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Arbuscular Mycorrhizal Diversity and Soil Physico-Chemical Parameters in Castor and Cotton Fields of Mahobatpara Village, Porbandar District, Gujarat

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ABSTRACT

Mycorrhizal fungi are vital components of agroecosystems, enhancing nutrient uptake, improving soil structure, and supporting plant robustness. This study compared the natural diversity of arbuscular mycorrhizal fungi (AMF) in Castor (*Ricinus communis* L.) and Cotton (*Gossypium hirsutum* L.) fields at seedling and mature stages in Mahobatpara village, Kutiyana Taluka, Porbandar District, Gujarat. Forty Soil samples were collected (10 per crop per stage) and analyzed for AMF spore density, species diversity, and soil parameters (pH, organic carbon, organic matter, available phosphorous). Results showed that spore density in castor fields increase markedly from 733-1332 spores/100 g soil at seedling stage to 1097-1997 at maturity, while cotton fields exhibited a general decline 1271-1662 at seedling to 1055-1578 at maturity. Soil pH remained neutral to slightly alkaline (6.5-7.8 in castor; 7.69- 8.63 in cotton), and organic carbon, organic matter content was stable (organic carbon: 0.5- 1.5%; organic matter: 0.87-2.9%). Available phosphorous showed a decreasing trend in both crops, more pronounced in cotton (seedling: 10-110 kg/ha; maturity: 18-106 kg/ha). Overall, castor supported higher AMF diversity with *Glomus* species dominating, while cotton showed relatively more large spored genera (Gigaspora, Scutellospora). These findings emphasize crop- specific influences on AMF communities and reinforce the role of AMF in sustainable agriculture, suggesting their potential application as biofertilizer to improve soil fertility and crop productivity in semi-arid regions.

Keywords: Arubuscular Mycorrhizal diversity, AMF, Castor, Cotton, Seedling stage, Mature stage, Soil health, Sustainable agriculture

INTRODUCTION

Mycorrhizal fungi are key components of terrestrial ecosystems, forming mutualistic associations with the roots of most plant species and enhancing nutrient acquisition, water uptake, and resistance to environmental stress (Smith & Read, 2008; Brundrett & Tedersoo, 2018; Turk *et al.*, 2006). Among these, arbuscular mycorrhizal fungi (AMF) of the phylum Glomeromycota are the most widespread, colonizing over 80% of vascular plants (Schüßler *et al.*, 2001; Wang & Qiu, 2006; Brundrett 1991). These symbioses not only improve plant growth but also contribute to soil aggregation, carbon sequestration, and ecosystem stability (Bethlenfalvay & Barea, 1994; Bender *et al.*, 2015; Gosling *et al.*, 2006).

The diversity and functioning of AMF are influenced by several biotic and abiotic factors, including plant species identity, soil properties, land-use intensity, and seasonal changes (Oehl *et al.,* 2003; Fang *et al.*, 2023). Crop type, in particular, can significantly influence AMF communities (Eom *et al.,* 2000). Additionally, soil pH, organic matter content, and moisture levels are known to be strong determinants of AMF distribution (Fang *et al.,* 2023; Johnson *et al.,* 1997).

In India, AMF have been widely studied for their potential in sustainable agriculture by reducing fertilizer dependence (Ashwin *et al.,* 2018). However, most research focuses on controlled inoculation trials, while field-level assessments of native AMF diversity remain limited, especially in semi-arid regions of Gujarat. Such baseline data are essential for understanding the inherent potential of native AMF communities and for designing site- specific biofertilization strategies (Gianinazzi *et al.,* 2010; Hijri, 2015).

Castor (*Ricinus communis* L.) and cotton (*Gossypium hirsutum* L.) are economically important crops widely cultivated in Gujarat. Both crops have been shown to associate with diverse AMF communities, which can influence nutrient cycling and plant health (Ramza *et al.,* 2020; Sarwade *et al.,* 2024). Yet, comparative studies on the natural AMF diversity between these crops, across different growth stages, and under field conditions are limited. Despite the known benefits of AMF in agriculture, due to unawareness of farmers in Mahobatpara village and similar regions rely heavily

on chemical fertilizers, often degrading soil health and microbial diversity. Without understanding the composition, abundance, and ecological role of indigenous AMF, opportunities for sustainable, low-input farming remain untapped.

