}$+PGPR (12) $N_{50\%}$ $P_{50\%}$

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$K_{100\%}$+PGPR. Potash (K) applied as 100% recommended dose. Each experimental unit contained 6 rows of 2.43 × 4.87 meter (L × W) with 28 cm row spacing and 30 cm bed space after two rows in each unit. The length of the seedling was from 22.86 cm to 30.48 cm.

Seedling inoculation and sowing

Seedlings of chili (*Capsicum frutescens* L.) cultivar Ghotic (seedlings were purchased from jafar group, Multan, PAK) roots were dipped into the PGPR solution for about half an hour. Then the inoculated seedlings were dry below shelter (to avoid direct sunshine) and seedlings were transplanted in prepared field with the planting distance of 30 cm on both side of ridge and then were irrigated immediately after transplanting.

Estimation of plant growth and nutrient content of plant tissue and soil

Sampling was done after 60 days of transplanting. The time of nutrient analysis is very important because with the age of tissue nutrient concentration decreased. In each investigation plant height of chili, fresh and dry weights of tissue were taken. Root system were analyzed included, length of root, surface area of root, estimated area, size, mean diameter, total number of tips and total number of roots with diameters of 0-05 mm and 0.5-1 mm. Nitrogen (N) and phosphorous (P) content were analyzed by using dry plant sampling. Estimation of nitrogen and phosphorous nutrient uptake of plant was done through plant uptake per gram multiplied yield per unit. The technique used for nutrient analysis.

Statistical analysis

Statistically data were analyzed using factorial design. The mean values of parameters were compared using the least significant difference (LSD) test. Statistical data was measured at α=0.05 using Statistical Analysis System 8.1.

Results

The results achieved in trial to improve growth of chili plants to various fertilizer amounts revealed that the growth of chili was considerably superior with 100% fertilizer rate as compared to other lower fertilizer rates through all parameters (fresh and dry shoot weights, fresh and dry root weights, plant height) (Table 1). Figure 1 shows growth index of chili plant against different fertilizer rates which is plot of growth at 60 days after planting.

Results revealed that plant heights significantly increased from treatment with PGPR plus 75% or 80% of fertilizer which were comparable to plant height with 100% fertilizer without PGPR (Table 2). After that growth index calculated multiplying height by width, the association between inoculated and uninoculated plant showed that the

Treatments	Fresh weight		Dry weight	
Percent fertilizer	Fresh shoot	Fresh root	Dry shoot	Dry root
100	136.63 a	7.18 a	55.64 a	5.46 a
80	115.42 b	6.21 b	39.91 b	4.61 b
75	107.05 c	5.68 c	33.61 c	3.83 c
70	95.61 d	5.16 d	28.13 d	3.05 d
60	78.73 e	4.88 d	19.66 e	2.32 e
50	65.23 f	4.23 e	15.03 f	2.08 f
LSD $_{(0.05)}$	3.65	0.47	1.75	0.21

Table 1: Some growth parameter in response of chili plant to different fertilizer treatments.

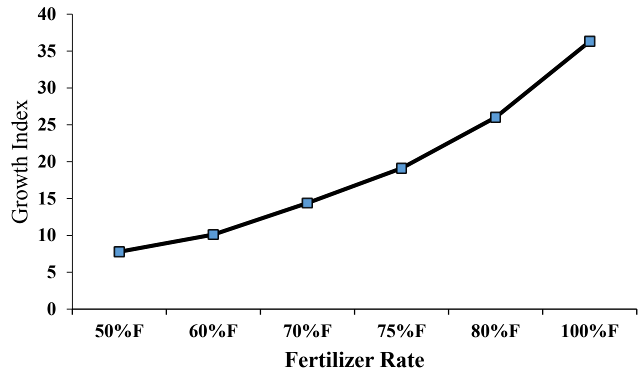

Figure 1: Growth response curve of chili to different fertilizer rates at 60 DAP (F: Fertilizer; DAP: Day After Planting).

