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Original article

Rhizophagus irregularis and nitrogen fixing azotobacter enhances greater yam (*Dioscorea alata*) biochemical profile and upholds yield under reduced fertilization

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ABSTRACT

Greater yam (*Dioscorea alata* L.) is a tropical plant with a large food reserve in its underground tubers. Cultivating the greater yam is considered an essential food security crop. Yam tuber yield and quality is decreased by poor soil fertility, heavy use of fertilizers and attack of insect pest. The heavy use of fertilizers impaired the soil structure polluted the environment, and adversely impacted human beings. We employed *Rhizophagus irregularis* (Arbuscular Mycorrhiza Fungus) and nitrogen fixing Azotobacter to help reduce the adverse effects of fertilisers on the plants. In this study, we applied five treatments such as (1) CF: normal with conventional package and practices, (2) 70%CF: 70% chemical fertilizer, (3) 70 %CF + RI: 70% CF + AMF (*R. irregularis*), (4) 70%CF + AC: 70% CF + PGPB (*Azotobacter chroococum*), and (5) 70%CF + RI + AC: 70% CF + *R. irregularis* + *Azotobacter chroococum*, as donated as T1, T2, T3, T4 and T5, obtained that 70%CF + RI + AC was found to be the most efficient treatment under reduce chemical fertilization for improving morphological traits and biochemical content of greater yam. Although some other treatments such as 70%CF + AC, 70%CF + RI, 70% CF and CF demonstrated considerable effects in yam compared with 70%CF: 70% chemical fertilizer.

1. Introduction

One economically significant tuber yielding plant is Greater yam (*Dioscorea alata* L.), commonly called yam. It is also called water or winged yam, the second most produced and most scattered species worldwide (Lebot et al., 2018). Yam crop is dioecious herbaceous vines majorly cultivated for their starchy tubers having high nutritional content (Vashi et al., 2018). It is considered an essential food security crop is grown in tropical and subtropical regions (Vashi et al., 2018). The chromosome number of *D. alata* is varied from 2n = 40,60,80; that's why it is called the polyploid spp. (Bredeson et al., 2021). Consequently, the importance of greater yam in food security has crossed several genetic improvement programs intending to develop new varieties with a higher yield (Arnau et al., 2017).

Furthermore, greater yam is the best source of starch, having a higher calorific value and a higher protein content than cassava and sweet potato by a factor of three. (Trung et al., 2017). It is important to note that this species has a low sugar content, which is quite beneficial to diabetic individuals (Udensi et al., 2010). Greater yam incorporates high protein and vitamin C content; nevertheless, poor lipid content was detected in the case of *D. alata* compared to other Dioscorea species such as *D. cayanensis*, *D. rotundata* and *D. trifida* (Oko and Famurewa, 2015).

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Not only does yam has a great nutritional value but also used for an industrial purposes; several industrial products are being formed from yam, including yam porridge, it is a popular dish in most countries and made by peeling the yam tuber, washing, dicing into cubes, and boiling with some other ingredients such as tomatoes, onions, meat, crayfish etc. (Lawal et al., 2012; Babajide and Olowe, 2013). Moreover, yam chips are prepared using dry yam tubers (Achi and Akubor, 2000; Babajide et al., 2006). Besides, fried yam chip is a popular, convenient, and readily eat snack in Africa. The potential use of yam in producing deep-fried crisps snacks was studied by Touré et al. (2012) and Tortoe et al. (2014).

For successful tuber production, yam requires a fertilizers dose, but chemical fertilizers are quite expensive and have high production costs. In addition, fertilizers also have adverse effects on the microbial population and soil health (Lenart, 2012). Consequently, the use of fertilizers dose has a negative impact on human health and soil. Therefore, to control the hazardous effect on human beings, microbial populations and soil, need substitution of biofertilizers in place of chemical fertilizers (Alengebawy et al., 2021). Biofertilizers came out to be the best alternative in maintaining soil fertility (Bhardwaj et al., 2014; Kour et al., 2020), and are gaining more importance in agriculture due to their non-hazardous, nontoxic and eco-friendly nature (Sudhakar et al., 2000; Nagananda et al., 2010), as they are useful for better production and crop yield (Yousefi et al., 2017).

Biofertilizers, commonly called bio-inoculants, are generally prepared from organic compounds containing microorganisms beneficial to agriculture products with enriched nutrients, primarily N and P (Chatterjee and Bandyopadhyay, 2017; Khanna et al., 2019; Yasmin et al., 2021). Biofertilizers, when used in seed treatment (Singh et al., 2016) or applied in soil (Wani et al., 2016; Egamberdieva et al., 2018), rapidly multiply to increase their number in the rhizosphere (Sharma et al., 2007). Biofertilizers including Azotobacter (Tripathi et al., 2008), Blue-green algae (Mehnaz, 2015), Azospirillum (Sadhana, 2014), mycorrhizae (Kumar et al., 2015; Kalayu, 2019) and P solubilizing microbes (Selvakumar et al., 2009) are used as an advanced tools to impart several benefits to the agriculture sector.

Among them, Azotobacter is most prominent utilized for agriculture; *Azotobacter* spp. are generally free-living, oval, or spherical shaped, gram-negative, aerobic soil-dwelling bacteria (Kaviyarasan et al., 2020), the use of Azotobacter for supply N to soil as biologically fixed N_2 indicating an important property of this microbe (Aasfar et al., 2021). The bacterium's role on the growth and development is stimulated by rhizospheric microbes (Parmar and Dufresne, 2011; Santoyo et al., 2021), bio-synthesizing an active substance and producing phytopathogenic inhibitors (Franche et al., 2009; Lenart, 2012). These bacteria utilize the atmospheric nitrogen to synthesize their cell protein. Azotobacter converts nitrogen into ammonia, which is later taken up by the plants (Shokri and Emtiazi, 2010), contributing the available nitrogen the crop plants. This plays a multifaceted role in growth stimulation of those plants which not only fix atmospheric N_2 but also promotes growth such as phosphate solubilization, PGRs production like auxins, cytokinins, gibberellins, amino acids and vitamins (Damir et al., 2011; Kashyap et al., 2017; Dutta et al., 2021).