This study therefore investigates the natural diversity of AMF in castor and cotton fields in Mahobatpara, Porbandar district, at seedling and maturity stages. By examining spore density, community composition, and soil physico-chemical parameters, it provides baseline data to bridge this knowledge gap and support sustainable agricultural practices in semi-arid Gujarat.

MATERIALS AND METHODS

Study Area

The present study was conducted in the agricultural fields of Mahobatpara village, Kutiyana taluka, Porbandar district, Gujarat, India (20.931475° N, 71.082764° E). This region falls under a semi-arid climatic zone with alluvial soils and seasonal rainfall. Castor (*Ricinus communis* L.) and cotton (*Gossypium hirsutum* L.) are widely cultivated in the area.

Soil sample collection

Soil samples were collected from castor (*Ricinus communis* L.) and cotton (*Gossypium hirsutum* L.) fields at two distinct crop growth stages: seedling stage (November 2024) and mature stage (March 2025). For each stage and crop type, ten soil samples were obtained by digging to a depth of 36-40 cm using a sterilized auger. A random sampling technique was employed to ensure equal representation from different parts of the field, thereby capturing the spatial variability of the site. Each sample was wrapped in paper, placed in a zip-lock polythene bag, and clearly labelled with sample number, crop type, and date of collection. In the laboratory, samples were air- dried and passed through a sieve to remove debris prior to further analysis.

Physico-chemical analysis of Soil

Detailed information on soil characteristics was obtained using standard analytical techniques. Soil pH was measured using a digital pH meter (Equiptronic Model EQ-611). Available phosphorous was determined using Olsen Method (Olsen *et al.,* 1954). Organic carbon content was estimated using the Walkey- Black method (Walkey and Black, 1934).

Isolation of Arbuscular Mycorrhizal fungal Spores

AMF spores were isolated from 100 gram of air- dried soil using the Wet Sieving and decanting method described by Gerdeman and Nicolson (1963). A set of sieves with pore sizes of 53 µm and 106 µm was used to separate spores from soil debris.

Identification of AMF

Individual AMF spores were carefully isolated using a 0000-grade fine pencil brush under a stereomicroscope (Almicro DS-50). Each spore was transferred onto a clean glass slide containing a drop of polyvinyl lactoglycerol (PVLG) solution, and a coverslip was gently placed to ensure proper mounting. The prepared slides were left to dry at room temperature for 24 hours to allow for proper setting and adhesion. Morphological identification of AMF spores was performed under an optical digital microscope, following the taxonomic key of Shenck and Pérez (1990). Spore characteristics, including size, colour, wall structure, subtending hyphae, and surface ornamentation, were further verified using descriptions available in the International Culture Collection of Vesicular Arbuscular Mycorrhiza (INVAM) online database. Spore size measurements were conducted under compound microscopy using an ocular micrometer, following recommended procedures by Brundrett *et al.,* (1996)

Data Analysis

Data analysis was carried out by first calculating the mean values for all replicates corresponding to each plant species using Microsoft Excel. The variability of the observations was assessed through the computation of standard deviation (SD), while standard error (SE) was determined to evaluate the accuracy of the mean estimates. To test for stage-wise differences (seedling vs. maturity) within each crop, Welch's independent two- sample t-tests were performed for spore density and available phosphorous. A probability value (p) of less than 0.05 was considered statistically significant. This statistical approach provided a clear understanding of the distribution patterns and specific characteristics of mycorrhizal spores associated with two plant groups-castor (*Ricinus communis* L.) and cotton (*Gossypium hirsutum* L.) – cultivated in the agricultural fields.

RESULTS

The data on arbuscular mycorrhizal Fungi (AMF) spore counts and associated soil physico- chemical

parameters for castor and cotton crops at seedling and maturity stages are summarized in **Table 1** and **Table 2** respectively. A total of 20 soil samples were analysed for each crop, with 10 collected at the seedling stage and 10 at the maturity stage.

