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Effect of Biofertilizers in Combination with Inorganic Phosphorus on Yield and Yield Attributes of Sorghum

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ABSTRACT

Yield and yield attributes of sorghum were evaluated with the application of different levels of phosphorus fertilizer along with biofertilizers during *rabi* 2022-23. The experiment was conducted at Agricultural College Farm, Bapatla and was laid out in randomized block design and replicated thrice. 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. Combined application of inorganic fertilizer and bio fertilizer proved significantly superior in growth and yield of sorghum over control and treatment with application of only biofertilizers.There was a 33.8 per cent increase in yield was observed with application of 75% RDP+PSB+VAM and it was on par with 100% RDP. The highest harvest index and test weight (1000 grain weight) was recorded with theapplicationof100%RDP on par with 75% RDP+PSB+VAM

Keywords: *Sorghum, Biofertilizers, yield, Harvest index and Test weight*

Sorghum (*Sorghum bicolor* (L.) Moench) is the fifth world's most important nutritional cereal crop after wheat, maize, rice and barley and also the major staple food crop for millions of people in arid and semi-arid tropics and can be grown in different climates around the world in approximately 48 million hectares area annually. 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 contains 10-12 per cent protein, 70 per cent carbohydrates, 3 per cent fats, vitamins, minerals and salts.

Phosphorus (P) is the second most important primary nutrient. Phosphorus is thought to be one of the most immobile, inaccessible and unavailable nutrient present in the soil. It is a constituent of ADP and ATP, two of the most important substances in life processes. An adequate supply of P is essential from the earliest stage of plant growth (Bertrand *et al*., 2003).

Biofertilizers like phosphorus solubilizing bacteria (PSB) and Mycorrhiza (VAM) which solubilize and mobilize soil phosphates and make them available to plants, can improve phosphorus use efficiency. PSB inoculum is used to increase phosphorus availability to crops. During phosphorus solubilization, some organic acids are produced which decrease the pH and acid phosphatases convert the organic phosphorus into inorganic form (Khan *et al*., 2009).

In soils, the applied phosphate fertilizer enters into complex reactions with various constituents of soils such as Fe, Al, Ca and Mg which get quickly converted to less soluble or insoluble forms, as a result approximately only 20-25 per cent of the applied phosphatic fertilizer is utilized by the crop(Johnston and Syers, 2009). Thus, understanding the relationship between various forms of P, their interactions in soil and various factors influencing P availability to plants are essential for efficient P management in soil. In the above context, an experiment was conducted to assess the effect of biofertilizers in combination with inorganic phosphorus on yield and yield attributes of sorghum.

MATERIAL AND METHODS

A field experiment was conducted at Agricultural College Farm, Agricultural College, Bapatla during *rabi,*2022. MLSH-296 was seeded on clay soil with a spacing of 45cm ×15cm in a randomized block design with three replications. The experimental soil was clay in texture, non-calcareous, slightly alkaline in nature, medium in organic carbon, low in available nitrogen, high in available phosphorus and available potassium and sufficient in micro nutrients *viz.* Zn, Fe, Mn and Cu. 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 farmyard manure @ 10 t ha^{-1} was applied 10 days before sowing. A recommended dose of nitrogen @ 100 kg ha^{-1} was applied in the form of urea in two equal splits *i.e.,* half as basal and half at 60 days after sowing. The recommended dose of P_2O_5@ 60 kg $ha^{-1}$was applied as per the treatments as basal just before sowing through single super phosphate. A recommended dose of K_2O 40 kg ha^{-1} was applied as muriate of potash as basal application. Biofertilizers *viz.,* PSB @ 1.25 L ha^{-1} and VAM @ 12.5 kg ha^{-1} were mixed with farm yard manure and applied as per the treatments. Recommended cultural practices and plant protection measures were taken throughout the cropping season.

Dry matter accumulation was obtained by at each sampling five plants were uprooted randomly in each treatment in the sampling row. These samples were shade dried followed by oven-dry at 65°C till a constant weight was obtained. The dry weight of the samples were recorded. Later, dry matter production was computed as per hectare basis and expressed in kgha^{-1}.

Grain yield was obtained by the panicles from each plot were harvested and dried properly in sun light. Threshing was done manually and grain yield was recorded after winnowing, cleaning and expressed in kg ha^{-1}.

Stover yield was obtained by plants from border rows were harvested first and removed from the field. Then the crop from the net plot area was harvested and left in the field to get completely dried under sunlight. After drying, they were bundled and the weight of each bundle was recorded and expressed in kg ha^{-1}.