In addition, *Azotobacter* spp. improves the growth of plants, germination of seeds (Wani et al., 2013; Sobariu et al., 2017), and have a positive response on Crop Growth Rate (CGR) (Kizilkaya, 2009) and, an abundant presence of these bacteria positively relates to physico-chemicals (Nongthombam et al., 2021). It is seen that *Azotobacter chroococcum* reduces the infection of nematodes by 48%, followed by Azospirillum (4%) and Pseudomonas (11%) (Nongthombam et al., 2021). Root and soil-dwelling organisms primarily affect plant nutrient uptake (Reid and Greene, 2013). Arbuscular mycorrhizal fungi (AMF) is used to mitigate the effect of fertilizers, have a symbiotic association with plants and roots located in the roots of plants and surround the tubers with a network of hypha, supply the nutrient to greater yam and yield enhanced (Bonfante and Genre, 2008; Sidibe et al., 2015).

In addition, the mutualistic relationship was found with the roots of more than 80% of land plants, including important crops (Kivlin et al., 2011), which also deliver minerals and nutrients, especially phosphate, to their host. In return, the fungi get photosynthetically fixed carbon from the host plants (Malhi et al., 2021). Therefore, we studied the effects of *Rhizophagus irregularis* and Azotobacter on important morphological and biochemical traits of yams.

2. Material and methods

2.1. Study location

The experiment was conducted in greenhouses at the Agriculture Research Farm of Kurukshetra (Haryana, India) for two consecutive years, 2018 and 2019 (29.94°N 76.89°E). The average temperature was 25.5 °C ± 6.0, and the relative humidity was between 50 and 68%. We choose greater yam (*Dioscorea alata* L.) cv. Sree Karthika (Central Tobacco Research Institute (CTRI), Thiruvananthapuram, Kerala, India). The crops were sown in mid-April both years, and they were harvested in the last week of January in both years. Growing the crop using 80 kilogrammes of nitrogen, 60 kilogrammes of phosphorus, and 80 kilos of potash per acre was advised by the research team.

2.2. Soil characteristics and treatments

Soil had a pH of 7.2 and had 70.5 percent sand, 24.8 percent silt, and 4.7 percent clay. It also contained 0.048% nitrogen, 0.020% accessible phosphorus, 0.05 percent organic carbon, and 0.048 percent nitrogen. The treatments were designed as (1) CF: normal with conventional package and practices, (2) 70 %CF: 70% chemical fertilizer, (3) 70 %CF + RI: 70% CF + AMF (*R. irregularis*), (4) 70 % CF + AC: 70% CF + PGPB (*Azotobacter chroococum*), and (5) 70 %C F + RI + AC: 70% CF + *R. irregularis* + *Azotobacter chroococum*. When comparing inoculated and non-inoculated fertilizer rates, the 70% chemical fertilizer rate was chosen because the interaction between AMF/PGPB and fertilizer was unable to provide consistent nutrient absorption below this level (Adesemoye and Kloepper, 2009).

The experiment has five treatments, as follows.

S. No	Treatments	Code
1	CF: normal with conventional package and practices	T1
2	70 %CF: 70% chemical fertilizer	T2
3	70 %CF + RI: 70% CF + AMF (Chemical fertilizers + *R.irregularis* (arbuscular mycorrhiza fungi)	T3
4	70 %CF + AC: 70% CF + PGPB (Chemical fertilizers + *Azotobacter chroococum* (Plant growth promoting bacteria)	T4
5	70 %CF + RI + AC: 70% CF + *R. irregularis* + *Azotobacter chroococum*	T5

2.3. Rhizophagus irregularis and Azotobacter treatment

Azotobacter chroococum was provided by DORA (Zoutleeuw, Flemish Brabant, Belgium), and *R. irregularis* was obtained from M/S ShriRam Solvent Extractions Pvt. Ltd., (India) at a colony-forming unit (CFU) count of 100 spores/g. For AMF treatment, the inoculated plants received (100 g) of material containing infective propagules (mycelium, spores and roots) prior to transplanting. A filtrate was then added to control the pots that didn't receive mycorrhizal inoculum to re-establish other free-living soil microorganisms accompanying the AMF. The filtrate was prepared by passing 100 g mycorrhizal inoculum in water (distilled) across a layer composed of filter papers approximately 15–20 μm (Whatman, GE Healthcare, UK) (Pirttilä and Sorvari, 2014). For PGPB treatment, the tuber planting material was dipped in a suspension of *Azotobacter chroococum* (40 g/lit) for 30 min.

2.4. Experimental design

In this study, the Phillips and Hayman staining method was used to determine the extent of root colonization (Phillips and Hayman, 1970), followed by the Giovannetti and Mosse (1980) method, using LED Microscope (Omax 40X-2500X). In both locations, the experiment was established in a randomized block design. The pot experiment was repeatedly carried out for three replicates. The percentage of AMF infected root segments were obtained using the formula: (number of root segments colonized / total number of root segments) × 100.

2.5. Morphological characterization

Morphological characterizations were investigated as a function of days until emergence, which was quantified as the mean of 5 plants per plant in every replication.. Days to first leaf emergence were calculated at the time leaf emergence of each plant in every replication, no. of leaves (30 DAE), no. of sprouts per seed tuber were recorded after plants emergence. Vine length (cm) is recorded after 45 days, and internode length (cm) were recorded as 5 reading per plant. Vine Length at Harvest (cm), leaf width (cm), Petiole length (cm) at maturity time were taken as the average of 5 plants in each replication. Tuber length (cm), Diameter of tuber (cm), Number of tubers per vine, Weight of tuber (kg), Stem girth (cm), Tuber yield per vine (kg) were recorded after harvesting as the average of 5 plants in each replication. In addition, the average of 5 plants in each replication were taken after harvesting, including dry matter (%), Moisture (%) and Mycorrhization (%).