Mycorrhizal spore density and soil physico-chemical parameters in Castor fields

The spore density of arbuscular mycorrhizal fungi (AMF) in castor fields showed considerable variation between the seedling and maturity stages **(Table 1)**. At the seedling stage, spore counts ranged from 733.3 to 1332 spores per 100 g of soil, with the highest count recorded in sample 8 and the lowest in sample 5. In contrast, the maturity stage exhibited a wide range of 1,097.3 to 1,997.3 spores per 100g, with maximum values recorded in sample 2. A general increase in spore numbers was observed from seedling to maturity, indicating a positive correlation with crop growth.

Soil pH in castor fields remained within a near-neutral to slightly alkaline range, from 7.28 to 7.92 at the seedling stage and 7.07 to 7.92 at maturity. Organic carbon content showed minimal variation across stages, fluctuating between 1.32- 1.40% at the seedling stage and 1.31- 1.46% at maturity. Organic matter percentages followed a similar pattern, ranging from 2.27% to 2.40%. Available phosphorous levels, however, exhibited a decreasing trend from seedling (32-114 kg/ha) to maturity (24-144 kg/ha) with notable reductions in several samples.

Mycorrhizal spore density and soil physico-chemical parameters in Cotton fields

In cotton fields **(Table 2)**, spore density at the seedling stage ranged from 1,271 to 1,662.6 spores per 100 g of soil, with the highest recorded in sample 6 and the lowest in sample 4. At maturity, the spore count varied between 1,055 and 1,578 spore per 100 g, with a general tendency for reduction compared to the seedling stage, unlike in castor.

Soil pH in cotton fields ranged from 7.12 to 8.68 at seedling stage and from 7.58 to 8.70 at maturity, indicating a predominantly alkaline nature. Organic carbon content was consistent across samples, ranging from 1.31-1.37% at seedling stage and 1.32-1.42% at maturity. Organic matter levels remained relatively stable, ranging from 2.26-2.37%. Available phosphorous varied substantially, with seedling stage values between 10 and 110 kg/ha, while maturity stage values dropped sharply in several samples, ranging from 4 to 44 kg/ha.

When comparing the two crops, castor fields showed a marked increase in spore density from seedling to maturity, whereas cotton fields exhibited a decline in most samples. pH levels in cotton were generally higher than in castor, indicating a more alkaline environment. Organic carbon and organic matter content remained relatively stable across both crops and stage, with only minor fluctuations. Available phosphorous showed a declining trend in both crops from seedling to maturity, with more pronounced reduction in cotton fields.

Significance testing of Spore density and available phosphorous

In castor fields, mean AMF spore density increased significantly from the seedling stage to the maturity stage with p=0.0055 (p<0.01). The available phosphorous showed a slight decline, but this change was not statistically significant (p=0.759; p>0.05).

In cotton fields, mean AMF spore density decreased slightly from seedling to maturity, but the reduction was not significant (p=0.1233; p>0.05). In contrast, available phosphorous levels declined significantly from seedling to maturity (p=0.0062; p<0.01)

Overall, castor supported a significant increase in AMF spore density with crop growth, while cotton exhibited a stage-specific decline. Changes in phosphorus availability were more pronounced and statistically significant in cotton compared to castor **(Table 3).**

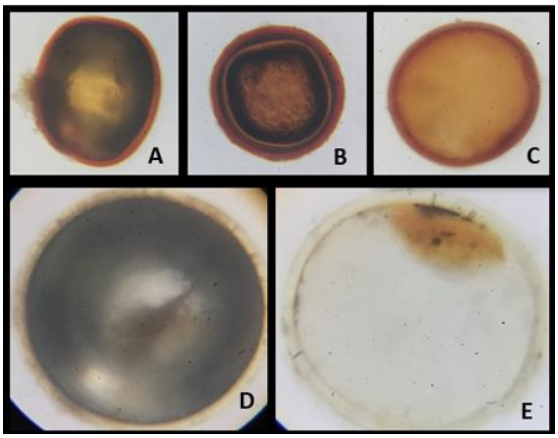

Figure 1: Arbuscular mycorrhizal fungi isolated from both the crop filelds. A, *Glomus claroideum* skipper (206.5 µm x 211.5 µm) B. Glomus mossae (192.5 µm); C- *Acaulospora* spp (129.5 µm x 115.5 µm) D- *Gigaspora* spp. (294 µm x 283.5 µm); E- *Scutellospora scutata* (280 µm x 266 µm)