Test weight of thousand grains was obtained by the grain samples drawn randomly from each plot produce of each treatment and their weight was recorded in grams.

Harvest index was obtained by the relationship of economic yield to the biological yield was denoted as harvest index and expressed in percentage.

Harvest index (%)=

$$\frac{\text{Economic yield (kg ha}^{-1})}{\text{Biological yield (kg ha}^{-1})} \times 100$$

All the data recorded in the study were subjected to 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 (pÂ0.05) to compare the effects of different treatments.

RESULTS AND DISCUSSION

Test weight

Highest grain weight (31.9 g) was recorded with 100% RDP (T_4) followed by 75% RDP + PSB + VAM -T_3 (29.2 g). While, the lowest grain weight (25.0 g) was recorded in 0% RDP (T_1) where no phosphorus and biofertilizers were applied (Table 1). Among the phosphorus levels, 100% RDP recorded heavier seed weight than other treatments which might be due to increased translocation of photosynthates from source to sink. Application of P and biofertlizers had significant effect on test weight as per reports of Dar *et al*. (2017).

Dry matter accumulation

The highest dry matter accumulation at harvest (10702 kg ha^{-1}) was recorded with the application of 100% RDP (T_4) which was on par with 75% RDP + PSB +VAM -T_{10} (10371 kgha^{-1}), 75% RDP + PSB -T_9(10161 kg ha^{-1}) and 75% RDP -T_3 (9749 kg ha^{-1}) and it was significantly superior over all other treatments. The significantly lowest dry matter accumulation (Table 1 and Figure 1) was observed in 0% RDP (7680 kg ha^{-1}) followed by 0% RDP + PSB (7934 kg ha^{-1}) and 0% RDP + PSB+ VAM (8354 kg ha^{-1}). Application of 100% RDP produced higher dry matter production than lower phosphorus levels at harvest. Crop plants supplied with adequate quantity of phosphorus resulted greater accumulation of photosynthates which accounted for higher dry matter production. Inoculation of microbial cultures like PSB or VAM showed the beneficial effect on P release and significantly enhanced plant growth and yield attributes of sorghum as compared to non-inoculated treatments. Enhanced amount of soluble P in the soil and increased plant biomass, proved that application of microbial inoculants along with phosphate had a positive effect on plant growth parameters and yield attributes.

Similar results were recorded by Patil *et al.* (2012) in maize where application of biofertilizers in combination with 100% RDP recorded significantly higher dry matter accumulation. The inoculated treatment provides the nutrients through solubilization and the inoculants were responsible for release of plant growth promoting substances like indole acetic acid *etc*. Kaleeswari *et al*. (2007) reported that the dissolution of P was significantly higher with P fertilizer + FYM + phosphate solubilizing microorganisms irrespective of the P sources.

Grain yield

The highest grain yield (3680 kg ha^{-1}) was recorded with the application of 100% RDP (T_4) and it was on par with 75% RDP +PSB +VAM -T_{10} (3391 kg ha^{-1}), 75% RDP +PSB -T_9 (3299 kg ha^{-1}) and 75% RDP -T_3 (3250 kg ha^{-1}) and it was significantly superior over all other treatments. Significantly lowest (2533 kg ha^{-1}) grain yield was observed in 0% RDP (Table 1 and Figure 2).

Application of biofertilizers both PSB and VAM (T_6) recorded higher grain yield when compared to their individual application (T_5). There was 45.2% increase in yield with the application of 100% RDP when compared to 0% RDP. It might be due to phosphorus application as it was directly related to the vegetative and reproductive phases of the crop and attributes complex phenomenon of phosphorus utilization in plant metabolism. The increase in grain yield might have been due to increase in P concentration and drymatter production. Rachana *et al*. (2018) reported application of phosphorus at higher levels resulted in higher kernel yield in maize.

The action of P biofertilizers like PSB was not only to release the plant available P but also the production of plant growth promoting and biologically active substances like indole acetic acid, gibberllins and cytokinin (Mahanta and Rai, 2008), which might enhance productivity. Similarly, VAM is widely recognized to improve plant acquisition of P by enhancing translocation and transfer of phosphate ions from the soil solution to the root cells and finally to the plant uptake (Vance *et al*., 2003; Yan *et al*., 2004).