2.6. Biochemical characterization

The biochemical traits such as starch content (g/100 g), Ascorbic acid (mg/100gm), TSS (%), Total sugar (g/100 g), Total Phenol (mg/100 g), beta carotene (ug/g), anthocyanin (mg/g), crude fat (%), crude fibre (%) and carbohydrate (%) were recorded during processing, as the average of 5 plants in each replication. The starch content was determined in the same manner as previously reported, in mg per 100 mg fresh weight, using glucose, ice-cold acid hydrolysis with sulphuric acid, perchloric acid, and ethanol, and a reference point of 630 nm absorption (Hedge and Hofreiter, 1962). The amounts of ascorbic acid present in the samples were calculated using 2, 6- dichloro phenol indophenols dye (Sadasivam and Balasubramanian, 1987). Total soluble solids of the tubers were determined using drops of the extract on a hand-held refractometer. Values were expressed in °Brix (Linus, 2014). The samples' total sugars (%) content was determined by combining 0.5 g of dried powdered materials with 20–25 mg of ethanol and heating for 2 h in a water bath (Sharma et al., 2021). To determine the total phenols in a sample, the volume of the extract was used. Pipette a volume of the extract (V1) into a flask containing 6–7 mL water, followed by the addition of a 0.5 mL Folin-Ciocalteu (diluted) regent sample. Three minutes later, 1 mL sodium carbonate was added, followed by another 25 mL of filtered water to achieve a total volume of 25 mL. (V). The optical density at 760 nm was measured using a laser after an hour of blanking with water and sodium carbonate (Luthria et al., 2010; Sharma et al., 2021). Additionally, slightly modifying the Karnjanawipagul et al. (2010) method determined the total beta carotene content. To prepare b-carotene as an identification standard, it was dissolved in hexane and concentrated to 4 lg/mL. Five grammes of fresh tubers were blended in a mechanical blender with a pinch of sodium carbonate. The mixture was placed in a centrifuge tube and agitated for two minutes under cold water, followed by the addition of ten millilitres of Tetrahydrofuran and centrifugation once more. To separate the supernatant from the mixture, it was centrifuged at 5000 g for 5 min. The following procedure was used to extract the data: To the supernatant, 15 mL dichloromethane and 15 mL 10% w/v NaCl was added and shaken for 2 min before collecting the extract. Spectrophotometric measurements at 450 nm were repeated twice more than the beta carotene standard curve at various concentrations. The organic layer was extracted and evaporated under nitrogen steam, leaving a 25 mL hexane residue. Following a second extraction, the results were expressed as (lg/gm). Additionally, the anthocyanin concentration in the sample was determined using the Hosseinian et al. (2008) pH differential method.

Moreover, the total fat content of the sample was determined by the procedure of Williams (1984). We used a 5 g powdered tuber sample placed in an extraction tube filled with petroleum ether (boiling point 40–60C) and extracted continuously until the extractor's solvent became colourless. Following ether extraction through distillation, the flask containing the residue was placed in an oven heated to 80°Celsius for 10 min before chilling and weighing in desiccators. This was expressed as a percentage of the dry weight of the crude fat content. Maynard method was used to evaluate the sample's crude fibre content (Maynard, 1970). Briefly, 2 gm of the sample were extracted with ether or petroleum ether to remove fat, dried, and then boiled in 200 mL of H2SO4 for 30 min, filtered through a muslin cloth, and washed with hot water until the washing was completely acid-free. The residue was heated in 200 mL NaOH for 30 min to remove any remaining residue. We calculated the weight difference between the residue before and after ashing at 600 °C and represented it as a percentage of dry matter in the tubers.

Additionally, total carbohydrate content was determined using the Hedge and Hofreiter (1962) anthrone method. In a test tube, 0.5 g dried tuber samples were mixed with 5 mL 2.5 N HCl and cooked for 3 h at 85–90 °C over a water bath, followed by 10 min of extraction. 4 mL of 0.2 percent anthrone reagent was added to the extract, which was then boiled for eight minutes in a boiling water bath. The intensity of the green color was read at 630 nm using Spectrophotometer. The total carbohydrate amount was determined from the standard glucose curve and expressed as gm/100 gm (%) dry weight.

2.7. Data analysis

Analysis of Variance (ANOVA) was conducted to detect the differences among means of each treatment using the Statistical tool for agricultural research (STAR) software package. Each mean was exposed to two-way ANOVA that examined the effect of the treatments. The experiment results were analyzed for studying parameters among treatments, and the significance of differences was calculated using least significant differences (LSD) $P < 0.05$. The

tests were conducted using the Statistical tool for agricultural research (STAR) software package. In addition, the results obtained were expressed as the mean values ± standard deviation and were subsequently calculated and statistically scrutinized. Statistical significance was marked at $P < 0.05$ unless stated otherwise.

3. Results

3.1. Analysis of variance

The analysis of variance for characters of both years under study is presented in Table 1.

