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Study on impact of different levels of inorganic phosphorus in combination with biofertilizers on nutrient content of sorghum in black soil

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Abstract
During *Rabi* 2022, the nutrient content of sorghum were evaluated after being treated with different levels of phosphorus fertilizer and biofertilizers. At the Agricultural College Farm in Bapatla, the experiment was set up in a randomized block design and duplicated three times. The treatments comprised of T_1- 0% RDP, T_2- 50% RDP, T_3- 75% RDP, T_4- 100% RDP, T_5- 0% RDP + PSB, T_6- 0% RDP + PSB + VAM, T_7- 50% RDP + PSB, T_8 -50% RDP + PSB + VAM, T_9 -75% RDP + PSB, T_{10}- 75% RDP + PSB + VAM. N, P, K, and micronutrient levels in the plant samples were determined using standard methods. The experiment showed that the treatments had a significant effect on P and Zn, whereas no effect on N, K, Fe, Mn, or Cu. The treatment (75% RDP + PSB + VAM (T_{10}) had the maximum nutrient content and it is on par with 100% RDP (T_4). Therefore, the nutrient content of sorghum was considerably enhanced by the combined application of inorganic fertilizer and biofertilizer compared to both the control and biofertilizers alone.

Keywords: Sorghum, biofertilizers, nutrient content, inorganic fertilizer and plant samples

1. Introduction
After wheat, maize, rice, and barley, sorghum (*Sorghum bicolor* (L.) Moench) is the fifth most important nutritious cereal crop in the world, with around 48 million hectares planted each year in a wide range of climates. In India, it is grown in an area of 4.24 million hectares with a total production of 4.78 million tonnes and productivity of 1128 kg ha^{-1} and in Andhra Pradesh, sorghum is cultivated in an area of 0.12 million hectares with an annual production of 0.37 million tonnes and productivity of 3070 kg ha^{-1} (Ministry of Agriculture, Govt. of India, 2020-21). Sorghum grain consists 10-12% protein, 70% carbohydrates, 3% fats, vitamins, minerals, and salts.

In terms of primary nutrients, phosphorus (P) is second only to nitrogen (N). Phosphorus is thought to be one of the most immobile, inaccessible, and unavailable nutrient in soil. Both adenosine diphosphate (ADP) and adenosine triphosphate (ATP) have it as a component. P is required for plant development from the earliest stages (Bertrand *et al.*, 2003) [5].

Phosphorus solubilizing bacteria (PSB) and mycorrhiza (VAM) are two examples of biofertilizers that may increase the efficiency with which plants use phosphorus. The application of PSB inoculum has been shown to boost plant uptake of phosphorus. Acid phosphatases transform organic phosphorus into inorganic form, and the pH drops as a result of the production of organic acids during phosphorus solubilization (Khan *et al.*, 2009) [13].

Due to the complex reactions that occur between the applied phosphate fertilizer and other soil components like Fe, Al, Ca, and Mg, only about 20-25% of the applied phosphatic fertilizer is actually used by the crop (Johnston and Syers, 2009) [12]. Therefore, successful P management in soil requires a knowledge of the link between different forms of P, their interactions in soil, and the numerous variables impacting P availability to plants. In light of the above, an experiment was designed to see how sorghum would respond to combined use of biofertilizers and inorganic phosphorus.

2. Material and methods
A field study was carried out in *Rabi*, 2022, at the Agricultural College Farm in Bapatla. The MLSH-296 seeds was seeded on clay soil with spacing 45 cm× 15 cm in a randomized block pattern with three replications.

