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Growth and yield of sorghum as influenced by application of biofertilizers and pink pigmented facultative methylotroph (PPFM) bacteria

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ABSTRACT

A field experiment was carried out on sandy clay soils during *rabi*, 2023-2024 at Agricultural College Farm, Bapatla to assess the response of biofertilizers and Pink Pigmented Facultative Methylotrophs (PPFM) bacteria on growth and yield of sorghum. The trial was laid out in a randomized block design with seven treatments and replicated thrice. The results of the investigation revealed that application of 100 % RDF (100: 60:40 NPK kg ha^{-1}) + Soil application of biofertilizers (*Azospirillum*, Phosphate Solubilizing Bacteria and Potassium Releasing Bacteria each @ 1250 ml ha^{-1}) + Foliar application of PPFM bacteria at 30 and 45 DAS @ 1250 ml ha^{-1} for each application resulted in higher plant height (165.5 cm), drymatter production (13468 kg ha^{-1}) at harvest, grain yield (4016 kg ha^{-1}) and stover yield (7272 kg ha^{-1}) of sorghum.

Key words: *Azospirillum, KRB, PPFM, PSB, Sorghum.*

Sorghum (*Sorghum bicolor* L. Moench) is an important grain and feed crop in the world. It is ranked fifth among the most important grain crops in the world after wheat, rice, maize and barley (FAOSTAT, 2021). This crop is distinctive due to its drought tolerance capacity, improved water and nutrient use efficiency. It is the main food for the inhabitants of the arid and semi-arid regions of the world. Living microbes are used as biofertilizers, inoculants, which are soil amendments intended to promote plant development. They boost crop output by 10-30% and are incredibly economical. They can partially replace or complement chemical fertilisers upto 25%. They promote soil biological activity and plant growth. In addition to protection against certain soil-borne illnesses, they replenish the natural fertility of the soil (El-yazeid *et al*., 2007). Among bio fertilizers, *Azospirillum* and phosphate solubilizing bacteria (PSB) are commonly used in crops like sorghum. An estimated amount of 25-30 % chemical nitrogen fertilizer can be saved by the appropriate use of *Azospirillum* inoculants (Sandya Rani *et al*., 2019). Phosphate solubilizing bacteria work by solubilizing the insoluble forms of phosphate in the soil, so that plants can use them. Potassium releasing bacteria work by the secretion of organic acids and convert the insoluble potassium (K) into a soluble form which can be readily available to the plants (Aleksandrov *et al*.,1967). Pink Pigmented Facultative Methylotrophs (PPFM) bacteria accountable for a diverse beneficial effect on plant includes hastening seed germination and seedling growth, accelerate vegetative growth by producing phytohormones, increase leaf area index and chlorophyll content, earliness in flowering, fruit set, maturation, improves fruit quality, colour, seed weight, yield increase by 10% and mitigate drought. In this context, present investigation was carried out to study the effect of application of Biofertilizers and Pink Pigmented Facultative Methylotrophs (PPFM) bacteria on Growth and yield of *rabi* sorghum.

MATERIAL AND METHODS

A field experiment was conducted at Agricultural College Farm, Bapatla during *rabi*, 2023-2024. The experiment was laid out in randomized block design with seven treatments *viz*., T_1: Control (100% RDF 100: 60: 40 NPK kg ha^{-1}), T_2: T_1 + Soil application of Biofertilizers (*Azospirillum*, Phosphate Solubilizing Bacteria and Potassium Releasing Bacteria each @ 1250 ml ha^{-1}), T_3: T_2 + Soil application of PPFM bacteria @ 2500