3.2. Effects on morphological traits

The treatment with 70 %CF + RI + AC was the most efficient for morphological traits. Although some other treatments such as 70 % CF + AC, 70 %CF + RI, 70% CF and CF demonstrated considerable effects in greater yam (Table 2). Data on days to emergence was applied in all the plants for knowing the best result of days to emergence. Minimum days to emergence was observed in the mixed consortium of 70 %CF + RI + AC (13.72 ± 0.14) followed by 70 %CF + AC (15.19 ± 0.34), 70 %CF + RI (16.26 ± 0.47), and CF (21.30 ± 0.31) treated plants which was far better than 70% CF (23.81 ± 1.60) (Table 2). Minimum days to first leaf emergence were observed in the consortium of 70 %CF + RI + AC (17.15 ± 1.13) and maximum in 70 %CF (25.70 ± 1.93) (Table 2). It was found that supreme increment of no. of leaves were recorded in the combination of 70 %CF + RI + AC (90.29 ± 5.31) followed by 70 %CF + AC (88.99 ± 1.44), 70 %CF + RI (80.58 ± 1.80), CF (72.79 ± 3.18) and 70% CF (62.93 ± 2.28). It is proved that T5, T4, T3 and T1 is to be the most effective treatment (See Table 2). Similarly, no of sprout per seed tuber also observed to be maximum with 70 %CF + RI + AC (2.16 ± 0.16), 70 %CF + AC (2.03 ± 0.03), 70 %CF + RI (1.63 ± 0.03), CF (1.56 ± 0.03) and 70 %CF (1.33 ± 0.06) (Table 2).

Further, Maximum increment was further justified in the treatment of 70 %CF + RI + AC (178.92 ± 6.24) followed by the combination 70 %CF + AC (145.63 ± 4.63), 70 %CF + RI (130.519 ± 2.87) and CF (120.30 ± 2.77). Internode length was highest which is treated with 70 %CF + RI + AC (14.91 ± 0.16) followed by 70 %CF + AC (13.99 ± 0.48), 70 %CF + RI (12.93 ± 0.52), CF (12.02) and 70 %CF (10.82 ± 0.95). It is apparent from Table 2 that vine length (cm) varied among different treatment, maximum vine length (cm) was recorded in the treatments 70 %CF + RI + AC (387.47 ± 14.60) followed by 70 %CF + AC (358.75 ± 14.95), 70 %CF + RI (349.78 ± 4.22), CF (300.94 ± 4.72) as compared to 70 %CF (242.26 ± 1.62). It is again proved that applying of CF, 70 %CF + RI, 70 %CF + AC, 70 %CF + RI + AC treatment having benefit role on morphological traits (Table 2). In addition, maximum leaf length (cm) was recorded in the treatments of 70 %CF + RI + AC (12.49 ± 0.58), 70 %CF + AC (10.46 ± 0.08), 70 %CF + RI (8.98 ± 0.07), CF (8.71 ± 0.19) and 70% CF (0.25 ± 0.42). Maximum, petiole length was recorded by applying treatments of 70 %CF + RI + AC (12.09 ± 0.58) followed by 70 %CF + AC (10.51 ± 0), 70 %CF + RI (8.86 ± 0.14), CF (8.33 ± 0.19) and CF (8.01 ± 0.06) (Table 2).

It is also evident from Table 2 that inoculated and treated plants show the different increment from among treatments. Data on tuber length was substantial in all the treated treatment, and maximum tuber length (cm) was observed in the mixed consortium of 70 %CF + RI + AC (32.45 ± 2.36) followed by 70 %CF + AC (31.37 ± 0.76), 70 %CF + RI (26.16 ± 0.39), CF (24.98 ± 0.38) and 70% CF (23.55 ± 1.58) (Table 2). Maximum dimeter of tuber (cm) increment was also recorded in the consortium of 70 %CF + RI + AC (9.91 ± 0.23), 70 %CF + AC (8.17 ± 0.04), 70 %CF + RI (7.18 ± 0.24), CF (6.80 ± 0.19) and 70% CF (4.71 ± 0.04). Likewise, number of tubers per vine was also observed in the consortium of 70 %CF + RI + AC (2.23 ± 0.03), 70 %CF + AC (1.5 ± 0.10) followed by 70 %CF + RI (1.23 ± 0.03), CF (1.23 ± 0.03) and 70% CF (1.16 ± 0.10). It is evident from table that weight of tuber (kg) was found to be increased by applying 70 %CF + RI + AC (2.67 ± 0.04) followed by 70 % CF + AC (1.47 ± 0.04), 70 %CF + RI (14 ± 0.00), CF (1.00 ± 0.02) and 70% CF (0.76 ± 0.01) (Table 2). In addition, stem girth (cm) increased of 70 %CF + RI + AC (5.32 ± 0.17) followed by 70 % CF + AC (4.40 ± 0.72), 70 %CF + RI (4.07 ± 0.05), CF (3.76 ± 0.01) and 70% CF (3.35 ± 0.03). Similarly, the increase in tuber yield per vine (kg) was also observed to be maximum with 70 %CF + RI + AC (2.75 ± 0.03) followed by 70 %CF + AC (1.80 ± 0.01), 70 % CF + RI (1.48 ± 0.02), CF (1.31 ± 0.01) and 70% CF (0.98 ± 0.06). Further, moisture (%) recorded an increase of 70 %CF + RI + AC (71.63 ± 0.37), 70 %CF + AC (64.73 ± 0.69), 70 %CF + RI (62.96 ± 0.12), CF (61.89 ± 0.29) and 70% CF (59.11 ± 0.08). In addition, maximum dry matter (%) is recorded of 70 %CF + RI + AC (40.88 ± 0.08) followed by 70 %CF + AC (36.75 ± 0.03), 70 %CF + RI (35.20 ± 0.91), CF (33.21 ± 0.66) and 70% CF (28.36 ± 0.37). Likewise, mycorrhization (%) exhibited an increment of by applying 70 %CF + RI + AC (54.65 ± 1.57), 70 %CF + RI (29.97 ± 0.99), and there is no growth if these treatments 70 %CF + AC, 70 %CF, CF applied. However, it should be noted that the most significant results were produced in the treatments (Table.2).

