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Performance of urdbean [*Vigna mungo* (L.) Hepper] under varying levels of fertility and microbial inoculation in semi-arid condition of Rajasthan

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Abstract
A field experiment was carried out with an objective to study the effect of fertility levels in dry matter of urdbean [*Vigna mungo* (L.) Hepper] at Agronomy farm, S.K.N. College of Agriculture Jobner, Jaipur (Rajasthan) during Kharif season of 2018 on loamy sand soil. The experiment of fertility levels and microbial inoculation was carried out with 20 treatments that was carried in RBD with three replications. Results revealed that application of 100% RDF significantly increased the growth and yield determining characters of urdbean *viz*., plant height, number of branches/plant and crop dry matter accumulation at most of the stages, number and weight of root nodules/plant, CGR and RGR, total chlorophyll content, leaf area index, number of pods/plant, grains/pod and test weight over other levels. It also recorded significantly higher grain (1285 kg/ha) over control. However, it showed statistical equivalence with 75% RDF, 50% RDF wherein, the maximum values of most of the growth and yield attributes as well as yield were obtained. Results further indicated that seed inoculation with PGPR + PSB + VAM significantly enhanced the plant height, number of branches/plant, dry matter accumulation, total and effective nodules/plant, fresh and dry weight of nodules, CGR, total chlorophyll content, leaf area index, number of pods/plant, grains/pod and test weight over PGPR, PGPR + PSB, PGPR + VAM and control. It also produced the highest grain yield (1285 kg/ha).

Keywords: Urdbean, PGPR, microbial inoculation, fertility level, loamy sand soil

Introduction
Pulses are considered as life blood of agriculture. They occupy a unique position in every known system of farming as main, catch, cover, green manure and intercrop and their inclusion in crop rotation keep the soil alive and productive. In India, where people are predominantly vegetarian, pulses are main source of high quality protein and thus gain vital importance in daily diet. Pulses account for 25.76 million hectare area with production of 16.47 million tonne in our country (Anonymous 2017-18) [1]. Pulses are not only improving soil health by enriching N status and long term fertility but also increase sustainability of cropping system. It meets up to 80% of its N requirement by symbiotic N-fixation. Production of pulses in our country is far below the requirement to meet even the minimum level of per capita per year consumption. The per capita availability of pulses is reduced from 21.1 kg in 1951 to 15 kg/capita/year in year 2012. In the year 2015, the per capita availability of pulses was 47.2 g, while the minimum requirement is 84 g/capita/day as prescribed by Indian Council of Medical Research, New Delhi (Anonymous 2017-18) [1].

Urdbean [*Vigna mungo* (L.) Hepper] is one of the important self-pollinated leguminous crop grown throughout India. It is generally consumed in the form of dal. It is chief constituent of papad, idly and dosa. It contains about 24% protein, 60% carbohydrates, 1.3% fat, 3.5% minerals and 0.9% fibre. High values of lysine make urdbean an excellent complement to rice in terms of balanced human nutrition. Being a short duration crop, it fits well in various multiple and intercropping systems. In India, it is grown on an area of 3.19 million hectare sharing the production of 1.9 million tonnes with productivity of 596 kg/ha (Anonymous (2017-18) [1]. It is mainly grown in the states of Andhra Pradesh, Karnataka, Madhya Pradesh, Maharashtra, Uttar Pradesh, Rajasthan, Tamil Nadu and Orissa. Maharashtra is the leading acreage holder and producing state in country. In Rajasthan, this crop occupies an area 2.98 lakh hectare with production of 1.14 lakh tonne (Anonymous 2017-18) [1]. It is mainly grown on arid and semi-arid districts like Chittorgarh, Udaipur, Ajmer, Jhalawar, Kota, Bundi, Baran, etc. Despite of being such an important crop, the average productivity of crop in the state is quite low than its potential.