Table 1: AM Spore count and associated soil physical parameter in Castor

	Castor seedling stage					Castor maturity stage				
Sample No.	**No. of spores/ 100 gm of soil**	**pH**	**Organic Carbon (%)**	**Organic Matter (%)**	**Available Phosphorus (kg/hac)**	**No. of spores/ 100 gm of soil**	**pH**	**Organic Carbon (%)**	**Organic Matter (%)**	**Available Phosphorus (kg/hac)**
1	997± 1.156	7.44± 0.036	1.39± 0.122	2.39	110	1550.3±0.882	7.64± 0.176	1.36± 0.326	2.33	30
2	1257.3±1.454	7.28± 0.028	1.37± 0.088	2.35	64	1997.3±0.882	7.92± 0.081	1.36± 0.390	2.33	144
3	813± 1.156	7.44± 0.036	1.36± 0.205	2.33	66	1988.6±0.0882	7.07± 0.0082	1.37± 0.176	2.35	86
4	1289.6±1.203	7.6±0.0157	1.36± 0.296	2.34	32	1279± 1.529	7.62± 0.004	1.32± 0.088	2.27	24
5	733.3±2.406	7.37± 0.024	1.37± 0.292	2.35	68	1214.6±2.029	7.29± 0.024	1.33± 0.273	2.28	36
6	1072.3±1.454	7.84± 0.008	1.34± 0.261	2.3	54	1523± 2.084	7.37± 0.024	1.31± 0.218	2.25	120
7	1210.3±0.882	7.69± 0.020	1.40± 0.322	2.4	46	1097.3±2.406	7.32± 0.012	1.46± 0.094	2.51	34
8	1332± 1.529	7.62± 0.024	1.32± 0.391	2.27	50	1328.6±3.760	7.81± 0.0081	1.39± 0.088	2.39	54
9	891.6±1.765	7.92± 0.082	1.37± 0.484	2.35	90	1106.6±1.454	7.69± 0.020	1.33± 0.066	2.28	62
10	965± 1.156	7.32± 0.034	1.37± 0.458	2.35	114	1422.3±1.454	7.45± 0.081	1.33± 0.145	2.3	56

Table 2: AM Spore count and associated soil physical parameter in Cotton field

	Cotton seedling stage					Cotton maturity stage				
Sample No.	**No. of spores/ 100 g of soil**	**pH**	**Organic Carbon (%)**	**Organic Matter (%)**	**Available Phosphorus (kg/hac)**	**No. of spores/ 100 gm of soil**	**pH**	**Organic Carbon (%)**	**Organic Matter (%)**	**Available Phosphorus (kg/hac)**
1	1280± 1.156	8.3± 0.176	1.33± 0.1635	2.3	106	1333.6 ±2.029	8.11±0.024	1.38 ±0.163	2.38	40
2	1352.6±0.882	7.34±0.081	1.35± 0.286	2.32	110	1432 ±1.734	7.91±0.030	1.37 ±0.107	2.35	42
3	1511.3±2.966	7.49±0.008	1.37± 0.329	2.35	76	1336.3 ±2.029	7.6± 0.079	1.42 ±0.150	2.45	44
4	1271± 1.734	7.93±0.031	1.37± 0.330	2.36	40	1419.3 ±2.188	8.58±0.081	1.37 ±0.459	2.35	4
5	1470.6±1.203	8.68±0.065	1.34± 0.329	2.31	60	1578 ±2.312	8.38±0.082	1.33 ±0.427	2.29	30
6	1662.6±1.454	7.12±0.054	1.31± 0.319	2.26	62	1055 ±2.648	7.8±0.0267	1.36 ±0.066	2.34	6
7	1387.3±1.203	7.61±0.087	1.37± 0.436	2.37	10	1393.6 ±2.731	7.58±0.083	1.37 ±0.565	2.37	12
8	1425± 2.084	8.05±0.045	1.37± 0.443	2.35	50	1183 ±1.858	8.41±0.074	1.39 ±0.290	2.39	8
9	1509± 1.529	8.48±0.075	1.35± 0.442	2.32	38	1329 ±2.084	8.7±0.0652	1.32 ±0.133	2.27	16
10	1396.6±1.454	7.69±0.015	1.36± 0.420	2.35	42	1251.6 ±1.454	8.63±0.063	1.35 ±0.166	2.32	34