3.3. Effect of different treatments on biochemical parameters of greater yam

It is evident from Table 3 that inoculated or treated plants showed a significant increase in growth compared to the 70% chemical fertilizer. The treatment with 70 %CF + RI + AC produces significant effects in the biochemical parameters (Table 3). Although some other treatments such as 70 %CF + AC, 70 % CF + RI, 70% CF and CF demonstrated considerable effects in yam. Introduction of treatments was recorded to be highest in 70 %CF + RI + AC (62.75 ± 0.17), 70 %CF + AC (57.95 ± 0.23), 70 %CF + RI (53.96 ± 0.84), CF (53.15 ± 0.15) and 70% CF (46.62 ± 0.16). Maximum ascorbic acid (mg/100gm) increment was also observed in the consortium of 70 %CF + RI + AC (24.33 ± 0.08) followed by 70 %CF + AC (19.30 ± 0.07), 70 %CF + RI (15.07 ± 0.03), CF (14.70 ± 0.11) and 70% CF (13.84 ± 0.02) (Table 3). In addition, the role of treatments TSS (%) further justified with the application of 70 %CF + RI + AC (12.11 ± 0.01), 70 %CF + AC (9.23 ± 0.03), 70 %CF + RI (8.45 ± 0.01), CF (8.26 ± 0.06) and 70% CF (6.35 ± 0.08). It is evident from table that total sugar (%) were found to be increment of 70 %CF + RI + AC (9.29 ± 0.11) followed by 70 %CF + AC (7.69 ± 0.12), 70 % CF + RI (6.95 ± 0.08), CF (6.01 ± 0.13) and 70% CF (4.31 ± 0.01). Likewise, total phenol (mg/100) also found maximum in consortium of 70 %CF + RI + AC (93.52 ± 0.80), 70 %CF + AC (92.49 ± 0.24), CF (92.46 ± 1.04), 70 %CF + RI (92.01 ± 0.17) and 70% CF (91.18 ± 0.92).

Further, Maximum increment was further justified in the treatment of 70 %CF + RI + AC (178.92 ± 6.24) followed by the combination 70 %CF + AC (145.63 ± 4.63), 70 %CF + RI (130.519 ± 2.87) and CF (120.30 ± 2.77). Beta carotene (ug/g) was highest which is treated with 70 %CF + RI + AC (1.85 ± 0.13) followed by 70 %CF + AC (1.54 ± 0.03), 70 %CF + RI (1.38 ± 0.02), CF (1.26 ± 0.05) and 70 %CF (1.01 ± 0.02). Maximum anthocyanin (mg/g) increment was also recorded in the consortium of 70 %CF + RI + AC (2.26 ± 0.19), 70 %CF + AC (1.66 ± 0.03), 70 %CF + RI (1.37 ± 0.04), CF (1.28 ± 0.03) and 70% CF (1.1 ± 0.01). Likewise, crude fat (%) was also observed in the consortium of 70 %CF + RI + AC (2.03 ± 0.02), 70 %CF + AC (1.17 ± 0.03) followed by 70 %CF + RI (1.05 ± 0.02), CF (0.95 ± 0.02) and 70% CF (0.82 ± 0.01).

In addition, crude fibre (%) increased of 70 %CF + RI + AC (4.08 ± 0.00) followed by 70 %CF + AC (3.17 ± 0.03), 70 %CF + RI (2.97 ± 0.06), CF (2.21 ± 0.06) and 70% CF (1.12 ± 0.01). Similarly, the

Table 1
Variance analysis of the effects of different treatments on morphological and biochemical traits of greater yam.

Traits	Treatments	Year	Treatments × Year
DF	4	1	4
Days to emergence	99.76	0.34	5.91
F	56.98	0.14	3.38
P	0	0.728	0.034
Days to first leaf emergence	78.13	1.42	8.2
F	72.54	0.62	7.62
P	0	0.475	0.001
No of leaves (30 DAE)	789.69	147.45	36.77
F	22.78	13.08	1.06
P	0	0.022	0.407
No. of sprouts per seed tuber	0.71	0.02	0.04
F	47.47	1.6	3.2
P	0	0.27	0.041
Vine length 45 DAE (cm)	5045.81	72.13	117.43
F	59.99	1.2	1.4
P	0	0.334	0.279
Internode length (cm)	21.2	0.16	1.68
F	15.05	0.1	1.19
P	0	0.77	0.351
Vine Length at Harvest (cm)	19127.94	1072.27	442.22
F	19.96	0.95	0.46
P	0	0.385	0.763
leaf width (cm)	23.67	0.73	0.64
F	31.71	0.34	0.87
P	0	0.59	0.504
Petiole length (cm)	17.55	0.87	0.38
F	30.04	0.68	0.65
P	0	0.455	0.634
Tuber length (cm)	95.29	0	13.34
F	27.6	0	3.87
P	0	0.999	0.022
Diameter of tuber (cm)	21.74	0.71	0.06
F	30.56	0.77	0.08
P	0	0.429	0.986
Number of tubers per vine	1.18	0	0.03
F	42.19	0.02	1.24
P	0	0.889	0.334
Weight of tuber (kg)	3.36	0	0
F	125.62	0.24	0.17
P	0	0.651	0.949
Stem girth (cm)	3.34	0.07	0.03
F	21.35	0.71	0.22
P	0	0.446	0.922
Tuber yield per vine (kg)	2.75	0	0
F	50.54	0.06	0.14
P	0	0.824	0.966
Starch content (g/100 g)	215.22	1.06	1
F	55.36	0.1	0.26
P	0	0.766	0.9
Ascorbic acid (mg/100gm)	115.4	0.02	0.03
F	1323.95	0.08	0.42
P	0	0.789	0.788
Moisture (%)	132.18	0	1.09
F	118.47	0	0.98
P	0	0.993	0.446
TSS(°B)	26.34	0	0.01
F	49.86	0.01	0.03
P	0	0.936	0.997
Total sugar (g/100 g)	20.76	0	0.08
F	156.33	0.01	0.61
P	0	0.938	0.66
Total Phenol (mg/100 g)	4.32	1.42	3.67
F	4.84	3.55	4.11
P	0.009	0.132	0.017
Dry matter (%)	127.29	1.88	1.65
F	124.07	0.61	1.61
P	0	0.477	0.22
Mychorrization (%)	3679.5	7.91	3.22
F	1095.41	1.95	0.96
P	0	0.234	0.455
Beta Carotene (ug/g)	0.59	0.09	0.01
F	657.61	18.49	16.15
P	0	0.01	0
Anthocyanin (mg/g)	1.24	0.1	0.03

