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Effect of Integrated Nutrient Management with VAM on Nutrient Uptake and Yield of Sorghum

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study evaluated the impact of integrated nutrient management practices and arbuscular mycorrhizal fungi (AMF) on sorghum yield, nutrient uptake, and soil fertility in swell-shrink soils. Eight treatments, including recommended dose of fertilizer (RDF) and various organic amendments

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(FYM, vermicompost) with and without AMF, were tested in a randomized block design with three replications during the *Kharif* season 2022-23. Results indicated that the application of 75% RDF combined with vermicompost (2.5 t ha^{-1}) and AMF (5 kg ha^{-1}) significantly enhanced sorghum yield and total nutrient uptake. This particular treatment (T_7) demonstrated a marked improvement in yield, achieving a 116.5% increase in grain yield and a 120.2% increase in fodder yield over the control. These results indicate that combining reduced fertilizer inputs with organic amendments and AMF can effectively enhance sorghum productivity while potentially reducing dependence on chemical fertilizers. Further analysis revealed strong, positive correlations between yield and the uptake of essential nutrients, including nitrogen (N), phosphorus (P), potassium (K), and sulfur (S). This indicates that treatments combining AMF and organic amendments not only support higher crop productivity but also optimize nutrient availability in the soil. Enhanced nutrient uptake was particularly evident with the T7 treatment, where AMF likely played a pivotal role in improving phosphorus availability by secreting phosphatase enzymes, supporting both nutrient dynamics and overall crop health. This integrated approach demonstrated its potential for improving soil health and agricultural productivity in swell-shrink soil environments.

Keywords: Vesicular Arbuscular Mycorrhiza (VAM); organic manure; Arbuscular Mycorrhizal Fungi (AMF) and crop yields.

1. INTRODUCTION

Sorghum, a versatile and resilient crop, has long been cultivated in India, particularly in regions characterized by nutrient-poor and drought-prone conditions. Its significance extends far beyond its traditional role as a food grain, encompassing a wide range of applications in agriculture, industry, and the environment. In addition to its nutritional value for human consumption, sorghum serves as a vital source of feed for livestock and poultry. Its high protein content and digestibility make it an attractive option for animal husbandry, contributing to the overall sustainability of agricultural systems. Furthermore, sorghum is increasingly recognized for its potential as a biofuel feedstock. The crop's ability to thrive in marginal lands and its high yield potential make it a promising alternative to fossil fuels, promoting energy independence and reducing greenhouse gas emissions. Beyond its agricultural and industrial uses, sorghum plays a crucial role in ecosystem services. Its deep root system helps to improve soil structure and prevent erosion, while its ability to tolerate drought and salinity contributes to the resilience of agricultural landscapes in challenging environments. To sustain sorghum productivity in intensive cropping systems, integrated nutrient management practices have gained prominence. Organic manures, like farmyard manure (FYM), play a crucial role in enhancing soil fertility and improving water retention capacity. While chemical fertilizers have been instrumental in accelerating agricultural production, the complementary use of organic and inorganic inputs is increasingly recognized for achieving balanced nutrient supply and promoting soil health. Arbuscular mycorrhizal fungi (AMF) have emerged as a promising tool for sustainable agriculture. These obligate symbionts form mutualistic associations with plant roots, facilitating nutrient uptake, particularly phosphorus and nitrogen. Studies have demonstrated the beneficial effects of AMF on plant growth, stress tolerance, and overall productivity (Allen, 1982, Frew, 2020 and Tylka et al., 1991). By secreting phosphatase enzymes, AMF can improve phosphorus availability in soils, benefiting plant nutrition (Tshibangu et al., 2020). Additionally, AMF can enhance plant resilience to biotic and abiotic stresses, contributing to increased crop yields (Erdinc et al., 2017 and Grant et al., 2014). In tropical forests, mycorrhizal associations are known to significantly influence soil fertility and plant growth (Bagyaraj, 1989). Understanding the role of AMF in sorghum cultivation can provide valuable insights for developing sustainable and resilient agricultural practices.