ml ha^{-1}, T_4: T_2 + Foliar application of PPFM bacteria at 30 and 45 DAS @ 1250 ml ha^{-1} for each application, T_5: 75% RDF (75: 45: 30 NPK kg ha^{-1}) + Soil application of Biofertilizers (*Azospirillum*, Phosphate Solubilizing Bacteria and Potassium Releasing Bacteria each @ 1250 ml ha^{-1}), T_6: T_5 + Soil application of PPFM bacteria @ 2500 ml ha^{-1}, T_7: T_5 + Foliar application of PPFM bacteria at 30 and 45 DAS @ 1250 ml ha^{-1} for each application and replicated thrice. The experimental soil was sandy clay in texture, slightly alkali in nature (7.69), non-saline (0.41 dS m^{-1}), medium in organic carbon (0.59 %), low in available nitrogen (220 kg ha^{-1}), high in available P_2O_5 (62.1 kg ha^{-1}) and K_2O (460 kg ha^{-1}). Application of fertilizers, biofertilizers and Pink Pigmented Facultative Methylotrophs (PPFM) bacteria was done as per the treatments. The variety used in this study was NTJ-5. Nitrogen, phosphorus and potassium were supplied through urea, single super phosphate (SSP) and muriate of potash (MOP), respectively. Nitrogen was applied in two equal split doses *viz*., first dose was applied as basal and second dose was applied at 30 DAS. Entire quantity of phosphorus and potassium were applied as basal as per the treatments. The data generated on various parameters during the course of investigation were statistically analyzed by applying the technique of analysis of variance contained in the procedures suggested by Gomez and Gomez (1984). Statistical significance was tested by applying F-test at 0.05 level of probability and critical differences were calculated for those parameters which were found significant to compare the effects of different treatments. When the treatment differences were found significant (F test), critical difference was worked out at five per cent probability level and the values were furnished.

RESULTS AND DISCUSSION

Significantly higher plant height at harvest (165.5 cm) was recorded with application of 100 % RDF + Soil application of biofertilizers (*Azospirillum*, phosphate solubilizing bacteria and potassium releasing bacteria each @ 1250 ml ha^{-1}) + Foliar application of PPFM bacteria at 30 and 45 DAS @ 1250 ml ha^{-1} for each application (T_4), but it was at par with application of 100 % RDF + Soil application of Biofertilizers (*Azospirillum*, Phosphate Solubilizing Bacteria and Potassium Releasing Bacteria each @ 1250 ml ha^{-1}) + Soil application of PPFM bacteria @ 2500 ml ha^{-1} (T_3) (152.1 cm) and application of 100 % RDF + Soil application of Biofertilizers (*Azospirillum*, Phosphate Solubilizing Bacteria and Potassium Releasing Bacteria each @ 1250 ml ha^{-1}) treatments (T_2) (149.1 cm). Significantly lower plant height at harvest (126.6 cm) was recorded with application of 75 % RDF 75: 45: 30 NPK kg ha^{-1} + Soil application of biofertilizers (*Azospirillum*, PSB and KRB each @ 1250 ml ha^{-1} (T_5). This might be due to increased levels of fertilizers which leads to increase in availability of nitrogen, which plays a key role in cell division and cell elongation there by leading to increase in plant height. Keerthi *et al*. (2015) reported that spraying pink-pigmented facultative methylotrophs (PPFM) is also said to influence the crop growth by producing plant growth regulators like zeatin and related cytokinins and auxins. The significant effect of PPFM bacteria might be due to stimulation of the auxin in content which are found to be the more essential phytohormone for plant growth. Similar results were reported by Vigneshvarraj *et al*. (2020) and Doifode (2021).

Significantly higher drymatter production at harvest (13468 kg ha^{-1}) was recorded with the application of 100 % RDF + Soil application of Biofertilizers (*Azospirillum*, Phosphate Solubilizing Bacteria and Potassium Releasing Bacteria each @ 1250 ml ha^{-1}) + Foliar application of PPFM bacteria at 30 and 45 DAS @ 1250 ml ha^{-1} for each application (T_4), but it was at par with application of 100 % RDF + Soil application of Biofertilizers (*Azospirillum*, Phosphate Solubilizing Bacteria and Potassium Releasing Bacteria each @ 1250 ml ha^{-1}) + Soil application of PPFM bacteria @ 2500 ml ha^{-1} (T_3) (12726 kg ha^{-1}) and application of 100 % RDF + Soil application of Biofertilizers (*Azospirillum*, Phosphate Solubilizing Bacteria and Potassium Releasing Bacteria each @ 1250 ml ha^{-1}) treatments (T_2) (11959 kg ha^{-1}). Significantly lower drymatter production at harvest (8927 kg ha^{-1}) was recorded with the application of 75 % RDF 75: 45: 30 NPK kg ha^{-1} + Soil application of Biofertilizers (*Azospirillum*, PSB and KRB each @ 1250 ml ha^{-1} (T_5). This might be due to foliar application of PPFM which might have enhanced the synthesis of growth promoters and the contribution of IAA, Cytokinin and GA to the enhanced root growth enabling the plants to absorb more nutrients in grapevine ultimately resulting in better growth and drymatter production, as was highlighted by Radha