Hence, our research efforts should be aimed to remove the constraints which are responsible for its poor productivity. The productivity of crop is largely influenced by fertility management. Being a legume crop, urdbean has capacity to fix atmospheric-N through root nodules. The major part of nitrogen is met through *Rhizobium* present in the root nodules. Hence, crop requires starter dose of additional nitrogen and phosphorus for growth and development. Chemical fertilizers have been found to be quite promising not only in maintaining higher productivity but also in providing greater stability in crop production (Nambiar and Abrol, 1992) [8]. Keeping this view, a field experiment was carried out at Jobner with the objective to study the effect of varying levels of fertility and microbial inoculation on productivity of urdbean crop under semi-arid conditions of Rajasthan.

Materials and Methods

Research area: The experiment was conducted at Agronomy Farm, S.K.N. College of Agriculture, Jobner situated at 26º05' N latitude and 75º28' E longitude and at an altitude of 427 meters above mean sea level. The region falls in Agro-climatic zone III-a (Semi-Arid Eastern Plain) of Rajasthan. The climate of this region is a typically semi-arid, characterized by extremes of temperature during both summers and winters. The average annual rainfall of this tract varies from 400 to 450 mm and is mostly received during the month of July to September. the relative humidity fluctuates between 42 to 87 percent. There is hardly any rain during winter and summers. The mean weekly weather parameters for the crop season recorded at the college meteorological observatory. These observations revealed that maximum and minimum temperature ranged between 30 ºC to 37.2 ºC and 19.1 ºC to 36.7 ºC, respectively, during *Kharif* 2018. Total amount of rainfall received during 2018 in urd bean crop was 307.8 mm and this was well distributed during crop growth period. The experimental soil was loamy sand in texture, low in organic carbon (0.23%), low available nitrogen (125.8 kg N ha^{-1}), medium in available phosphorus (16.10 kg P_2O_5 /ha) and available potassium (150.29 kg K_2O/ha). The soil was non-saline with a pH value of 8.25.

Experimental design and treatment details: The experiment comprised four levels of fertility (control, 50% RDF, 75% RDF, 100% RDF) and five treatments of microbial inoculation (control, PGPR, PGPR+PSB, PGPR+VAM, PGPR+PSB+VAM) thereby making twenty treatment combinations that were laid down in randomized block design and replicated three times. The treatments were randomly allotted to different plots, using random number table of Fisher and Yates (1963) [2]. Seeds of different varieties were sown on the 07th July, 2018 in the rows spaced at 30 cm apart with help of hand operated 'desi' plough with 'pora' attachment using a seed rate of 16 kg /ha. Thinning, hoeing and weeding were done after 20 days of sowing to maintain recommended spacing, proper aeration and weed free field.

Observation and data collection: Five plants were selected randomly from each plot and tagged permanently. The height of each plant was measured from base of the plant to the tip of main shoot at 25, 50 DAS and at harvest. Dry matter production was recorded at 25, 50 DAS and at harvest stage. For this, plants from one meter row length were uprooted randomly from sample rows of each plot. After removal of root portion, the samples were first air dried for some days and finally dried in an electric oven at 70 ºC till constant weight. The numbers of branches of the five tagged plants of urd bean from each plot were counted at harvest. The mean number of branches per plant in each experimental unit at aforesaid growth stages were worked out and recorded. Leaf Area Index is calculated by the formula given by Watson (1958) [11]. For counting the number of root nodules per plant in sampling rows and removed them carefully after wetting the soil and taking the soil up to 30 cm depth. The plants were removed with soil from the plot and the adhered soil was washed out with a fine jet of water. The nodules were removed with the help of forceps, counted and the mean of three plant nodules was recorded as number of nodules per plant. The crop was harvested on 27th September, 2018 after leaving two border rows on each side of plot along the length on both sides, a net area of 3.0 m × 1.8 m was harvested separately from each plot to assess the grain and straw yields from net plot area. In each plot, bundles were tied and tagged properly and transported on threshing floor for proper sun drying. After complete drying, produce of each plot was weighed on physical balance and the threshing was done manually by beating with wooden sticks and winnowed traditionally. The clean grain obtained from individual plot was weighed separately and weight recorded as grain yield (kg/plot). The straw yield (kg/plot) was obtained by subtracting the grain yield from biological yield recorded earlier.