2. METHODOLOGY

2.1 Experimental Site

The present investigation was conducted during the *Kharif* season of 2022 at the Research Farm of the Department of Soil Science, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, located in a subtropical region at an altitude of 307.42 meters above mean sea level, with an average annual precipitation of 830 mm. The initial soil of the experimental site were analyzed for different parameters as presented in Table 1. The experiment was structured in a randomized block design with eight treatments, each replicated three times. Sorghum variety CSH-9 was sown on June 30, 2022, at a spacing of 45×15 cm, utilizing a seed rate of 12-15 kg ha^{-1}. The treatments implemented in this study were: T_1 (Absolute control), T_2 (100% Recommended Dose of Fertilizers, RDF), T_3 (100% RDF + VAM @ 5 kg ha^{-1}), T_4 (75% RDF + VAM @ 5 kg ha^{-1}), T_5 (75% RDF + Farm Yard Manure @ 5 t ha^{-1} along with VAM @ 5 kg ha^{-1}), T_6 (75% RDF + FYM @ 5 t ha^{-1}), T_7 (75% RDF + Vermicompost @ 2.5 t ha^{-1} along with VAM @ 5 kg ha^{-1}), and T_8 (75% RDF + Vermicompost @ 2.5 t/ha). VAM was applied through soil application at a rate of 5 kg ha^{-1}.

2.2 Soil Sampling

Composite initial surface soil samples (0-20 cm) before sowing in *Kharif* and treatment wise soil samples were collected after harvest of sorghum. Soil samples were air dried in shade and stored in polythene bags for further analysis. The air-dried samples were carefully and gently ground with the wooden pestle to break soil lumps (clods) and passed through sieve of 2 mm diameter. The sieved samples were mixed thoroughly and stored in polythene bags, properly labelled, and preserved for subsequent analysis for pH, electrical conductivity, organic carbon, and the availability of nitrogen, phosphorus, potassium, and sulfur.

2.3 Statistical Analysis

The data collected were subjected to Analysis of Variance (ANOVA) in accordance with the randomized block design, following standard statistical methods as described by Gomez and Gomez (1984).

3. RESULTS AND DISCUSSION

3.1 Grain Yield and Fodder Yield

The data with respect to the effect of integrated nutrient management with VAM on grain and fodder yield is presented in Fig. 1 The data regarding grain and fodder yield of sorghum was found to be significant. The significantly highest grain yield was recorded with the application of 75% RDF + Vermicompost @ 2.5 t ha^{-1} along with VAM @ 5 kg ha^{-1} (18.55 q ha^{-1}) which was found at par with all treatments except control, 100% RDF and 75% RDF+ VAM @ kg ha^{-1} (Dass *et al*., 2008; Singh 2019; Sonune *et al.,* 2003 and Sharma *et al.,* 2018). The treatment T_7 showed an enhancement in grain yield, achieving 18.55 q ha^{-1}, which is a 116.5% increase compared to the control (T_1), which yielded 8.57 q ha^{-1}. This marked improvement underscores the effectiveness of T_7 in boosting productivity. In comparison to other treatments, T_7 produced 24.2% more yield than T_2 (14.93 q ha^{-1}), 10.6% more than T_3 (16.77 q ha^{-1}), and 22.6% more than T_4 (15.13 q ha^{-1}). Among the highest-yielding treatments (T_5, T_6, and T_8), T_7 still outperformed T_5 (17.6 q ha^{-1}) by 5.4%, while slightly exceeding the yields of T_6 and T_8. This consistent superiority in yield reflects the impact of T_7 on grain production, establishing it as a potentially optimal treatment for enhancing yield outcomes significantly compared to both the control and other treatments. For fodder yield, the treatment T_7 achieved a fodder yield of 47.23 q ha^{-1}, marking a 120.2% increase over the control (T_1) (Reza Kamaei *et al*., 2019), which produced 21.45 q ha^{-1}. In comparison to other treatments, T_7 showed significant gains, yielding 25.7% more than T_2 (37.56 q ha^{-1}), 10.5% more than T_3 (42.73 q ha^{-1}), and 21.9% more than T_4 (38.72 q ha^{-1}). Although Treatments T_5 and T_8 had similar yields at 45.73 and 45.93 q ha^{-1}, respectively, T_7 maintained a slight edge, with a 3.3% increase over T_5 and a 2.8% increase over T_8. This improvement in fodder yield underscores the effectiveness of T_7 in enhancing overall biomass production compared to both the control and other treatments.