Table 3: Stage-wise comparison of spore density and phosphorus (mean ± SE) in castor and cotton; p-values from t-tests

Parameters	Castor			Cotton		
	Seedling Stage (Mean±SE)	**Maturity Stage (Mean±SE)**	**P- Value**	**Seedling Stage (Mean± SE)**	**Maturity Stage (Mean±SE)**	**P-Value**
Spore density (per 100 g soil)	1056.1 ± 66.4	1450.8± 102.6	0.0055	1426.6 ± 37.3	1331.1 ± 45.6	0.1233
Available Phosphorous (kg/ha)	69.4± 8.6	64.6± 12.8	0.7591	59.4 ± 9.8	23.6 ± 5.1	0.0062

($p < 0.05$ was considered statistically significant; significant results are highlighted in bold)

DISCUSSION

AMF Spore Density. The spore density of arbuscular mycorrhizal fungi (AMF) in the studied soils varied considerably across sampling sites and between the two critical growth stages (seedling and maturity). In Castor fields, total spore counts ranged from 733.3±1.406 to 1332.6± 1.529 at the seedling stage, and from 1097.6±2.406 to 1997 ±0.882 at maturity. The highest value at maturity was recorded in sample 2 (1997± 0.882), while at the seedling stage, the highest was observed in sample 8 (1332± 1.529). A consistent increase in spore density was observed in most castor samples from seedling to maturity, with eight out of 10 samples following this trend. This likely reflects enhanced root- fungus interactions as the plant matures, with expanded root systems and increased root exudation stimulating AM fungal colonization and sporulation, a pattern consistent with earlier reports by Smith and Read (2008).

In contrast, Cotton fields exhibited a less consistent pattern. Spore counts at the seedling stage ranged from 1271±1.734 to 1662.6±1.454. with the highest value in sample 6 (1662.6± 1.454). At maturity, counts ranged from 1055±2.648 to 1578±2.312. with the highest in sample 5 (1578±2.312). Unlike Castor, six of the ten cotton samples showed a decline in spore density from seedling to maturity, suggesting either a reduced mutualistic requirement in later growth stages or environmental/ chemical factors that hinder AMF sporulation. Cotton's known production of allelochemicals and potential stage- specific root exudates shifts may contribute to this decline, as root exudation is the principal pathway of allelochemical release and strongly influences microbial interactions in the soil (Scavo *et al.,* 2019). Root colonization and spore numbers can vary between cultivars, which suggests that host genotype can influence the extend and efficiency of AMF symbiosis (Ashwin *et al.,* 2018)

Soil Physico-Chemical Parameters. This section provides valuable information on the relationships between mycorrhizal spore numbers and soil physico-chemical parameters like Available Phosphorous, Organic Carbon, Organic matter and soil pH.

Organic Carbon and Organic Matter. Across both crops and growth stages, organic carbon and organic matter levels fell within or above the standard range for fertile soils (organic carbon:0.5-1.5%; organic matter: 0.87-2.9%). In Castor fields, seedling-stage organic carbon ranged from 1.32±0.391% to 1.40±0.322%, with corresponding organic matter values of 2.27-2.40%. At maturity, organic carbon values ranged from 1.31± 0.218% to 1.46±0.094%, with organic matter between 2.25-2.51%. Cotton fields showed similar ranges: at seedling stage, organic carbon varied from 1.31±0.319% to 1.37±0.443% (organic matter:2.26-2.37%), while at maturity, carbon values were 1.32±0.133% to 1.42±0.150% (organic matter:2.27-2.45%). It has been observed that higher Organic matter improves soil structure, nutrient availability, microbial activity, which in turn favors AMF spore

density and colonization levels (Ashwin *et al.,* 2018; Bhantana *et al.,* 2021).