The experimental soil had a clay texture, was non-calcareous, slightly alkaline in nature (7.69), had a medium in organic carbon (0.41dS m^{-1}), a low amount of available nitrogen (210 kg ha^{-1}), a high amount of available phosphorus (61.6 kg ha^{-1}) and available potassium (426 kg ha^{-1}), and a sufficient amount of micro nutrients *viz*. Zn, Fe, Mn, and Cu (1.66, 6.81, 3.86, 1.92, respectively). The experiment consisted of ten treatments *viz*., T_1- 0% RDP, T_2- 50% RDP, T_3- 75% RDP, T_4- 100% RDP, T_5- 0% RDP + PSB, T_6- 0% RDP + PSB + VAM, T_7- 50% RDP + PSB, T_8 -50% RDP + PSB + VAM, T_9 -75% RDP + PSB, T_{10}- 75% RDP + PSB + VAM. Well decomposed farm yard manure @ 10 t ha^{-1} was applied 10 days before sowing. Half of the nitrogen was applied as a basal application and the other half was applied 60 days after planting, for a total of the prescribed @ 100 kg ha^{-1} of nitrogen. Single super phosphate was used to apply the prescribed @ 60 kg P_2O_5 basal dosage per treatment in advance of planting. Muriate of potash, at the required amount of 40 kg ha^{-1}, was used as the first fertilizer treatment. Farm yard manure was combined with biofertilizers (PSB @ 1.25 L ha^{-1} and VAM 12.5 kg ha^{-1}) and applied in accordance with the treatments. All crop protection measures and recommended cultural practices were implemented.

2.1 Collection and preparation of plant samples

For this experiment, plant samples collected at the flowering and harvesting stages were washed once with diluted HCl and once with distilled water. Air drying in the shade was followed by oven-dried at 65 °C and finally, the samples were then crushed into a powder in a Willey mill.

2.2 Plant analysis

2.2.1 Nitrogen: In sorghum plants, nitrogen content was estimated by using the micro Kjeldahl distillation technique (Piper, 1966) [17] and the results are given as a percentage.

2.2.2 Preparation of acid extract by wet digestion: A di-acid combination (HNO_3 and $HClO_4$ in a 9: 4 ratio) was used to digest one gram of powdered plant material in a 150 mL Erlenmeyer flask. The sample digest was passed through using Whatman No.42 filter paper and rinsed with double glass distilled water to remove chloride before being analyzed for phosphorus, potassium, iron, zinc, copper, and manganese.

2.2.3 Phosphorus: Tandon (2009) [23] Vanadomolybdo phosphoric yellow colour technique using a spectrophotometer at 420 nm wavelengths was used to measure phosphorus in the di-acid extract of plant samples and the results were expressed as a percentage.

2.2.4 Potassium: Using a flame photometer and the procedure described by Tandon (2009) [23], the percentage of potassium in the di-acid extract of plant samples was estimated.

2.2.5 Micronutrients: Using atomic absorption spectrophotometer, we determined zinc, manganese, copper, and iron in the di-acid extract, following the specifications mentioned by Lindsay and Norvell (1978) [15] and the results expressed in mg kg^{-1}.

3. Results and Discussion

At harvest stage of sorghum, data recorded on different nutrient contents indicated that only phosphorus and zinc content were significantly influenced by treatments, whereas other nutrient contents were unaffected.

3.1 Nitrogen content

According to the results Table 1, increased levels of phosphorus in grain and stover throughout the harvest stage of the sorghum had no significant influence on nitrogen content. The highest nitrogen content (1.44%) was recorded with the application of 100% RDP (T_4) followed by 75% RDP + PSB + VAM (1.41%), (T_{10}), T_9 (75% RDP + PSB), (1.40%) and T_3 (75% RDP) (1.39%) in grain. In stover, the highest (0.68%) nitrogen content was recorded with the application of 100% RDP (T_4) followed by T_{10} (0.64%) and lowest (0.48%) nitrogen content was observed in 0% RDP (T_1).

According to Das *et al*. (1989) [8], the advantageous impact of phosphorus on cell division, increased root elongation of plant and root hairs may account for the reported increase in nitrogen content with improve in phosphorus application. These changes allow the plant to explore a wider area for nutrient absorption, which in turn leads to a higher nutrient concentration. Arbuscular mycorrhizal fungus (AMF) treated rice had a greater nitrogen content in both the grain and straw. Arbuscular mycorrhizal fungi were shown to positively contribute to the host plant's increased nitrogen uptake and assimilation. (Cavagnaro *et al*., 2012; Lee *et al*., 2012) [6, 14]

3.2 Phosphorus content

Phosphorus content in harvested grain and stover showed a statistically significant difference between treatments with application of biofertilizers and different levels of inorganic phosphorus fertilizer (Table 1 and Fig. 1).