Percent fertilizer	Fertilizer	Fertilizer + PGPR
100	39.14 a	40.37 a
80	35.23 b	41.34 a
75	33.43 c	40.35 a
70	31.00 d	38.33 b
60	28.61 e	36.64 c
50	25.21 f	35.62 d
LSD $_{(0.05)}$	1.42	1.01

Table 2: Plant height of chili with different treatment fertilizer with inoculation.

inoculated plant significantly increase the growth of the plants, even at lower fertilizer rates. Also, the growth index for plant resulting from treatment 75% or 80% fertilizer plus PGPR which were comparable with 100 fertilizer without inoculants (Figure 2).

Yield of chili fruits showed that 75% fertilizer plus PGPR or 80% fertilizer plus PGPR were statistically equivalent to 100% fertility without PGPR (Figure 3). For the fertilizer plus PGPR treatment, only 80% fertilizer plus PGPR produced the same yield as 100% fertility without PGPR. The 70% fertility plus PGPR treatment produced lower yield. The results revealed that 80% fertility plus PGPR produced comparable results with 100% fertility but similar treatment with 75% fertility was not stable.

Growth and nutrient content tests

The plants that intake 75% or 80% fertility plus PGPR or 100% fertility without PGPR showed same effects (Figure 4). The quantity of nitrogen per gram of chili root and shoot tissues were statistically alike for 100% fertility without PGPR and 75% fertilizer plus inoculant (Figures 5 and 6 for root and shoot, respectively). Also, plants that take 70% fertility with PGPR produced similar quantity of nitrogen in shoot with respect to 100% fertility without PGPR (Figure 5). The plant tissues that received 75%, 80% or 100% fertility plus PGPR produced results which were statistically equal to 100% fertilizer without inoculants (Figure 7). Co-inoculation of PGPR with 75% fertility gave the best result, resulting in phosphorus (P) uptake comparable to that with 100% fertilizer without PGPR (Figure 8).

Discussion

The results of the present research here support the hypothesis that fertilizer or combination of fertilizer with PGPR can increase the fertilizers use proficiency. When the recommended dose of fertilizer was reduced and PGPR were used, plant height, shoot and root, fresh and dry weight, uptake of nutrient and yield were like those with

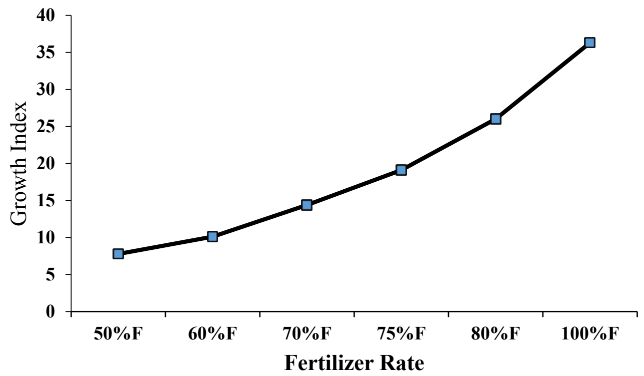

Figure 2: Growth index of chili at different fertilizer rate with or without PGPR.

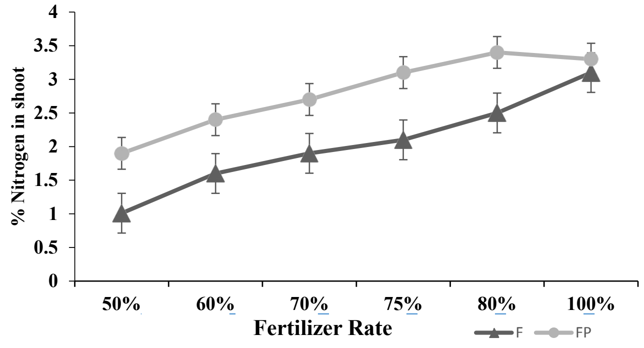

Figure 5: Nitrogen uptake per gram of chili shoot with or without PGPR (F: Fertilizer; FP: Plant Growth Promoting Rhizobacteria).