Results and Discussion

Plant height and dry matter accumulation: All the fertility levels significantly improved the plant height of urdbean over control. At 25 DAS, application of 75% RDF registered 6.3 and 14.2 percent higher plant height over 50% RDF and control but found statically at par with 100% RDF. At later stages of crop growth, the maximum height was recorded under 100% RDF which was significantly superior over 75% RDF, 50% RDF and control by 6.3, 13.4 and 22.0 percent at 50 DAS and 6.5, 14.0 and 27.9 percent at harvest stage, respectively individual as well a combined inoculation with PGPR, PSB and VAM had significant influence on plant height at all the growth stages of urdbean. Seed inoculation with PGPR+PSB+VAM registered the maximum plant height at all the stages, which was 8.2, 16.2 and 25.8 percent higher at 50 DAS and 8.3, 17.2 and 30.4 percent at harvest are PGPR+PSB, PGPR and control, respectively. The seed inoculation of urdbean with PGPR+PSB+VAM was found statistically at par with PGPR+VAM and PGPR+PSB at 25 and 50 DAS and at harvest stages and at 25 DAS application of 75% RDF accumulated significantly higher crop dry matter over 50% RDF and control by 8.2 and 23.5 percent, respectively. However, it was found at par with 100% RDF. At later stages of crop growth, the maximum dry matter of 95.2 and 139.1 g/m row length was recorded with 100% RDF which was significantly superior over rest of the treatments. It registered significant increase of 7.6, 17.5 and 36.0 percent higher at 50 DAS and 6.9, 17.4 and 32.5 percent higher at harvest over 75% RDF, 50% RDF and control, respectively. The crop dry matter accumulation at all the stages crop growth over control. At 25 DAS, seed inoculation with PGPR+ PSB+VAM recorded significantly higher dry matter accumulation over PGPR+PSB, PGPR and control by 9.9, 19.2 and 31.5 percent, respectively but found at par with

PGPR+VAM. Whereas, on later stages of crop growth, seed inoculations with PGPR+PSB+VAM found statistically superior over rest of the treatments. The percent increase in dry matter incurred due to this treatment was 7.8, 11.7, 25.54 and 57.9 at 50 DAS and 8.2, 11.1, 21.3 and 43.3 percent at harvest over PGPR+VAM, PGPR + PSB, PGPR and control, respectively.

Branching and leaf area index: The number of branches/plant of urdbean varieties significantly varied among each other was recorded use of biofertilizers in urdbean brought about significant enhancement in number of branches/plant over no inoculation at both the stages of observation. Results revealed that microbial inoculation with PGPR + PSB and PGPR + VAM found at par with each other at 50 DAS and at harvest stage. The maximum number of branches/plant were obtained under microbial inoculation with PGPR + PSB + VAM which were 12.8, 18.0, 36.2 and 77.3 percent higher at 50 DAS and 8.9, 14.7, 32.2 and 109.5 percent higher at harvest stage over PGPR+VAM, PGPR + PSB, PGPR and control, respectively and Data pertaining to the effect of that different fertility levels on leaf area index in urdbean. Data showed that every increase in level of fertility upto 100% RDF resulted significant improvement in LAI of over preceding levels. it registered LAI of 4.15 which was 11.6, 29.7 and 72.9 percent higher than obtained under 75% RDF, 50% RDF and control, respectively data given further showed that seed inoculation with PGPR, PGPR + PSB, PGPR + VAM and PGPR + PSB + VAM significantly increased the LAI over control. Inoculation with PGPR + PSB + VAM attained the maximum LAI (3.78) among all the treatments indicating a significant increase of 6.8, 9.6, 18.5 and 32.2 percent over PGPR+VAM, PGPR+PSB, PGPR and control, respectively. Being at par with each other PGPR+VAM and PGPR+PSB also resulted in significant improvement of 23.8 and 20.6 percent in LAI over control, respectively.