Again, VAM responds to lower threshold concentration of P for absorption than do plant roots (Bolan, 1991). PSB and VAM mobilized more P to the plant from soil. The compatibility of P and VAM can be attributed to the fact that the vesicular arbuscular mycorrhiza might have increased the surface area of absorption through hyphae and improved the availability of nutrients from inaccessible areas. VAM increased the uptake of P and more unavailable nutrients through exploration of soil volume. This is achieved by decreasing the distance for diffusion of phosphate ions by increasing the surface area for absorption (Tinker, 1980). The release of citric, malonic, malic and succinic acids through roots, which can solubilize P from soil (Singh *et al*., 2001) and provided higher soil available P to the crop. PSB solubilize insoluble P by excreting organic acids, i.e., citric and gluconic acids (Kucey *et al*., 1989) and chelating materials in immediate vicinity of rhizosphere.

Stover yield

The highest stover yield (6650 kg ha^{-1}) was recorded with 100% RDP (T_4), which was on par with 75% RDP + PSB + VAM (T_{10}), 75% RDP + PSB (T_9) and 75% RDP -T_3 (6347, 6179 and 6130 kg ha^{-1} respectively) and it was significantly superior over all other treatments. The lowest stover yield (4989 kg ha^{-1}) was recorded in 0% RDP (T_1) where, no phosphorus was applied (Table 1 and figure 2).

Increased stover yield might be due to higher photosynthetic activity because of increased leaf area index, which ultimately promoted dry matter production resulting higher yield. Recommended dose of phosphorus fertilizer along with suitable liquid biofertilizer recorded highest stover yield in maize (Sivamurugan *et al*., 2018). This trend of yield enhancement was similar to the results of Yosefi *et al*. (2011) and Yadav *et al*. (2016) The increased grain and stover yield could be attributed to build up of population of phosphate solubilizing and mobilizing microorganism in rhizosphere due to inoculation which increased the availability of phosphorus to plant through solubilization effect and translocation of nutrient through network of hyphae in soil which absorbs P from non-rhizospheric zone and transport to plant roots (Hilda and Fraga, 1999).

Harvest index

The harvest index of sorghum ranged from 33.1 to 36.1% (Table1). Highest harvest index was recorded in T_4 (100% RDP) (36.1%), while the lowest harvest index was recorded in T_1 (0% RDP) (33.1%). This increase might be due to efficiency of this treatment in converting photo-assimilates into drymatter in grain. Similar results were reported by Rachana *et al*. (2018). Harvest index shows the physiological efficiency of plant to convert the fraction of photo-assimilates to kernel yield

Chemical properties

Available nitrogen

Data pertaining to the available nitrogen content of the soil at harvest stage of the sorghum crop presented in table 2 revealed that influence of different levels of inorganic phosphorus, PSB and VAM application was found to be non-significant.

The highest nitrogen availability was observed in the treatment (T_4) 100% RDP (240 kg ha^{-1}) followed by 75% RDP + PSB (T_{10}) (238 kg ha^{-1}) whereas, lowest availability of nitrogen was observed in T_1 (216 kg ha^{-1}) in 0% RDP. However, the effect was found to be non-significant.

Available phosphorus

The data presented in table 2 revealed that there was a significant variation in available phosphorus content of the soil among the treatments at harvest stage of the sorghum crop. However, the availability of phosphorus was increased in all treatments when compared to the initial soil status. The phosphorus availability in the soil ranged from 57.7 to 85.8 kg ha^{-1} at harvest stage of sorghum.

At harvest stage, the phosphorus availability was higher (85.8 kg ha^{-1}) in the treatment received 100% RDP (T_4) and it was on par with 75% RDP + PSB +VAM (T_{10}) (83.2 kg ha^{-1}), 75% RDP + PSB (T_9) (77.2 kg ha^{-1}) and 75% RDP (T_3) (76.0 kg ha^{-1}) and it was significantly superior over all the other treatments. While, the significantly lowest phosphorus availability (57.7 kg ha^{-1}) was observed in 0% RDP (T_1).

The availability of phosphorus in 100% RDP (T_4)treatment was on par with 75% RDP + PSB +VAM (T_{10}) and 75% RDP + PSB (T_9)which indicates that even after reducing 25% RDP could be able to maintain the available P in the soil by substituting with PSB and VAM.

Available potassium

It is evident from data in table 2 that available potassium content of soil did not varied significantly due to application of different levels of inorganic phosphorus and biofertilizers at harvest stage of sorghum.