Table 1 (*continued*)

Traits	Treatments	Year	Treatments × Year
F	2804.98	22.25	72.33
P	0	0	0
Crude fat (%)	1.36	0	0
F	2895.8	0.8	8.56
P	0	0.42	0
Crude fiber (%)	7.44	0	0.01
F	7730.15	1.06	14.32
P	0	0.36	0
Carbohydrate (%)	865.38	0.73	22.05
F	1518.23	0.45	38.7
P	0	0.53	0

Table 2
Effects of several treatments with and without AMF and PSB on morphological features of larger yam.

Traits	Years	CF	70 %CF	70 %CF + RI	70 %CF + AC	70 %CF + RI + AC
Days to emergence	2018	20.99 ± 0.97a	25.45 ± 1.23a	16.74 ± 0.21a	14.84 ± 0.33a	13.72 ± 0.14a
	2019	21.62 ± 1.78a	22.17 ± 1.42b	15.78 ± 1.22a	15.53 ± 1.64a	15.58 ± 0.73a
	Overall	21.30 ± 0.31a	23.81 ± 1.60c	16.26 ± 0.47a	15.19 ± 0.34a	14.65 ± 0.92a
Days to first leaf emergence	2018	23.86 ± 1.13a	27.63 ± 1.22a	20.03 ± 0.40a	17.91 ± 0.57a	16.01 ± 0.43b
	2019	23.25 ± 0.76a	23.77 ± 1.18b	18.95 ± 1.43a	19.01 ± 0.75a	18.29 ± 0.84a
	Overall	23.55 ± 0.32b	25.70 ± 1.93c	19.40 ± 0.53c	18.46 ± 0.33b	17.15 ± 1.13c
No of leaves (30 DAE)	2018	75.98 ± 1.33b	65.21 ± 3.04b	82.38 ± 0.68b	87.49 ± 0.61a	95.61 ± 1.69a
	2019	69.16 ± 4.03c	60.64 ± 7.64c	78.78 ± 6.53b	90.49 ± 4.05b	84.98 ± 7.16a
	Overall	72.79 ± 3.18c	62.93 ± 2.28d	80.58 ± 1.80b	88.99 ± 1.44a	90.29 ± 5.31a
No. of sprout per seed tuber	2018	1.6 ± 2.20a	1.26 ± 0.09a	1.66 ± 0.09a	2.00 ± 0.00a	2.33 ± 0.09a
	2019	1.53 ± 0.09a	1.4 ± 0.16a	1.86 ± 0.16a	2.06 ± 0.09a	2.0 ± 0b
	Overall	1.56 ± 0.03b	1.33 ± 0.06c	1.63 ± 0.03c	2.03 ± 0.03c	2.16 ± 0.16b
Vine length 45 DAE (cm)	2018	123.06 ± 3.63a	105.74 ± 3.18c	103.40 ± 0.29b	150.27 ± 0.25d	172.67 ± 3.89c
	2019	117.53 ± 3.15a	98.33 ± 11.83b	127.63 ± 11.20d	140.99 ± 13.65b	185.17 ± 5.21b
	Overall	120.30 ± 2.77c	102.04 ± 3.70d	130.519 ± 2.87c	145.63 ± 4.63b	178.92 ± 6.24a
Internode length (cm)	2018	12.00 ± 0.23b	9.26 ± 0.16c	13.46 ± 0.29b	14.47 ± 0.08c	15.08 ± 0.23c
	2019	12.03 ± 1.56a	10.82 ± 0.95b	12.41 ± 1.59a	13.51 ± 1.65a	14.75 ± 0.81b
	Overall	12.02 ± 0.01c	10.04 ± 0.78d	12.93 ± 0.52bc	13.99 ± 0.48ab	14.91 ± 0.16a
Vine length at harvest (cm)	2018	296.22 ± 16.07b	243.88 ± 16.55c	345.55 ± 7.25c	373.71 ± 4.39b	402.07 ± 2.61a
	2019	305.66 ± 29.33a	240.63 ± 21.28b	354.00 ± 22.27a	343.80 ± 20.77b	372.87 ± 61.19a
	Overall	300.94 ± 4.72c	242.26 ± 1.62d	349.78 ± 4.22b	358.75 ± 14.95ab	387.47 ± 14.60a
leaf width (cm)	2018	8.51 ± 16.0b	7.65 ± 0.29c	9.06 ± 0.16d	10.38 ± 0.13c	13.07 ± 0.79c
	2019	8.90 ± 1.28a	6.85 ± 0.80b	8.91 ± 0.27b	10.54 ± 1.41a	11.90 ± 1.31b