Available Phosphorous. Arbuscular mycorrhizal fungi (AMF) play a critical role in enhancing plant phosphorous (P) uptake from the soil in exchange for plant- derived carbohydrates. A well-documented biological pattern is the reduction in AMF colonization and sporulation when soil P levels are high, as plant rely less on fungal- mediated uptake (Smith and Read, 2008). The present study reveals both this inverse P- spore density relationship and notable deviations from it, depending on crop type and growth stage.

Seedling Stage. In Castor fields, P levels at the seedling stage ranged from 32 to 114 kg/ha. Lower P concentrations often corresponded with higher spore densities. Fore instance, sample 4 (32 kg/ha) recorded a high spore count of 1289.6, sample 7 (46 kg/ha) had 1210.3, and sample 8 (50 kg/ha) showed the highest seedling stage value of 1332. Conversely, higher P samples such as sample 1 (110 kg/ha) and sample 10 (114 kg/ha) showed more moderate spore counts of 997 and 965, respectively. A mid-range P value also appeared favourable with sample 2 having 64 kg/ha exhibited a high spore density of 1257.3 spore density, reinforcing the fact that moderate -to-low P availability promotes AMF activity. An exception was sample 5, where despite low P (68 kg/ha), the spore count was the lowest recorded (733.3), possibly due to localized variation, unfavourable pH, or microbial competition. In the present study, spore density was found to be higher than the range (19-47 spores per 100 g soil) reported by Sarwade *et al.,* (2024), who studied AMF diversity in Castor in Dharashiv district in Maharashtra. This suggests that edaphic or climatic factors prevailing in the current study area appears to be more favourable for AMF sporulation.

In Cotton fields, seedling stage P values ranged from 10 to 110 kg/ha. A similar mild inverse trend was observed, with lower P generally supporting higher spore counts. For example, sample 7 (10 kg/ha) has 1387.3 spores, sample 3 (38 kg/ha) had 1442, and samples 5 (48 kg/ha) recorded 1516. Moderate P levels such as 76 kg/ha in sample 8 also supported relatively high spore count of 1487.3. In contrast, higher P values were associated with comparatively lower spore densities- sample 1 (110 kg/ha) recorded 1280, and sample 2 (106 kg/ha) has 1352.6 spore count. These results align with earlier findings that plant dependence on AMF fungi is greater when P availability is low to moderate (Dalpe *et al.,* 2004, Ashwin *et al.,* 2018).

Maturity Stage. By maturity, the inverse P- spore density relationship weakened in both crops. In Castor, P levels ranged from 24 to 144 kg/ha. The highest spore count at maturity (1997.3) was unexpectedly recorded in sample 2, which also ha the highest P level (144 kg/ha), contradicting the expected trend. Nevertheless, some low-P samples still conformed to the inverse relationship- for example, sample 4 (24 kg/ha) had 1279 spores, and sample 3 (86 kg/ha) had 1988.6 spores. However, mid-to-high P samples such as sample 6 (120 kg/ha) still showed high spore densities (1523), suggesting that once AM fungal networks are established, spore production becomes less dependent on P scarcity. This persistence may be due to accumulated organic matter, extensive root colonisation, and sustained fungal growth irrespective of nutrient availability. The findings of matured stage samples in the present study contradicts with the fact that at high P levels, AMF symbiosis is reduced as suggested by Dalpe *et al.,* (2004). These results suggests that once AMF networks are established, sporulation may be regulated by additional factors beyond phosphorous availability. Soil moisture, microclimatic fluctuations, and microbial competition likely contribute to these deviations (Scavo *et al.,* 2019).