However, the availability of potassium was increased in all treatments when compared to the initial soil status (426 kg ha^{-1}). The highest potassium availability (439 kg ha^{-1}) was noticed with the application of 100% RDP (T_4) at harvest stage. However, the lowest potassium availability (420 kg ha^{-1}) was observed in 0% RDP (T_1).

Potassium availability in soil was not significantly influenced by levels of phosphorus 0% RDP, 75% RDP and 100% RDP. However, the availability of potassium was increased with increasing application of phosphorus and also with biofertilizer inoculation.

Combined application of inorganic phosphorus fertilizer and biofertilizers improved the yield and yield attributes of sorghum. There was a increase in yield with application of 75% RDP+PSB+VAM which was on par with 100% RDP. The yield was on par with the application of 75% RDP + PSB + VAM with 100% RDP alone indicated that the reduction in 25% RDP increased the crop yield by 33.8 per cent.

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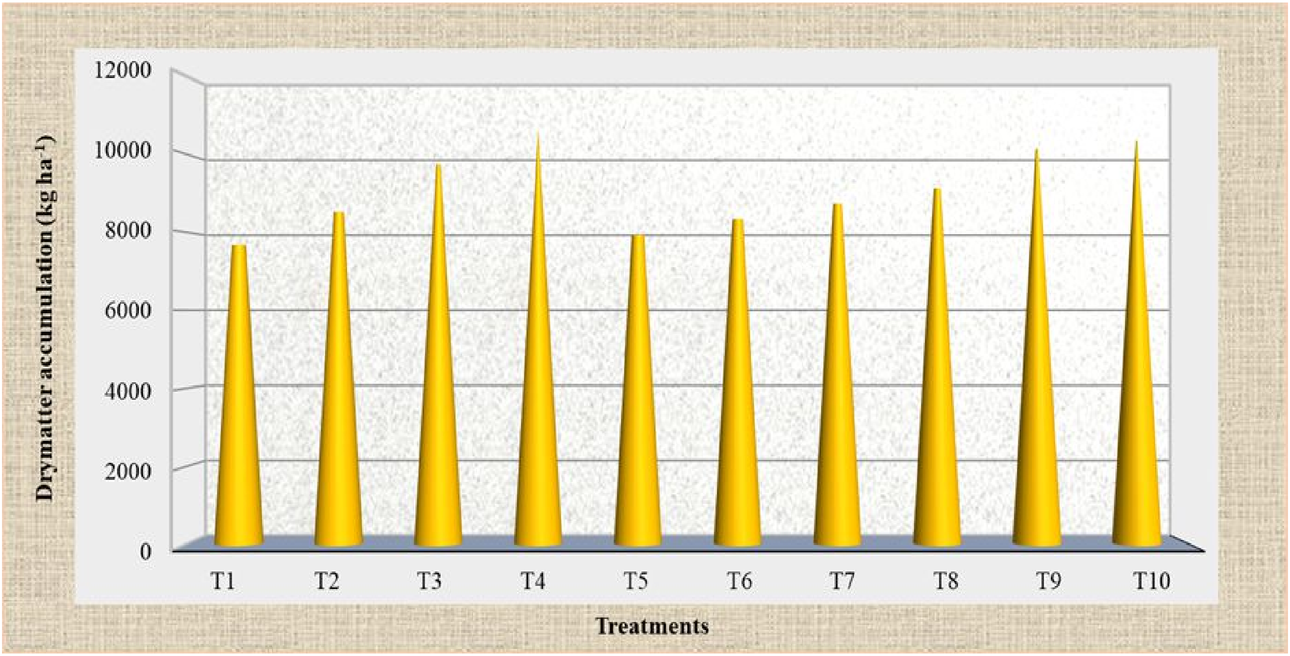

Fig1:Effect of biofertilizers in combination with inorganic phosphorus on drymatter accumulation at harvest of sorghum