The highest phosphorus content (0.55%) was recorded with the application of 100% RDP (T_4) and it was on par with T_{10} (75% RDP + PSB + VAM), (0.54%), T_9 (75% RDP + PSB), (0.53%) and T_3 (75% RDP), (0.52%) and it was significantly superior over all the other treatments and significant lowest (0.39%) phosphorus content was observed in 0% RDP (T_1) in grain. In stover, the highest (0.29%) phosphorus content was recorded with the application of 100% RDP (T_4) and it was on par with T_{10} (75% RDP + PSB + VAM) (0.27%), T_9 (75% RDP + PSB) (0.23%) and T_3 (75% RDP) (0.21%) and it was significantly superior over all the other treatments and significant lowest (0.12%) phosphorus content was observed in 0% RDP (T_1).

The phosphorus content in sorghum plants grown with inorganic P and biofertilizers was found to be substantially greater than in the control plants. The treatment resulted in important increase in P absorption in both kernels and stover. As phosphate fertilizer levels were raised, phosphorus concentrations followed suit. From 0 to 60 kg P_2O_5 ha^{-1}, the phosphorus content of maize kernels and stover rose dramatically (Gahukar *et al*., 2011) [9]. PSB inoculation aids in releasing phosphorus from native soils and protects phosphate fixation through the excretion of organic acids and enzymes; some of these hydroxy acids (organic acids) can form chelates with cations like Ca^{2+} and Fe^{2+}, resulting in the efficient solubilization of phosphates and a greater supply of plant-available phosphorus. Collaboration between Satpal (1992) [19] and Kapoor (2018) [27] (Sivamurugan *et al.*, 2018) [22] yielded these findings.

Yosefi *et al.* (2011) [26] and Yadav *et al.* (2016) [25] findings on yield improvement were consistent with this pattern. An increase in grain and stover yield was observed after inoculation with phosphate-solubilizing and mobilizing microorganisms (Hilda and Fraga, 1999) [11]. This was due to the microorganisms ability to solubilize phosphate and translocate the nutrient through a network of hyphae in the soil.

3.3 Potassium content

Application of inorganic phosphorus, PSB and VAM had no significant effect on the potassium content of harvested sorghum (Table 1). The maximum potassium level (0.97% and 1.12%, respectively) was found in grain and stover treated with 100% RDP (T_4) during harvest. However, 0% RDP (T_1) had the lowest potassium level (0.76 and 0.84%).

Sorghum plants treated with VAM were shown to accumulate more potassium. Several crop types have shown increased K buildup in plants after inoculation with AM fungus (Baslam *et al.*, 2013) [3]. For physiological processes like plasma membrane polarization, stomatal aperture, growth, or adaptation to environmental changes (Anschütz *et al.*, 2014; Shabala and Pottosin, 2014; Benito *et al.*, 2014) [2, 20, 4] and for enhancing hydric stress tolerance (Wu and Xia 2006), keeping K levels high in plant cells is crucial.

3.4 Zinc content

Zinc content values at harvest (grain and stover) stage were obviously impacted by treatments, as shown by data relating to the effect of varied amounts of phosphorus and biofertilizers application reported (Table 2 and Fig 2).

The maximum (23.9 and 29.6 mg kg^{-1}) zinc content were received in 0% RDP (T_1) followed by 0% RDP + PSB + VAM (T_6), (22.1 and 27.4 mg kg^{-1}) in grain and stover, respectively at harvest stage of crop. Whereas 100% RDP (T_4) had the lowest zinc level (17.2 and 21.6 mg kg^{-1}). As P content rise, zinc levels dropped precipitously. Zinc concentration was shown to decrease from P_{10} to P_{30} by Inderpal Singh *et al.*, 2017 [21]. Shoot and grain zinc levels in cereal crops have been demonstrated to drop after receiving phosphorus sprays (Ryan *et al.*, 2008). In addition, P is known to have complicated interactions with cations like Fe and, in particular, Zn. Zn contents in all maize plant sections were found to be lower when P application rates were increased, as reported by Chahal and Ahluwalia (1977) [7].

