PGPR Inoculated-Seed Increases the Productivity of Forage Sorghum under Fertilized Conditions

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Abstract: Plant growth promoting rhizobacteria (PGPR) are used for seed inoculation. This study was carried out to determine the influence of seed inoculation with PGPR and different nitrogen (N) and phosphorus (P) levels on the productivity and quality of fodder sorghum. The study was conducted in randomized complete block design (RCBD) under factorial arrangement at Agronomic Research Area, University of Agriculture, Faisalabad during, 2014. The experiment composed of N and P levels such as 0%, 50%, 75% and 100% of recommended doses ha^{-1} and seed inoculation with $PGPR_1$ (*Azotobacter brasilense+Pseudomonas fluorescens*) and $PGPR_2$ (*Azotobacter chroococcum+Pseudomonas flurescens*) with un-inoculated seeds as control. The results revealed that application of N and P, and seed inoculation appreciably increased the productivity and quality of sorghum. Maximum green fodder yield (63.12 t ha^{-1}), dry matter yield (14.51 t ha^{-1}), crude protein (11.02%) and ash contents (8.97%) were recorded with recommended dose of NP. Regarding seed inoculation maximum green fodder yield (62.40 t ha^{-1}), dry matter yield (14.09 t ha^{-1}), crude protein (10.59%) and ash contents (9.07%) were recorded with $PGPR_1$. In conclusion, application of recommended dose of NP and seed inoculation with $PGPR_1$ significantly improved the forage productivity and quality of sorghum.

Keywords: PGRP, Fertilizers, Sorghum, Yield, Quality.

INTRODUCTION

Livestock is an essential part of the agriculture in Pakistan. It has a contribution of 58.6% to value added by the agriculture and 11.6% to the national GDP during 2015-16 [1]. The demands of green forage are increasing in Pakistan due to rapidly expanding livestock industry. Forage sorghum may be an acceptable and low cost as compared to maize grown for silage as the existing irrigation water availability continues to decline in semiarid regions of the world. N and P fertilizer rates may affect yield and nutritive value of forage sorghum and maize when grown in limited situations [2].

Sorghum has much potential to fulfill the demands of the livestock, grain foods, and beverages in future [3]. The synthetic fertilizers have many hazardous effects, as they affect the beneficial microorganism, further their leaching also results in water pollution [4]. In addition, (PGPR) can be used along the chemical fertilizers to improve the crop yield, and they substantially reduced the use of chemical fertilizers [4]. PGPR are important bacteria that are beneficial and they reside in the rhizosphere. They colonize the roots of plants which results in rapid plant growth. PGPR can affect the growth of plants through multiple mechanisms such as plant growth regulators production [5] nitrogen fixation and by increasing uptake of plant nutrients and water [6].

The enhancement in crop production yields per unit area is an urgent need of the day to accomplish the rising food demands of fast growing population. This situation accelerates the use of non-conventional approaches, such as an emerging trend in modern-day agriculture is the use of PGPR to enhance crop production and growth [7]. A range of PGPRs are being used in the form of inoculants to increase the productivity and nutrients availability in crops, however, *Rhizobium spp., Azotobacter spp*., *Azospirillum spp., Bacillus spp.,* and *Pseudomonas spp.* are the most commonly used [8]. Nitrogen and Phosphorous are macro nutrients required in great amounts for the plant functioning. These are the most limiting nutrients present in the soil. Phosphorus (P) is one of the common plant nutrients which is responsible for the reduction of production potential of agricultural soils [9]. In Pakistan phosphorous contents vary from 0.02 to 0.5% in surface layer of the soil but the plant-available P is very low due to the precipitation of the P at high soil pH. Nitrogen is a major component of livestock and poultry feed [10]. Nitrogen (N) is also vital nutrient for the plant growth and development. It is part of amino

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acids, therefore, it is important in plant anatomy [11]. Amino acids are utilized in the construction of protoplasm, the home for cell division and therefore affecting plant phenology [11]. Among the main reasons for low use of P in Pakistan are high prices, lack of promotional activities and unavailability during the peak demand seasons [12]. Thus, inadequate use of phosphorous is also a critical problem in our country. Therefore, this study was conducted to determine the influence of seed inoculation with rhizobium along with the nitrogen and phosphorus application on the forage yield and quality of sorghum.

MATERIALS AND METHODS

This study was carried out at the Agronomic Research Area, University of Agriculture, Faisalabad, during the year 2014. The climate of the region is semi-arid. The experimental area was located at 73 ^{o}E, 31 ^{o}N, and at an altitude of 184.4 m. The prevailing climatic conditions during crop growth period are given in Table **1**. For physio-chemical analysis of experimental soil, composite and representative soil samples to a depth of 0-20 cm were obtained with soil auger. Soil samples were analyzed for various physio-chemical properties using standard procedures described by Homer and Pratt, 1961 [13]. The soil was loamy having pH (7.8), Ec (1.84 ds m^{-1}), organic matter (1.03%), total available nitrogen (0.051%), phosphorus (13.3 ppm) and potassium (50 ppm) respectively.