In Cotton, maturity stage P values ranged from 18 to 106 kg/ha. Some low P samples maintained high spore counts- for example, sample 5 (30 kg/ha) had 1578 spores, and sample 9 (32 kg/ha) recorded 1432 spores. Sample 6, with low P (26 kg/ha), still maintained 1055 spores. However, the pattern was not consistent; certain low P values such as sample 4 (28 kg/ha) and sample 7 (20 kg/ha) had only moderate spore counts, indicating that other environmental factors may influence sporulation more strongly at later stages. This stage- specific weakening of the inverse P-AMF spore relationship mirrors that seen in Castor and is consistent with reports that mature plants can maintain AMF populations even under high nutrient conditions once colonization is well established (Sadhana, 2014). Ramza *et al.,* (2020) reported AMF spore densities ranging from 144-440 spores per 100 g of soil in cotton rhizospheres, with soils spanning slightly acidic to neutral pH (5.48-7.83).

Across both crops, the seedling stage generally demonstrated a clearer inverse relationship between available phosphorous and spore density, with lower

P supporting higher AMF activity. By maturity, this relationship became inconsistent- possibly because established fungal networks continue sporulating regardless of P levels, aided by stable organic matter content and extended root- fungus associations. The stronger consistency of the inverse pattern in Castor at seedling stage, compared to Cotton, may reflect differences in root exudate composition, allelochemical release, and crop- specific P uptake strategies. Different plant species exhibit varying degrees of dependency on mycorrhizal fungi, influenced by their root morphology, nutrient acquisition strategies, and ecological adaptations (Bagyaraj *et al.,* 2015; Liu and Wang, 2003). Also, functionally, P uptake or transfer can differ strongly across genera, implying that AMF community composition play important role for plant performance and community structure (Dodd *et al.,* 2000). This supports the findings of Brundrett (2009), who emphasized that plant lineages display distinct mycorrhizal associations patterns shaped by both their evolutionary history and ecological adaptations, a well as by environmental factors such as climate, soil fertility, and vegetative structure.

Soil pH. Soil pH remained within neutral to strongly alkaline ranges, generally between 6.5 and 8.68. Castor soils mostly stayed within the optimal AMF range (6.5-7.8) across both stages, supporting balanced microbial activity and nutrient availability. Cotton soils showed a tendency toward higher alkalinity, with pH increasing in seven out o ten samples from seedling to maturity like in sample 10 (7.69 to 8.63). Elevated alkalinity may reduce phosphorous availability, as seen in some mature-stage cotton samples. Soil pH influences the composition and abundance of AMF communities, with neutral to slightly acidic conditions generally favouring higher colonization rates (Bagyaraj *et al.*, 2015; Fang *et al.*, 2023; Liu and Wang, 2003). Ramza *et al.,* (2020) reported soil pH to be slightly acidic to neutral (5.48-7.83), with their spore densities ranging from 144-440 spores per 100 gram of soil. In our study, contrast is obtained that even under slightly alkaline conditions the spore densities were relatively higher ranging from 1055±2.648 to 1578±2.312. This contrast highlights that AMF sporulation in semi- arid agroecosystems may be less constrained by alkalinity than previously assumed, possibly due to favourable organic matter content, crop- specific root traits, or microbial interactions. Such capacity to thrive under alkaline conditions adds to the ecological significance of these fungi in sustaining soil fertility where alkaline soils predominate.

AMF Diversity. The AMF community in both crop rhizospheres comprised four genera: Glomus, Gigaspora, Scutellospora and Acaulospora. Among these, Glomus spp, *Glomus claroideum* and *Glomus mossae* were recorded with *Glomus claroideum* dominating with almost 90% frequency in both systems, followed by Acaulospora emphasizing their cosmopolitan presence in agricultural soils. Previous studies have also reported Acaulospora and Glomus as the most species-rich genera, thereby supporting the present findings. (Bonfim *et al.*, 2016; Gai *et al.,* 2006; Patale and shinde, 2010; Klironomos and Hart, 2002; Chen *et al.*, 2007; Muthukumar and Udaiyan, 2002; Oehl *et al.,* 2023; Zhao *et al.,* 2001) *Scutellospora scutata* and *Gigaspora* spp., characterized by large spores (>250µm), were less frequent in Castor samples but more in Cotton samples. Ramza *et al.* (2020) also reported the presence of AMF species from the genera Glomus, Acaulospora, Gigaspora, and Scutellospora in cotton fields, which supports the present findings.