	Overall	8.71 ± 0.19c	7.25 ± 0.42d	8.98 ± 0.07c	10.46 ± 0.08b	12.49 ± 0.58a
Petiole length (cm)	2018	8.52 ± 0.17c	7.94 ± 0.33b	9.00 ± 0.15b	10.51 ± 0.10b	12.67 ± 0.25a
	2019	8.14 ± 0.84c	8.08 ± 1.43a	8.71 ± 0.45a	10.51 ± 1.08b	11.51 ± 0.68a
	Overall	8.33 ± 0.19c	8.01 ± 0.06c	8.86 ± 0.14c	10.51 ± 0b	12.09 ± 0.58a
Tuber length (cm)	2018	25.59 ± 0.87a	21.96 ± 0.37a	26.41 ± 0.43a	30.60 ± 0.67a	34.80 ± 0.45a
	2019	25.36 ± 1.84a	25.13 ± 1.04a	25.63 ± 1.31a	32.14 ± 3.52a	30.11 ± 2.44a
	Overall	24.98 ± 0.38c	23.55 ± 1.58b	26.16 ± 0.39c	31.37 ± 0.76c	32.45 ± 2.36b
Dimeter of tuber (cm)	2018	7.00 ± 0.17c	4.76 ± 1.16c	7.42 ± 0.11b	8.22 ± 0.11c	10.15 ± 0.63a
	2019	6.61 ± 0.17c	4.67 ± 1.49b	6.94 ± 0.48a	8.12 ± 0.21a	9.67 ± 0.81a
	Overall	6.80 ± 0.19c	4.71 ± 0.04d	7.18 ± 0.24bc	8.17 ± 0.04b	9.91 ± 0.23a
Number of tubers per vine	2018	1.2 ± 0c	1.06 ± 0.09c	1.20 ± 0.00c	1.6 ± 2.20c	2.26 ± 0.18a
	2019	1.26 ± 0.09c	1.26 ± 0.09c	1.26 ± 0.24c	1.4 ± 0.28a	2.20 ± 0.16a
	Overall	1.23 ± 0.03c	1.16 ± 0.10c	1.23 ± 0.03c	1.5 ± 0.10b	2.23 ± 0.03a
Weight of tuber (kg)	2018	0.98 ± 0.03c	0.78 ± 0.07e	1.13 ± 0.06b	1.51 ± 0.45c	2.71 ± 0.24b
	2019	1.02 ± 0.13c	0.75 ± 0.05c	1.14 ± 0.07a	1.43 ± 0.16a	2.63 ± 0.21c
	Overall	1.00 ± 0.02c	0.76 ± 0.01d	1.14 ± 0.00c	1.47 ± 0.04b	2.67 ± 0.04a
Stem girth (cm)	2018	3.77 ± 0.06d	3.32 ± 0.19b	4.11 ± 0.03b	4.45 ± 0.01b	5.50 ± 0.18b
	2019	3.75 ± 0.06c	3.39 ± 0.41d	4.02 ± 0.03c	4.35 ± 0.72b	5.15 ± 0.42a
	Overall	3.76 ± 0.01 cd	3.35 ± 0.03d	4.07 ± 0.05bc	4.40 ± 0.72b	5.32 ± 0.17a
Tuber yield per vine (kg)	2018	1.32 ± 0.08c	1.04 ± 0.13d	1.50 ± 0.05b	1.81 ± 0.03b	2.72 ± 0.42a
	2019	1.29 ± 0.04c	0.92 ± 0.18d	1.46 ± 0.02c	1.79 ± 0.19b	2.79 ± 0.38a
	Overall	1.31 ± 0.01c	0.98 ± 0.06d	1.48 ± 0.02c	1.80 ± 0.01b	2.75 ± 0.03a
Moisture (%)	2018	61.60 ± 0.19b	59.20 ± 0.56c	62.84 ± 0.28b	65.43 ± 0.08b	71.26 ± 0.87a
	2019	62.19 ± 1.73c	59.03 ± 0.84b	63.09 ± 1.01c	64.02 ± 0.68c	72.00 ± 1.44a
	Overall	61.89 ± 0.29c	59.11 ± 0.08d	62.96 ± 0.12c	64.73 ± 0.69b	71.63 ± 0.37a
Dry matter (%)	2018	32.54 ± 0.58d	28.73 ± 0.87d	34.29 ± 0.34c	36.79 ± 0.25b	40.79 ± 0.56a
	2019	33.87 ± 1.74d	27.99 ± 1.44c	36.11 ± 0.72c	36.71 ± 1.27b	40.97 ± 0.84a
	Overall	33.21 ± 0.66d	28.36 ± 0.37e	35.20 ± 0.91c	36.75 ± 0.03b	40.88 ± 0.08a
Mycorrhization (%)	2018	0.00 ± 0.00c	0.00 ± 0.00c	28.98 ± 1.25b	0.00 ± 0.00c	53.07 ± 1.70a
	2019	0.00 ± 0.00c	0.00 ± 0.00c	30.96 ± 4.25b	0.00 ± 0.00c	56.23 ± 0.83a
	Overall	0.00 ± 0.00c	0.00 ± 0.00c	29.97 ± 0.99b	0.00 ± 0.00c	54.65 ± 1.57a