Crop growth rate (CGR) and relative growth rate (RGR): different levels of fertility and microbial inoculation for urdbean have a significant effect on CGR in urdbean due to varying levels of fertility during all the stages. The values of CGR were lower during 0-25 DAS stage, highest during 25-50 DAS and then moderate during 50 DAS-harvest stage. Application of 100% RDF attained the highest CGR values of 0.85, 2.95 and 1.47 g/m^2/day during 0-25 DAS, 25-50 DAS and 50 DAS-harvest stages, respectively among all levels. During 0-25 DAS, application of 100% RDF increased CGR by 11.8 and 28.8 percent over 50% RDF and control, respectively, whereas the corresponding increase during 50 DAS-at harvest were 17.6 and 25.7 percent. But it was found at par with 75% RDF at these stages. Whereas, during 25-50 DAS stage CGR increased with increasing levels of fertility upto 100% RDF which registered significant increase of 8.5, 19.0, 38.5 percent over 75% RDF, 50% RDF, and control, respectively. Further comparison of the data revealed noted that all the seed inoculations *viz.* PGPR, PGPR+PSB, PGPR+VAM, PGPR+PSB+VAM recorded significantly higher CGR values than obtained under control (Table 2). The maximum CGR values during 0-25 DAS, 25-50 DAS and 50 DAS-harvest stages were obtained when urdbean seed was inoculated with PGPR + PSB + VAM (0.87, 3.06 and 1.45 g/m^2/day. It increased the CGR to the extent of 31.8%, 6.7% and 18.9% percent over control during 0-25 DAS, 25-50 DAS and 50 DAS – harvest, respectively. However, it was found statistically similar with PGPR+VAM during 0-25 DAS stage and RGR in urdbean was increase with increasing levels of fertility during 25-50 DAS. The maximum value of RGR was recorded with the application of 100% RDF (25.81 mg/g/day) which was significantly superior over control and 50% RDF and it was found at par with the application of 75% RDF during 25-50 DAS. Whereas, during 50 DAS – harvest RGR was decreased with increasing levels of fertility and maximum RGR (16.44 mg/g/day) was observed when no use of fertilizers. Further examination of data revealed that seed inoculation with bio-fertilizers significantly improved the value of RGR during 25–50 DAS. Seed inoculation with PGPR+PSB+VAM, PGPR +PSB, PGPR+VAM and PGPR alone, recorded 13.80, 12.54, 12.07 and 9.85 percent higher RGR over control during 25-50 DAS. However, during 50 DAS-at harvest stage decreasing trend in RGR was observed. Maximum RGR (18.54 mg/g/day) was observed with no seed inoculation.

Number and weight of nodules: It is clear from the data presented in Table 2 that increasing level of fertility enhanced significantly the total number of nodules/plant upto 100% RDF. Application of 100% RDF recorded the significantly highest the number of total nodules/plant (39.80) over rest of the fertility levels. The percent increase in total nodules/plant due to this level of fertility was 6.5, 19.2 and 50.8 percent over 75% RDF, 50% RDF and control, respectively. Further showed that number of total nodules/plant were significantly improved due to microbial inoculation of urdbean seed. Combined inoculation of PGPR + PSB + VAM recorded the highest number of nodules/plant (39.15) which was 11.3, 21.6 and 39.9 percent higher than recorded under seed inoculation with PGPR + PSB, PGPR, control respectively. Data given in Table 2 showed that application of different fertility levels significantly influenced the fresh weight of root nodules/plant in urdbean. Results showed that application of 100% RDF significantly improved the fresh weight of root nodules/plant over rest of the treatments. It recorded 133.13 mg fresh weight/plant which was 6.5, 14.3 and 25.8 percent higher over 75%RDF, 50% RDF and control, respectively. Further examination of the data (Table 2) indicated that all the seed inoculants resulted significant enhancement in fresh weight of nodules/plant as compared to no inoculation. PGPR+PSB+VAM recorded the highest fresh weight (137.35 mg/plant) which was followed by PGPR+VAM (128.50 mg), PGPR+PSB (121.59 mg) and PGPR (112.10 mg). These treatments significantly increased the fresh weight of nodules/plant by margin of 36.0, 27.2, 20.4 and 11.0 percent over control, respectively.