Spore size analysis revealed distinct crop-specific patterns. In Castor soils, most spores fell within the range of 50-200 µm (63 spores), typical of *Glomus* spp. and *Acaulospora* spp. and large sized spores of the range 200-350 µm were rare (27 spores). The broad 50–350 µm size range suggests a diverse fungal community with both fast-colonizing and less common large-spored species. Cotton soils, in contrast, were dominated by larger spores: the 200–350 µm range accounted for 55 spores, followed by 50-200 µm range for 49 spores. This indicates a higher prevalence of large-spored genera such as *Scutellospora* and *Gigaspora*, potentially linked to cotton's soil chemistry or root exudate profile. Differences in AMF spore size and morphology can be linked to specific genera which may have varied ecological roles and colonization strategies (Thilagar *et al.,* 2016). Overall, the even distribution of *Glomus* spp. was observed across both crops suggesting a strong adaptation of this genus to varied soil environments, while the spore size distribution patterns reflect host plant influence and soil conditions on AM community structure.

Significance testing of Spore density and Available phosphorous in Cotton and Castor

The significant increase in spore density from seedling to maturity in castor indicates a strong

positive interaction between crop growth stage and AMF proliferation. As castor develops, root biomass and exudation likely increase, providing greater carbon resources for AMF sporulation. This finding aligns with earlier observations that AMF activity tends to intensify with plant maturity (Smith and Read, 2008). In contrast, cotton showed a decline in spore density toward maturity, although this was not statistically significant. This pattern may reflect cotton's production of allelochemicals or root exudate shifts that reduce fungal colonization in later stages, a phenomenon previously reported in cotton-AMF interactions (Ramza *et al.,* 2020).

Phosphorous availability exhibited contrasting significance patterns between the two crops. In castor, phosphorous levels declines slightly but without significant differences, suggesting that AMF sporulation may persist independently of P availability once fungal networks are established. Similar deviations from the classic inverse P-AMF relationships have noted in mature crops (Dalpé & Monreal, 2004). By contrast, cotton soils showed a highly significant decline in phosphorous, consistent with crop uptake and possible reduced replenishment in later stages. The stronger phosphorous decline in cotton may partially explain the less consistent AMF response compared to castor.

These results emphasize the crop- specific nature of AMF associations. Castor appears to foster stable and progressively intensifying AMF communities, whereas cotton interactions are more variable and sensitive to nutrient dynamics. Such differences have direct implications for sustainable agriculture: promoting castor in crop rotations could enhance native AMF populations, improve soil fertility, and reduce dependence on chemical fertilizers in semi-arid systems.

CONCLUSION

This study emphasizes the underground interplay between host plants and arbuscular mycorrhizal fungi (AMF), revealing that crop species shape fungal community structure and symbiotic dynamics in distinct ways. Castor supported a stable and progressively strengthening AMF association, while cotton exhibited more variable interactions, likely shaped by biochemical traits and soil conditions. Phosphorous availability emerged as an important driver in early growth stages, though other environmental factors also influenced AMF sporulation at maturity. Beyond their agronomic role, AMF serve as vital contributors to soil health, nutrient cycling and long-term ecosystem endurance. Recognizing these benefits, future research should extend beyond controlled experiments to field-based applications, integrating crop-specific AMF management into sustainable farming practices. Farmer training on the role and diversity of AMF can promote low-input, eco-friendly microbial soil management, reduce dependence on chemical fertilizers, and improve crop yields sustainably. Protecting and managing AMF- rich agricultural sites, especially in semi-arid regions, is crucial to ensuring the long-term sustainability of these symbiotic partnerships for both ecological stability and crop productivity. This study was restricted to a single village site with 10 replicates per crop and stage, and relied on morphological identification of AMF spores. While this approach provided valuable baseline insights, future studies incorporating molecular tools and multi-site, large-scale sampling could yield deeper and more generalizable understanding of AMF diversity and function.

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CONFLICT OF INTEREST

The author declares about no conflict of interest

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