3.5 Iron content

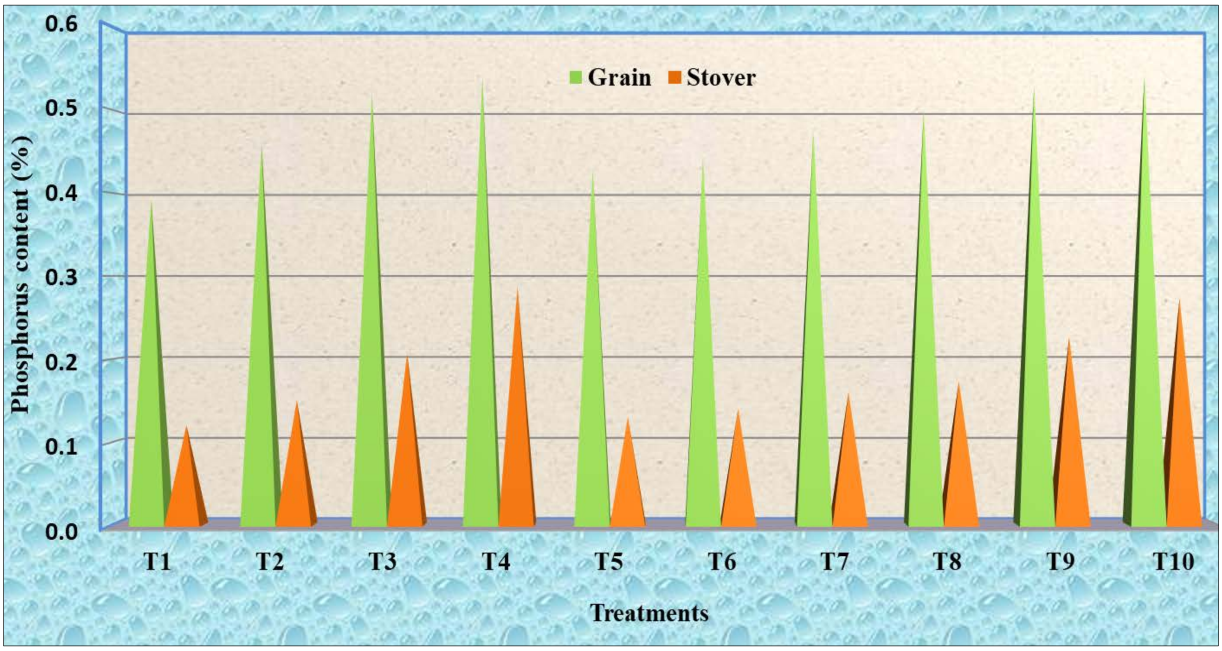
According to the data, there was no statistically significant difference between the application of biofertilizers and different levels of inorganic phosphorus fertilizer (Table 2).

The maximum (39.0 and 54.5 mg kg^{-1}) iron content were recorded with the application of 0% RDP (T_1) followed by 0% RDP + PSB + VAM (T_6) (38.9 and 53.8 mg kg^{-1}) and lowest iron content was found under the treatment with 100% RDP (T_4) 33.1and 48.5 mg kg^{-1} at harvest in grain and stover, respectively. With higher amounts of P, iron content dropped. Inderpalsingh *et al.* (2017) [21] found that Fe content was decreased with an increase in P level from P_{10} to P_{30}.

3.6 Manganese content

Table 2 displays information gathered on the manganese content in harvested sorghum. Data analysis showed that imposed treatments (such as phosphorus levels or biofertilizers) had no discernible effect on the crop Mn content.