Experiment was laid out in a randomized complete block design (RCBD) under factorial arrangement with three replications. The net plot size was 5.0 m × 1.8 m. The experiment comprised of four fertilizer levels (both for N and P), which were 0%, 50%, 75%, and 100% of recommended dose of N and P per hectare and the inoculation with the $PGPR_1$ (*Azotobacter brasilense* + *Pseudomonas fluorescens*) and $PGPR_2$(*Azotobacter chroococcum* + *Pseudomonas fluorescens*) along with control (uninoculated) treatment.

Two ploughings followed by planking were done to attain the required seedbed. Seed of sorghum cultivar Hegari, was collected from the Fodder Research Institute, Ayub Agricultural Research Institute, Faisalabad. Before sowing, seeds were inoculated with the PGPR inoculums using standard procedure. Sowing was done with the help of single row hand drill and row to row distance was 30 cm. A seed rate of 75 kg ha^{-1} was used for all the plots. Recommended dose of fertilizer for sorghum fodder is 75:60 kg NP ha^{-1}, which was applied to the crop according to the treatment in the form of urea (46% N) and diammonium phosphate (DAP) (46%P and 18% N). One half of the N and full dose of P was applied at the time of the sowing and the other half of N was applied with the first irrigation. Experiment was conducted during the 2nd week of July. Crop was harvested manually at 50% flowering stage. All other management practices were kept uniform and crop was irrigated thrice. Crop was harvested manually at maturity and all the growth and yield parameters were recorded by using standard methods. Further, the quality parameters were determined by following the standard procedures of A.O.A.C. (1990). The collected data was analyzed by Fishers analysis of variance technique and treatment means were compared by using least significance difference (LSD) at 5% probability [14].

RESULTS AND DISSCUSSION

The application of fertilizers (N and P) and seed inoculations significantly improved the forage yield and quality of sorghum (Table **2**). The results revealed that applied fertilizers and seed inoculations significantly increased the leaves per plant, plant height and stem diameter. In case of fertilizers application of 100% recommended dose of NP produced maximum leaves per plant (11.2), tallest plants (189.56 cm) and thick stems (1.25 cm). Similarly, seed inoculation with $PGPR_1$ gave highest leaves per plant (11), maximum plant height (186.58 cm) and stem diameter (1.13 cm), whereas the minimum leaves per plant, plant height and stem diameter was recorded without the use of fertilizers and seed inoculation (Table **2**). The increase in leaves per plant by fertilizers and inoculants can be

Table 1: Prevailing Climatic Conditions of the Experimental Site during Crop Growing Seasons

Months	Monthly Mean Max. Temp (°C)	Monthly Mean Min. Temp (°C)	Monthly Avg. Temp (°C)	R.H (%)	Rainfall (mm)
Jul-2014	37.0	28.0	32.5	53.9	57.5
Aug-2014	37.1	27.3	32.2	52.7	4.8
Sep-2014	33.9	24.5	29.2	61.2	140.2
Oct-2014	31.3	19.1	25.2	54.6	3.6

Table 2: Effect of Fertilizer (NP) and PGPR on Yield and Quality Attributes of Sorghum

Treatments	LP^{-1}	PH (cm)	SD (cm)	FW (g)	DW (g)	GFY (t ha^{-1})	DMY (t ha^{-1})	CPC (%)	CFC (%)	TAC (%)
0% NP	9.6 b	165.26 c	0.80 c	158.66 d	35.68 c	56.35 c	12.95 c	8.75 c	28.00 c	7.37 b
50% NP of RD	9.8 b	179.33 b	0.97 b	164.85 c	37.27 c	59.88 b	12.77 c	9.49 bc	30.21 b	7.56 b
75% NP of RD	10.3 ab	185.33 ab	1.15 a	172.29 b	40.51 b	60.26 b	13.85 b	9.79 b	30.13 b	8.98 a
100% NP of RD	11.2 a	189.56 a	1.25 a	180.29 a	44.03 a	63.12 a	14.51 a	11.02 a	32.06 a	8.97 a
LSD (P ≤0.05)	0.96	8.05	0.15	1.92	3.17	2.83	0.65	1.02	1.82	1.25
No inoculation	9.7 b	174.75 b	0.94 b	166.66 c	37.48 b	58.71 b	13.24 b	8.95 b	29.21 b	7.77 b
$PGPR_1$	11.0 a	186.58 a	1.13 a	171.35 a	41.01 a	62.40 a	14.09 a	10.59 a	31.34 a	9.07 a
$PGPR_2$	10.9 b	178.50 b	1.05 ab	169.05 b	39.63 ab	58.61 b	13.22 b	9.76 ab	29.76 b	7.93 b
LSD (P ≤0.05)	0.83	6.98	0.13	1.66	2.74	2.45	0.56	0.88	1.57	1.08