3.2 Correlation Matrix

The data pertaining to the correlation matrix between yield and nutrient uptake by sorghum as influenced by integrated nutrient management with VAM is presented in Table 2. The correlation matrix between yield and nutrient uptake in sorghum indicates strong, positive correlations across all variables, with significance at the 0.01 level (2-tailed). Yield showed a very high correlation with N uptake (0.997), P uptake (0.970), K uptake (0.981), and S uptake (0.994). Similarly, N uptake had strong correlations with P uptake (0.990), K uptake (0.997), and S uptake (0.997). P uptake also exhibited high correlations with K uptake (0.997) and S uptake (0.993). Additionally, K uptake was strongly correlated with S uptake (0.996). These results suggest that higher nutrient uptake is consistently associated with increased yield, emphasizing the interconnectedness of nutrient absorption and sorghum productivity.

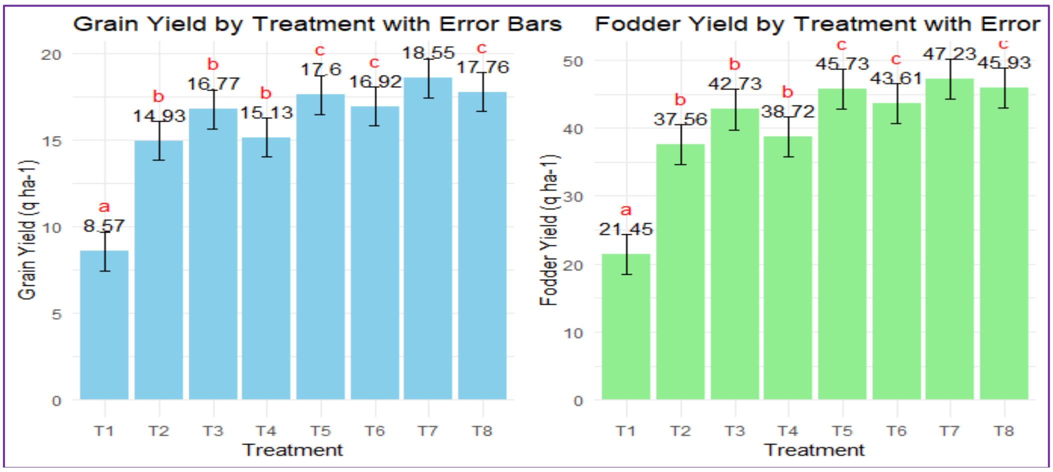

Fig. 1. Effect of Integrated nutrient management with VAM on grain and fodder yield of sorghum

Multiple regression analysis of grain yield, soil parameters and soil quality indicators