At harvest, the grain and stover with the highest manganese content (30.5 and 32.5 mg kg^{-1}) were treated with 100% RDP (T_4), whereas the grain and stover with the lowest Fe level (21.5 and 25.8 mg kg^{-1}) were treated with 0% RDP (T_1). Adding more phosphorus to the soil did not substantially affect the manganese content of wheat grain, according to a study published in 2017 by Inderpalsingh *et al.* and according to research by Amin *et al.* (2013) [1], P treatment had no discernible impact on Mn concentrations in the maize plant's roots and shoots. Although Haldar and Mandal (1981) [10] showed that adding phosphorus to rice fields reduced Mn levels in both the plant leaves and its roots, the reduction was quite minor. This implies that the absorption of manganese by rice plants is not much affected by the inclusion of phosphorus to the soil.



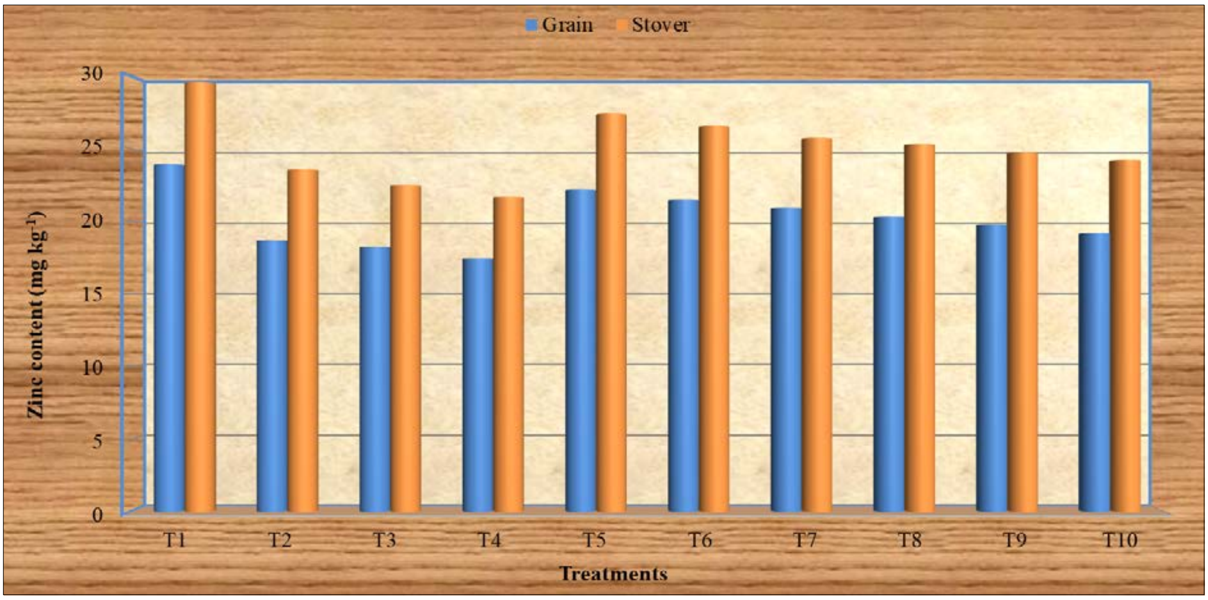
T_1- 0% RDP T_4- 100% RDP T_7- 50% RDP + PSB T_{10}- 75% RDP +PSB +VAM
T_2- 50% RDP T_5- 0% RDP + PSB T_8- 50% RDP + PSB +VAM
T_3- 75% RDP T_6- 0% RDP + PSB + VAM T_9- 75% RDP +PSB

Fig 1: Effect of biofertilizers in combination with inorganic phosphorus on phosphorus content at harvest stage of sorghum

3.7 Copper content

Copper levels in harvested grain and stover did not change significantly among treatments that comprised the use of biofertilizers and varying quantities of inorganic phosphorus fertilizer (Table 2).

Copper content in harvested grain and stover was highest (7.1 and 8.8 mg kg^{-1}) when treated with 100% RDP (T_4) and lowest was recorded (6.0 and 7.3 mg kg^{-1}) with 0% RDP (T_1). Because micronutrients are less mobile from stover to grain, the copper level in stover was higher than in grain. Due to less mobility of micronutrients, rising levels of P were shown to have a negligible effect on the Cu content in wheat grain (Inderpal Singh *et al.*, 2017) [21].