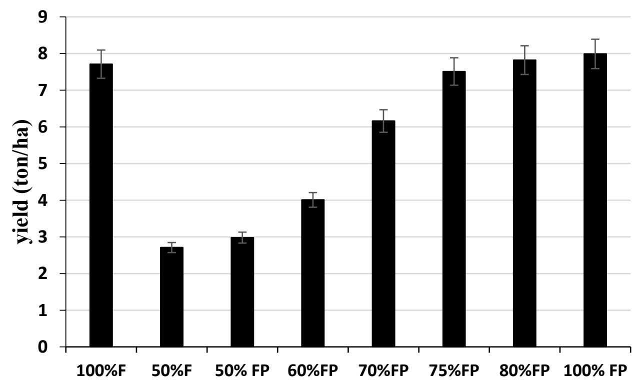

Figure 3: Yield of chili with or without inoculant (F: Fertilizer; FP: Plant Growth Promoting Rhizobacteria).

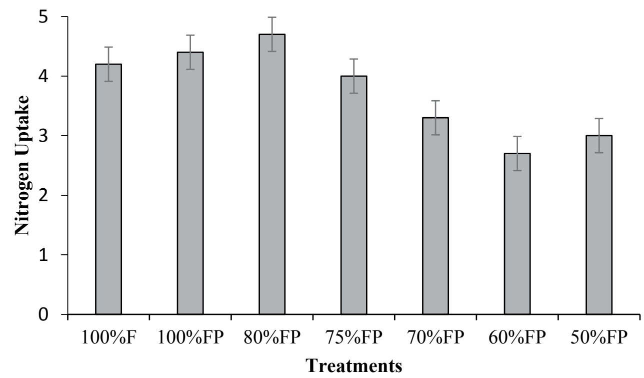

Figure 6: Nitrogen uptake per gram of root tissue with or without PGPR (F: Fertilizer; FP: Plant Growth Promoting Rhizobacteria).

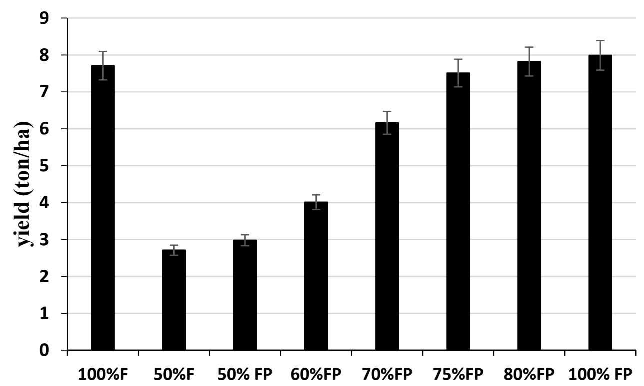

Figure 4: Dry biomass of plants with or without PGPR (F: Fertilizer; FP: Plant Growth Promoting Rhizobacteria).

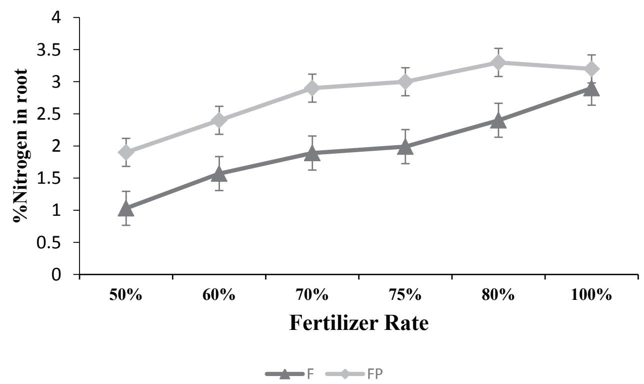

Figure 7: Nitrogen uptake on dry whole plant basis with PGPR and fertilizer (F: Fertilizer; PGPR: Plant Growth Promoting Rhizobacteria). Calculate by multiplying concentration of N per gram of tissue by N%.

the recommended fertilizer rate without PGPR (Table 2 and Figure 2). The plants that received 75% fertility plus PGPR produced stable results which were equivalent to 100% fertilizer without inoculant. The experimental results revealed that full rate of fertilizer 100% produced maximum plant growth that was superior then all other lower rates of fertilizer if PGPR were not supplementary added (Table 1 and Figure 1). These results are in line with Biswas et al. [7] who reported an interdependence of fertilizer nitrogen responses and inoculants for ideal gain in rice production.