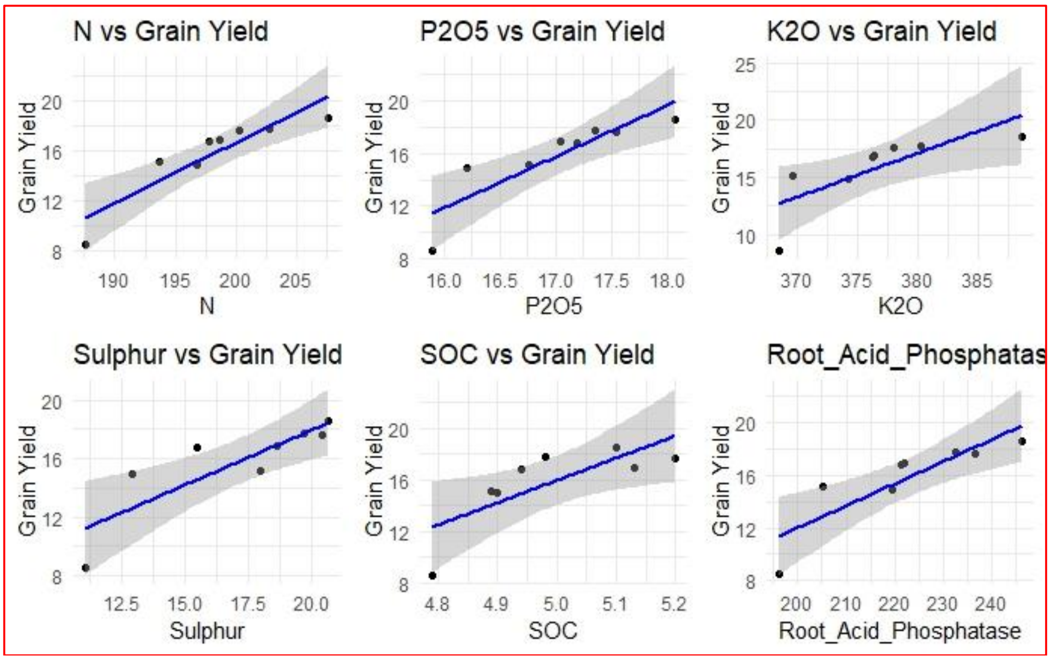

Fig. 2. Multiple regression of grain yield, soil parameters and soil quality indicators

The Fig. 2. presents a series of scatter plots with linear regression lines, illustrating the relationship between different soil parameters and grain yield. Each plot focuses on a specific parameter: The analysis reveals that various soil parameters have a significant influence on grain yield, with several positive linear relationships observed. Nitrogen (N) shows a positive relationship with grain yield, suggesting it may be a limiting factor for crop growth in this soil. Similarly, phosphorus (P_2O_5) and potassium (K_2O) both display positive trends with grain yield, emphasizing their roles as essential nutrients that can significantly impact yield. Sulphur (S) also shows a positive linear relationship with grain yield, highlighting its importance for crop growth. Soil Organic Carbon (SOC) has a positive association with yield, underlining its role in enhancing soil structure, water retention, and nutrient availability. Finally, Root Acid Phosphatase (RAP) activity is positively correlated with grain yield, indicating its importance in phosphorus acquisition and uptake by plants. These findings collectively suggest that optimizing these soil parameters can substantially improve grain yield and overall crop productivity.

Table 1. Initial nutrient status of soil before sowing of sorghum

Sr No.	Soil properties	Values
1	Order	Vertisol
2	Subgroup	Typic Haplusterts
3	Bulk density (Mg m^{-3})	1.41
4	Hydraulic conductivity (cm hr^{-1})	0.66
5	pH (1:2.5)	7.95
6	EC (dS m^{-1})	0.26
7	Organic carbon (g kg^{-1})	4.82
8	Available N (kg ha^{-1})	188.2
9	Available P (kg ha^{-1})	15.90
10	Available K (kg ha^{-1})	372
11	Available S (kg ha^{-1})	23.54

Table 2. Correlation matrix between yield and nutrient uptake by sorghum

	Yield (q ha^{-1})	N Uptake (kg ha^{-1})	P Uptake (kg ha^{-1})	K Uptake (kg ha^{-1})	S Uptake (kg ha^{-1})
Yield (q ha^{-1})	1	.997**	.970**	.981**	.994**
N Uptake (kg ha^{-1})	.997**	1	.990**	.997**	.997**
P Uptake (kg ha^{-1})	.970**	.990**	1	.997**	.993**
K Uptake (kg ha^{-1})	.981**	.997**	.997**	1	.996**
S Uptake (kg ha^{-1})	.994**	.997**	.993**	.996**	1

*** Correlation is significant at the 0.01 level (2-tailed).*

4. CONCLUSION

From the present investigation, it can be concluded that the integrated application of 75% RDF + VAM @ 5 kg ha^{-1} along with vermicompost @ 2.5 t ha^{-1} or FYM @ 5 t ha^{-1} found beneficial for enhancing sorghum yield and nutrient uptake. The significantly higher yield and total uptake of nutrients by sorghum was observed with application of 75 % RDF + vermicompost @ 2.5 t ha^{-1} along with VAM @ 5 kg ha^{-1}.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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