Table 1: Plant height and Drymatter production of sorghum at harvest as influenced by application of biofertilizers and Pink Pigmented Facultative Methylotrophs (PPFM) bacteria.

Treatments	Plant height (cm)	Drymatter production (kg ha^{-1})
T_1 - Control - (100 % RDF 100 : 60 : 40 NPK kg ha^{-1})	137.9	11038
T_2 - T_1 + Soil application of Biofertilizers (*Azospirillum*, Phosphate Solubilizing Bacteria and Potassium Releasing Bacteria each @ 1250 ml ha^{-1})	149.1	11959
T_3 - T_2 + Soil application of PPFM bacteria @ 2500 ml ha^{-1}	152.1	12726
T_4 - T_2 + Foliar application of PPFM bacteria at 30 and 45 DAS @ 1250 ml ha^{-1} for each application	165.5	13468
T_5 - 75 % RDF (75: 45: 30 NPK kg ha^{-1}) + Soil application of Biofertilizers (*Azospirillum*, PSB and KRB each @ 1250 ml ha^{-1})	126.6	8927
T_6 - T_5 + Soil application of PPFM bacteria @ 2500 ml ha^{-1}	131.8	9648
T_7 - T_5 + Foliar application of PPFM bacteria at 30 and 45 DAS @ 1250 ml ha^{-1} for each application	135.4	9962
SEm±	6.7	594
CD (p = 0.05)	20.8	1830
CV (%)	8.2	9.3

et al. (2009). Similar findings were reported by Krishnaprabu (2014) and Bhuriya *et al*. (2015).

Foliar application of PPFM bacteria at 30 and 45 DAS @ 1250 ml ha^{-1} for each application in addition to *Azospirillum*, PSB and KRB @ 1250 ml ha^{-1} soil application along with RDF (100: 60: 40 N, P, K kg ha^{-1}) (T_4) significantly registered higher grain yield (4016 kg ha^{-1}), but it was at par with application of 100 % RDF + Soil application of biofertilizers (*Azospirillum*, phosphate solubilizing bacteria and potassium releasing bacteria each @ 1250 ml ha^{-1}) + Soil application of PPFM bacteria @ 2500 ml ha^{-1} (T_3) (3823 kg ha^{-1}) and application of 100 % RDF + Soil application of biofertilizers (*Azospirillum*, phosphate Solubilizing bacteria and potassium releasing Bacteria each @ 1250 ml ha^{-1} (T_2) (3627 kg ha^{-1}). Significantly lower grain yield (2843 kg ha^{-1}) was recorded with the application of 75 % RDF 75: 45: 30 NPK kg ha^{-1} + Soil application of biofertilizers (*Azospirillum*, PSB and KRB each @ 1250 ml ha^{-1}) (T_5). This might be due to increased nitrogen fixation, solubilization and realising of nutrients due to addition of biofertilizers. Greater availability of nutrients and metabolites for the growth and development of reproductive structures, led to higher productivity of individual plants. Srinivasan and Aananthi (2017) revealed that application of PPFM at 500 ml ha^{-1} at 75 and 90 DAS + KCl (1 per cent) at 78 and 93 DAS with crop residue mulch recorded higher growth, yield characters and seed cotton yield of cotton. Thangamani and Sundaram (2007) confirmed that the facultative methylotrophs are more important in increasing the growth and yield of various crop plants. Combined inoculation of PPFM, *Azospirillum* and PSB has resulted in higher plant growth parameters like maximum plant height, plant dry matter production, yield attributes like higher boll number, boll weight per plant and seed cotton yield per ha (Raja and Sundaram, 2006). Such observations were also reported by Kayalvizhi *et al*. (2021), Priya *et al*. (2021) and Sushmitha *et al*.(2023).