When plant received 70% fertility or lower rate of fertility plus PGPR, chili growth and development was perceived lower or unpredictable growth compare to 100% fertility control. In some cases, inoculation of PGPR plus 70% rate of fertilizer produced results that were comparable to 100% fertility without inoculant (Figure 2 or Table. 2) or comparable yield (Figure 3). In the present research, fertilizers were reduced to 75% if supplemented with PGPR that is the smallest level at which results were stable. The supported results are dissimilar from the statement of Elkoca et al. [15] and Canbolat et al. [16] who described no statistically difference in biomass of root and shoot or seed yield of chickpea and also no statistically difference in root and shoot biomass of barley, respectively, according to these results, it was recommended that PGPR could be an substitute to fertilizer for chick

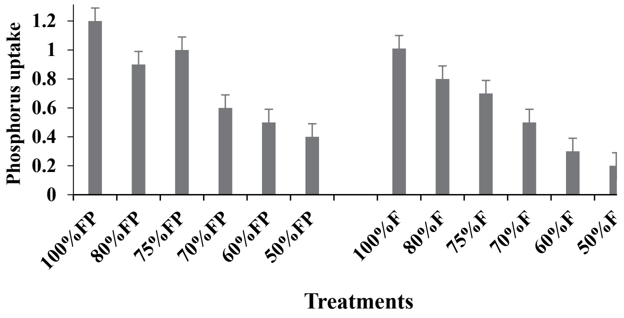

Figure 8: Phosphorus uptake on dry whole plant basis with PGPR and fertilizer (PGPR: Plant Growth Promoting Rhizobacteria; F: Fertilizer). Uptake was calculated by multiplying concentration of P per gram of tissue by dry weight of plant.

pea [15]. In dissimilarity, the present results determine that, for chili, Plant growth promoting rhizobacteria allow reduced application level of fertilizer but they will not substitute fertilizer.

The results are in line with Hernandez and Chailloux [17] who stated that, tomato grown under greenhouse with 75% fertility in combination with inoculant, dry weight of tomato statistically superior to those with 100% fertility without inoculant. PGPR continually improved dry biomass (Figure 4). Also, uptake of nitrogen on a whole plant basis and uptake of nitrogen per gram of tissue statistically superior then the non-inoculated control (Figures 5-7). However, in case of phosphorus (P), statistically give good results on whole plant but not per gram of plant tissue (Figure 8). Therefore, improve nitrogen use proficiency in retort to inoculation was bigger than that of phosphorus (P).

Saubidet et al. [18] described that N content in wheat plant decreased if rate of N supply increased in wheat plant inoculated with *A. brasilense,* the total N content was similar between uninoculated and inoculated wheat plant. Shaharoona et al. [9] testified in wheat N use proficiency improve in reply to inoculation with *Pseudomonas fluorescens*. From the previous works, the PGPR performance increase with co-inoculation with several PGPR strains [19,15,10,11]. For example, Belimov et al. [19] stated co-inoculation of *Arthrobacter mysorens* 7 and *Azospirillum lipoferum* 137 or *Agro bacterium* 10 and *Azospirillum lipoferum* 137 give results significantly maximum uptake of phosphorus P in shoot of barley. Adesemoye et al. [20] reported two strain mixture (PGPR and AMF) also could be effective in both growth and development and uptake of N and P.

PGPR increase root surface area and root architecture also stimulate the plant growth [7,8]. The result proposes that PGPR may allow reducing in the present high rates of fertilizer and resulting environmental problem without conceding plant yield.

Conclusion

Based on experiment conducted, it is determined that the effect of fertilizer+Plant growth promoting rhizobacteria on growth, yield of chili (*Capsicum frutescens* L.) ($N_{100\%}$ $P_{75\%}$ $K_{100\%}$+PGPR) showed better results compare to other treatments.

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