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

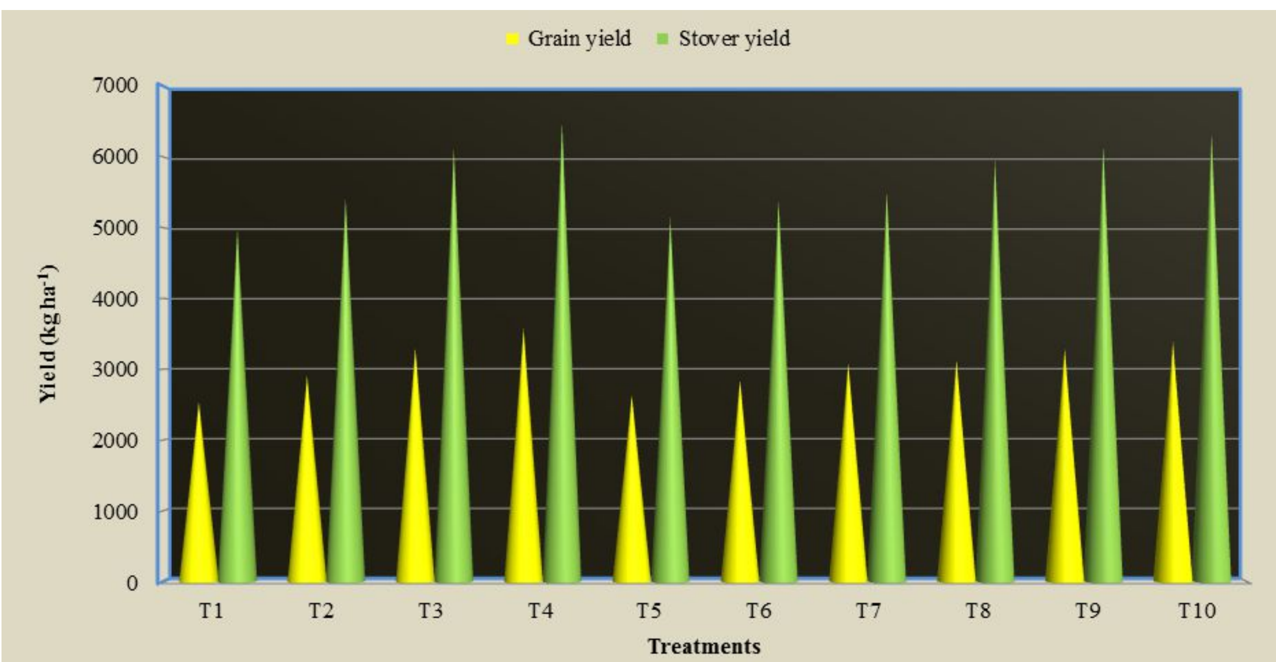

Fig2:Effect of biofertilizers in combination with inorganic phosphorus on yield of sorghum

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

Table1:Effectofbiofertilizers in combination with inorganic phosphorus on dry matter accumulation, yield and yield attributes of sorghum

Treatments	Drymatter accumulation (kg ha-1)	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Test weight (g)	Harvest index (%)
T_1: 0% RDP	7680	2533	4989	25	33.1
T_2: 50% RDP	8534	2908	5420	25.9	33.9
T_3: 75% RDP	9749	3250	6130	27.9	34.7
T_4: 100% RDP	10702	3680	6650	31.9	36.1
T_5:0% RDP + PSB	7934	2638	5143	25.3	33.4
T_6:0% RDP + PSB + VAM	8354	2852	5395	25.7	33.6
T_7: 50% RDP + PSB	8745	3085	5528	26.5	34.1
T_8: 50% RDP + PSB + VAM	8940	3101	5746	27.1	34.4
T_9:75% RDP + PSB	10161	3299	6179	28.5	34.8
T_{10}:75% RDP + PSB + VAM	10371	3391	6347	29.2	35.7
SEm (±)	568	157	282	1.25	2.33
CD (P = 0.05%)	1710	475	847	3.85	**NS**
CV (%)	10.7	8.9	8.49	7.96	11.7

Table 2. Effect of biofertilizers in combination with inorganic phosphorus on available macronutrients(N,P_2O_5andK_2O) at harvest stage of sorghum

Treatments	Available macronutrients (kg ha-1)		
	N	**P_2O_5**	**K_2O**
T_1: 0% RDP	216	57.7	420
T_2: 50% RDP	227	68	427
T_3: 75% RDP	234	76	432
T_4: 100% RDP	240	85.8	439
T_5:0% RDP + PSB	223	63.5	422
T_6:0% RDP + PSB + VAM	224	65	425
T_7: 50% RDP + PSB	228	70	429
T_8: 50% RDP + PSB + VAM	230	73.4	430
T_9:75% RDP + PSB	236	77.2	433
T_{10}:75% RDP + PSB + VAM	238	83.2	436
SEm (±)	11	3.61	19
CD (P = 0.05%)	**NS**	**10.9**	**NS**
CV (%)	8.31	8.65	7.66

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