Grain and Stover yield:-It is apparent from the data presented in Table 2 that grain yield of urdbean was increased significantly due to all the levels of fertility in comparisons to control. Application of 100% RDF produced the highest grain yield of 1285 kg/ha among all the fertility levels. The magnitude of increase in grain yield due to 100% RDF was 75 kg, 200 kg and 663 kg/ha over 75% RDF, 50% RDF and control respectively. Application of 75% RDF and 50% RDF also improved the grain yield by 94.5 and 40.2 percent, respectively and thus found next in order. Futher data presented in Table 2 showed that grain yield of urdbean was

also significantly influenced due to seed inoculation with microbial inoculation. The maximum grain yield (1241 kg/ha) was recorded when urdbean seed was inoculated with PGPR + PSB + VAM. This treatment increased the grain yield by 10.0, 10.3, 28.7and 61.8 percent over PGPR+VAM and PGPR+PSB, PGPR and control, respectively. Seed inoculation with PGPR + PSB (1125 kg/ha) and PGPR + VAM (1156 kg/ha) were found at par each other and recorded 46.7 and 50.7 percent higher yield over no inoculation and 16.7 and 19.9 percent over inoculation with PGPR, respectively and It is obvious from the data presented in Table 2 that application of varying level of fertility significantly influenced straw yield of urdbean. Results showed that straw yield of urdbean was increased with increasing level of fertility. Maximum straw yield was obtained at application of 100% RDF (2236 kg/ha) which increased the straw yield by the quantum of 130, 306 and 665 kg/ha over 75% RDF, 50% RDF and control, respectively. The extent of increase in straw yield under 75% RDF (2106 kg/ha) was 9.1and 34.1 percent over 50% RDF and control, respectively. The data presented in Table 2 showed that individual as well as combined inoculation of biofertilizers had significant effect on straw yield over no inoculation. Seed inoculation with PGPR+PSB+VAM registered the maximum straw yield of 2258 kg/ha and was found significantly superior over rest of the treatments. It registered significant increase in straw yield with the magnitude of increase of 158, 250, 418 and 662 kg/ha in over seed inoculation with PGPR+VAM, PGPR+PSB, PGPR and control, respectively. Being at par with each other, inoculation with PGPR+PSB and PGPR+VAM also gave significantly higher straw yield over inoculation with PGPR and no inoculation. These treatment improved the straw yield by 9.1 and 14.1 percent over PGPR and 25.8 and 31.6 percent over no inoculation, respectively.

Table 1: Effect of fertility levels and microbial inoculation on plant height, dry matter accumulation, branches and leaf area index of urdbean