T_1- 0% RDP T_4- 100% RDP T_7- 50% RDP + PSB T_{10}- 75% RDP +PSB +VAM
T_2- 50% RDP T_5- 0% RDP + PSB T_8- 50% RDP + PSB +VAM
T_3- 75% RDP T_6- 0% RDP + PSB + VAM T_9- 75% RDP +PSB

Fig 2: Effect of biofertilizers in combination with inorganic phosphorus on zinc content at harvest stage of sorghum

Table 1: Effect of biofertilizers in combination with inorganic phosphorus on macronutrient contents at harvest stage of sorghum

Treatments	N content (%)		P content (%)		K content (%)	
	Grain	Stover	Grain	Stover	Grain	Stover
T_1: 0% RDP	1.27	0.48	0.39	0.12	0.76	0.84
T_2: 50% RDP	1.33	0.57	0.46	0.16	0.85	1.03
T_3: 75% RDP	1.39	0.60	0.52	0.21	0.90	1.07
T_4: 100% RDP	1.44	0.68	0.55	0.29	0.97	1.12
T_5: 0% RDP + PSB	1.29	0.54	0.43	0.13	0.78	0.97
T_6: 0% RDP + PSB + VAM	1.32	0.56	0.44	0.14	0.80	0.99
T_7: 50% RDP + PSB	1.34	0.58	0.48	0.16	0.86	1.04
T_8: 50% RDP + PSB + VAM	1.35	0.59	0.50	0.17	0.89	1.05
T_9: 75% RDP + PSB	1.40	0.62	0.53	0.23	0.92	1.10
T_{10}: 75% RDP + PSB + VAM	1.41	0.64	0.54	0.27	0.94	1.11
S.Em (±)	0.07	0.03	0.02	0.01	0.04	0.06
CD (P = 0.05%)	NS	NS	0.06	0.03	NS	NS
CV (%)	9.13	11.0	8.93	13.0	9.08	10.7

Table 2: Effect of biofertilizers in combination with inorganic phosphorus on micronutrient contents at harvest stage of sorghum

Treatments	Zn content (mg kg^{-1})		Fe content (mg kg^{-1})		Mn content (mg kg^{-1})		Cu content (mg kg^{-1})	
	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover
T_1: 0% RDP	23.9	29.6	39.0	54.5	21.5	25.8	6.0	7.3
T_2: 50% RDP	18.7	23.5	34.4	49.5	25.3	27.3	6.5	7.6
T_3: 75% RDP	18.2	22.4	33.9	49.0	26.3	30.1	6.8	8.2
T_4: 100% RDP	17.2	21.6	33.1	48.5	30.5	32.5	7.1	8.8
T_5: 0% RDP + PSB	21.4	26.5	37.8	52.8	23.5	26.1	6.1	7.4
T_6: 0% RDP + PSB + VAM	22.1	27.4	38.9	53.8	24.8	26.2	6.3	7.5
T_7: 50% RDP + PSB	20.3	25.3	35.8	51.9	25.3	27.4	6.6	7.8
T_8: 50% RDP + PSB + VAM	20.7	25.7	36.9	52.2	25.8	28.5	6.7	8.0
T_9: 75% RDP + PSB	19.1	24.1	34.9	50.2	26.4	31.0	6.9	8.4
T_{10}: 75% RDP + PSB + VAM	19.7	24.7	35.5	51.3	28.4	32.2	7.0	8.6
S.Em (±)	1.00	1.28	1.86	3.60	1.57	1.63	0.32	0.41
CD (P = 0.05%)	3.00	3.84	NS	NS	NS	NS	NS	NS
CV (%)	8.68	9.12	8.96	12.4	10.5	9.89	8.57	9.03

4. Conclusion
It was determined that the sorghum harvested from the 75% RDP + PSB + VAM (T_{10}) treatment had highest nutrient content (P) and it was on par with 100% RDP (T_4) treatment. Zn content was significantly higher with no phosphorus application and it is lower in 100% RDP (T_4). Increases in phosphorus levels along with biofertilizers had no effect on the nitrogen, potassium, iron, manganese, and copper concentrations in harvested sorghum.

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