The stover yield of sorghum followed the same trend as that was noticed in respect of grain yield of sorghum crop. Significantly higher stover yield (7272 kg ha^{-1}) was recorded with the application of 100 % RDF + Soil application of

Biofertilizers (*Azospirillum*, Phosphate Solubilizing Bacteria and Potassium Releasing Bacteria each @ 1250 ml ha^{-1}) + Foliar application of PPFM bacteria at 30 and 45 DAS @ 1250 ml ha^{-1} for each application (T_4), but it was at par with application of 100 % RDF + Soil application of biofertilizers (*Azospirillum*, Phosphate solubilizing bacteria and potassium releasing bacteria each @ 1250 ml ha^{-1}) + Soil application of PPFM bacteria @ 2500 ml ha^{-1}) (T_3) (7259 kg ha^{-1}) and application of 100 % RDF + Soil application of biofertilizers (*Azospirillum*, phosphate solubilizing bacteria and potassium Releasing Bacteria each @ 1250 ml ha^{-1}) (T_2) (6925 kg ha^{-1}). Significantly lower stover yield (5617 kg ha^{-1}) was recorded with the application of 75 % RDF + Soil application of biofertilizers (*Azospirillum*, PSB and KRB each @ 1250 ml ha^{-1}) (T_5).

Gawad *et al.* (2015) inferred that PPFM foliar spraying to cotton resulted in significantly higher plant growth parameters than uninoculated plants. The significant effect of PPFM bacteria when combined with different biofertilizers along with RDF might be due to enhanced root and shoot growth and cell multiplication, leading to more absorption of other nutrients from deeper layers of the soil. This ultimately resulted in increased plant growth attributes and finally increased the stover yield. Srinivasan and Aananthi (2017) revealed that application of PPFM at 500 ml ha^{-1} at 75 and 90 DAS + KCl (1 per cent) at 78 and 93 DAS with crop residue mulch recorded higher growth, yield characters and seed cotton yield of cotton. The results are in concordance with the findings of Gawad *et al*. (2015), Kumar *et al.* (2022) and Anil kumar *et al.* (2023).

Table 2: Grain yield and Stover yield of sorghum influenced by biofertilizers and Pink Pigmented Facultative Methylotrophs (PPFM) bacteria application

Treatments	Grain Yield (kg ha^{-1})	Stover Yield (kg ha^{-1})
T_1 - Control - (100 % RDF 100 : 60 : 40 NPK kg ha^{-1})	3375	6494
T_2 - T_1 + Soil application of Biofertilizers (*Azospirillum*, Phosphate Solubilizing Bacteria and Potassium Releasing Bacteria each @ 1250 ml ha^{-1})	3627	6925
T_3 - T_2 + Soil application of PPFM bacteria @ 2500 ml ha^{-1}	3823	7259
T_4 - T_2 + Foliar application of PPFM bacteria at 30 and 45 DAS @ 1250 ml ha^{-1} for each application	4016	7272
T_5 - 75 % RDF (75: 45: 30 NPK kg ha^{-1}) + Soil application of Biofertilizers (*Azospirillum*, PSB and KRB each @ 1250 ml ha^{-1})	2843	5617
T_6 - T_5 + Soil application of PPFM bacteria @ 2500 ml ha^{-1}	2935	5748
T_7 - T_5 + Foliar application of PPFM bacteria at 30 and 45 DAS @ 1250 ml ha^{-1} for each application	3064	5915
SEm±	203	381
CD (p = 0.05)	626	1172
CV (%)	10.4	10.2

CONCLUSION

Based on the findings, it could be concluded that the combined application of RDF (100: 60: 40 NPK kg ha^{-1}) + Soil application of Biofertilizers + Pink Pigmented Facultative Methylotrophs (PPFM) bacteria foliar spray recorded significant results on overall crop growth and yield. The combined application of RDF (100: 60: 40 NPK kg ha^{-1}) + Soil application of Biofertilizers + Soil application of pink pigmented facultative methylotrophs (PPFM) bacteria can be an alternative option with the ability to yield

comparable results without adversely impacting the overall growth and yield.

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