Treatments	Plant height (cm)			Dry matter accumulation			Number of branches/plant		Leaf area index
	25DAS	50DAS	Harvest	25DAS	50DAS	Harvest	At 50DAS	At harvest	
Fertility levels									
Control	13.40	39.82	47.04	16.60	69.94	105.00	3.50	5.26	2.40
50% RDF	14.40	42.85	52.76	18.95	80.94	118.50	4.80	6.81	3.20
75% RDF	15.30	45.72	56.46	20.50	88.41	130.10	5.60	7.48	3.72
100% RDF	15.87	48.58	60.15	21.37	95.14	139.10	6.00	8.11	4.15
SEm±	0.27	0.96	1.27	0.39	1.88	2.93	0.12	0.16	0.06
CD (P=0.05)	0.77	2.74	3.64	1.12	5.36	8.39	0.34	0.45	0.18
Microbial Inoculation									
Control	13.80	38.80	46.00	16.50	62.25	98.85	3.48	4.10	2.86
PGPR	14.76	42.00	51.20	18.21	78.30	116.82	4.53	6.50	3.19
PGPR + PSB	14.81	45.10	55.40	19.75	88.00	127.56	5.23	7.49	3.45
PGPR + VAM	15.11	46.50	57.90	20.60	91.20	131.00	5.47	7.89	3.54
PGPR + PSB+VAM	15.41	48.80	60.00	21.70	98.30	141.65	6.17	8.59	3.78
SEm±	0.30	1.07	1.42	0.44	2.10	3.28	0.13	0.18	0.07
CD (P = 0.05)	0.86	3.07	4.07	1.25	6.00	9.38	0.38	0.51	0.20

Table 2: Effect of fertility levels and microbial inoculation on CGR, RGR, number and weight of nodules and yield of urdbean

Treatments	CGR (g/m^2/day)			RGR (mg/g/day)		Number of nodules/plants		Weight of nodules/plant (mg)		Yield (kg/ha)	
	0-25 DAS	25-50 DAS	50-At harvest	25-50 DAS	50-At harvest	Total nodules	Effective nodules	Fresh weight	Dry weight	Grain	Straw
Fertility levels											
Control	0.66	2.13	1.17	24.85	16.44	26.40	24.18	105.82	58.36	622	1571
50% RDF	0.76	2.48	1.25	25.09	15.44	33.39	28.18	116.51	65.48	1085	1930
75% RDF	0.82	2.72	1.39	25.26	15.64	37.38	30.52	124.97	70.88	1210	2106
100% RDF	0.85	2.95	1.47	25.81	15.39	39.80	32.67	133.13	75.55	1285	2236
SEm±	0.02	0.06	0.03	0.56	0.17	0.72	0.59	2.66	1.51	23.63	39.85
CD (P=0.05)	0.05	0.16	0.09	NS	NS	2.06	1.69	7.59	4.31	67.54	113.91
Microbial Inoculation											
Control	0.66	1.83	1.22	23.03	18.54	28.00	23.88	101.01	55.02	767	1596
PGPR	0.73	2.40	1.28	25.30	16.04	32.20	27.25	112.10	64.70	964	1840
PGPR + PSB	0.79	2.73	1.32	25.92	14.89	35.20	29.70	121.59	69.90	1125	2008
PGPR + VAM	0.82	2.82	1.33	25.81	14.52	36.67	30.60	128.50	71.60	1156	2100
PGPR + PSB+VAM	0.87	3.06	1.45	26.21	14.65	39.15	33.00	137.35	76.60	1241	2258
SEm±	0.02	0.06	0.03	0.63	0.19	0.81	0.66	2.97	1.69	26.42	44.56
CD (P = 0.05)	0.06	0.18	0.10	NS	NS	2.31	1.88	8.49	4.82	75.51	127.35

Conclusion

Based on the results of this experiment, it may be inferred that urdbean variety T-9 was found most suitable for obtaining higher productivity in urdbean. Similarly, 100% RDF with seed PGPR+PSB and PGPR+VAM at branching + flowering stage was observed as the most effective for enhancing growth and yields of Urdbean. Overall, it can be concluded that adoption of Urdbean T-9 variety with PGPR+PSB and PGPR+VAM at branching+ flowering stage inoculation can be advocated as sustainable management strategy for enhancing productivity and profitability of urdbean under semi– arid conditions of Rajasthan.

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