Means sharing the same letter for a single parameter do not differ significantly at P ≤ 0.05.
LP^{-1}: Leaves per plant, **PH**: Plant height; **SD**: Stem diameter; **LA**: Leaf area. **FW**: Fresh weight per plant; **DW**: Dry weight per plant, **GFY:** Green fodder yield, **DMY:** Dry matter yield, **CPC:** Crude protein contents, **CFC:** Crude fiber contents, **TAC:** Total ash content, **N:** Nitrogen, **P:** Phosphorus, **RD:** Recommended dose, **$PGPR_1$:** *Azotobacter brasilense+Pseudomonas fluorescens*, **$PGPR_2$:** *Azotobacter chroococcum+Pseudomonas flurescens*

due to better availability of nutrients which, resulted in development of more leaves. These results are in line with previous findings of Hassan *et al*. [15] and Shaterabadi *et al*. [16]. The increase in plant height and stem diameter by fertilizers application may be due to continuous supply of fertilizer, because fertilizer helps to assist plants in dispensation of carbohydrates to build up new tissues and increasing the inter-nodal distance. Similarly, the increase in plant height and stem diameter by PGPR treatments might be due to phytohormone production which promote plant growth, root biomass and also enhance nutrients use efficiency. These results are in line with the findings of Burd *et al*. [17] and Gholami *et al*. [18], they reported substantial increase in plant height stem diameter with the application of fertilizers and rhizobium.

The application of various levels of fertilizers and seed inoculants appreciably increased the fresh and dry weight per plant (Table **2**). The maximum value of fresh weight (180.29 g) and dry weight (44.03 g) per plant was recorded from the plants fed with 100% recommended dose of nitrogen and phosphorus fertilizers, whereas seed inoculation with $PGPR_1$ produced maximum fresh weight (171.35 g) and dry weight (41.01 g) per plant. The lowest value of fresh and dry weight per plant was recorded from plots without the application of nitrogen, phosphorus and seed inoculations. The increase in fresh weight could be due to better availability of nutrients by fertilizers and fixation of nutrients by rhizobium which increased the vegetative growth and ultimately the weight per plant. The increase in dry weight was due to the increase in fresh weight. These results are in quite line with the findings of Ayuke *et al*. [19] who also found a considerable increase in plant fresh and dry weight with application of fertilizers and PGPR.

The use of fertilizers and seed inoculation considerably increased the green fodder and dry matter yield. The maximum green fodder yield (63.12 t ha^{-1}) and dry matter yield (14.51 t ha^{-1}) was obtained from the plots where 100% recommended dose of nitrogen and phosphorus was applied while in case of seeds inoculations maximum fresh fodder yield (62.40 t ha^{-1}) and dry matter yield (14.09 t ha^{-1}) was obtained with the $PGPR_1$. Moreover, the minimum green fodder and dry matter yield was obtained without the use of fertilizers and inoculants. This increase in fresh fodder and dry matter yield by fertilizers and seed inoculation can be due to efficient participation of nitrogen, phosphorus and other nutrients fixed by rhizobium in metabolic processes involved in the production of thick stems, tallest plants and more number of leaves. The increase in fresh fodder and dry matter yield in this study are in consistence with previous findings of Azam *et al*. [20] and Sarajuoghi *et al*. [21] as they reported remarkable increase in fresh fodder and dry matter yield with the application of fertilizers.

The maximum value of crude protein (11.02%), crude fiber (32.06%) and ash contents (8.97%) was recorded with the recommended dose of NP, similarly, seed inoculations with $PGPR_1$ registered maximum value of crude protein (10.59%), crude fiber (31.34%) and ash contents (9.07%). Meanwhile, the minimum values for these parameters were recorded with no fertilizer and no seed inoculation. This increase in protein contents by fertilizers application could be due to the more availability of nitrogen which helps in the synthesis of protein in plants. These results are same as reported by Shehzad *et al*. [22] and Shabbir [23]. In our study, the increase in fertilizer rates substantially increased the crude fiber contents. These results are in accordance with Sharar *et al*. [24] as they stated that crude fiber percentage was increased with increasing

levels of nitrogen and phosphorus, similarly El-Kholy *et al*. [25] also found significant increase in fiber contents with the seed inoculations. Similarly, the increase in ash with fertilizers can be due to more production of dry matter. These results are similar to those of Shehzad *et al*. [22] and Shabbir [23]. They reported significant differences in ash contents by adding different levels of nitrogen and phosphorus in forages.

CONCLUSION

The application of fertilizers (N and P) and seed inoculations significantly increased the yield and quality of sorghum. However, the use of recommended dose of NP and seed inoculations with $PGPR_1$ significantly increased the forage yield and quality of sorghum over the rest of treatments.

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