Means followed by the same letters are not significantly different at $P < 0.05$ (Newman-Keuls test).

Table 3
Effects of several treatments with and without AMF and PSB on biochemical parameters of greater yam.

Traits	Years	CF	70 %CF	70 %CF + RI	70 %CF + AC	70 %CF + RI + AC
Starch content (g/100 g)	2018	53.00 ± 0.90c	46.46 ± 2.34c	54.80 ± 0.14b	58.19 ± 0.34b	62.93 ± 1.33a
	2019	53.30 ± 3.30b	46.78 ± 3.23e	53.11 ± 0.67b	57.72 ± 2.02b	62.58 ± 0.76a
	Overall	53.15 ± 0.15c	46.62 ± 0.16d	53.96 ± 0.84c	57.95 ± 0.23b	62.75 ± 0.17a
Ascorbic acid(mg/100gm)	2018	14.58 ± 0.22c	13.87 ± 0.05d	15.04 ± 0.12b	19.37 ± 0.38c	24.24 ± 0.32b
	2019	14.81 ± 0.09b	13.82 ± 0.36c	15.11 ± 0.18e	19.22 ± 0.41b	24.41 ± 0.36b
	Overall	14.70 ± 0.11d	13.84 ± 0.02e	15.07 ± 0.03c	19.30 ± 0.07b	24.33 ± 0.08a
TSS (%)	2018	8.20 ± 0.00c	6.26 ± 0.96c	8.46 ± 0.04c	9.26 ± 0.16b	12.13 ± 1.10a
	2019	8.33 ± 0.04c	6.43 ± 1.08d	8.43 ± 0.04c	9.20 ± 0.08b	12.1 ± 0.98a
	Overall	8.26 ± 0.06c	6.35 ± 0.08d	8.45 ± 0.01bc	9.23 ± 0.03b	12.11 ± 0.01a
Total Sugar	2018	6.14 ± 0.24d	4.30 ± 0.62b	6.86 ± 0.06d	7.82 ± 0.06c	9.18 ± 0.17b
	2019	5.87 ± 0.81c	4.32 ± 0.49c	7.03 ± 0.06b	7.56 ± 0.17d	9.40 ± 0.36c
	Overall	6.01 ± 0.13d	4.31 ± 0.01e	6.95 ± 0.08c	7.69 ± 0.12b	9.29 ± 0.11a
Total Phenol (mg/100 g)	2018	91.42 ± 0.16b	90.52 ± 0.12b	91.83 ± 0.07a	92.74 ± 0.18a	94.32 ± 0.13a
	2019	93.51 ± 1.07a	92.11 ± 0.26a	92.18 ± 1.19a	92.24 ± 1.57a	92.71 ± 0.27a
	Overall	92.46 ± 1.04c	91.18 ± 0.92a	92.01 ± 0.17a	92.49 ± 0.24c	93.52 ± 0.80b
Beta Carotene (ug/g)	2018	1.21 ± 0.01b	0.99 ± 0.02b	1.36 ± 0.05a	1.51 ± 0.02b	1.72 ± 0.04b
	2019	1.31 ± 0.02a	1.04 ± 0.01a	1.41 ± 0.04a	1.58 ± 0.04a	1.99 ± 0.01a
	Overall	1.26 ± 0.05a	1.01 ± 0.02a	1.38 ± 0.02a	1.54 ± 0.03b	1.85 ± 0.13c
Anthocyanin (mg/g)	2018	1.25 ± 0.03b	1.09 ± 0.02a	1.33 ± 0.04b	1.63 ± 0.03b	2.07 ± 0.03b
	2019	1.32 ± 0.02a	1.11 ± 0.02a	1.41 ± 0.00a	1.69 ± 0.02a	2.46 ± 0.02a
	Overall	1.28 ± 0.03c	1.1 ± 0.01b	1.37 ± 0.04b	1.66 ± 0.03c	2.26 ± 0.19a
Crude fat (%)	2018	0.93 ± 0.01b	0.83 ± 0.02a	1.08 ± 0.03a	1.14 ± 0.02b	2.01 ± 0.02b
	2019	0.97 ± 0.02a	0.81 ± 0.01a	1.03 ± 0.02b	1.21 ± 0.02a	2.05 ± 0.02a
	Overall	0.95 ± 0.02b	0.82 ± 0.01a	1.05 ± 0.02b	1.17 ± 0.03b	2.03 ± 0.02a
Crude fiber (%)	2018	2.27 ± 0.02a	1.11 ± 0.01a	2.91 ± 0.03b	3.14 ± 0.04b	4.09 ± 0.01a
	2019	2.14 ± 0.01b	1.13 ± 0.02a	3.04 ± 0.04a	3.21 ± 0.04a	4.08 ± 0.02a
	Overall	2.21 ± 0.06b	1.12 ± 0.01a	2.97 ± 0.06b	3.17 ± 0.03b	4.08 ± 0.00c
Carbohydrate (%)	2018	67.61 ± 0.40a	51.87 ± 0.42b	74.75 ± 0.52a	77.71 ± 0.52a	81.42 ± 0.62b
	2019	60.55 ± 0.41b	53.75 ± 0.59a	75.46 ± 1.08a	78.42 ± 0.96a	83.61 ± 1.12a
	Overall	64.08 ± 3.53a	52.81 ± 0.94b	75.1 ± 0.35a	78.06 ± 0.35b	82.51 ± 1.09b

*Means followed by the same letters are not significantly different at P < 0.05 (Newman-Keuls test).

increase in carbohydrate (%) was also observed to be maximum with 70 %CF + RI + AC (82.51 ± 1.09) followed by 70 %CF + AC (78.06 ± 0.35), 70 %CF + RI (75.1 ± 0.35), CF (64.08 ± 3.53) and 70% CF (52.81 ± 0.94). However, it should be noted that the most significant results were produced in the treatments (Table 3).

4. Discussion

Natural soil comprises millions of microbial colonies such as *Rhizophagus irregularis* and Nitrogen Fixing Azotobacter, playing an indispensable role in plant growth and development (Sangwan et al., 2012; Rana et al., 2020). To determine the effect of treatments chemical fertilizer, 70% chemical fertilizer, 70% chemical fertilizer + RI, 70% chemical fertilizer + AC and 75% CF + RI + AC are applied to know the feasibility of microbial inoculation *Rhizophagus irregularis*, Nitrogen Fixing Azotobacter and chemical fertilizers particularly their combination as different microorganism have different effects on plants (Bhardwaj et al., 2021). It is declared from results that consortium treatment having 75% CF + RI + AC was proved to be the best treatment out of all treatments. 75% chemical fertilizer, *Rhizophagus irregularis* (AMF) and Azotobacter out of all arbuscular mycorrhiza fungi involved for growth of roots of greater yam and Azotobacter fix the atmospheric nitrogen to the greater yam which might be why our study days to emergence and days to first leaf emergence increased compared to 75 %CF (Mohamed et al., 2014; Cherif et al., 2015). This might be the reason for the days to emergence and days to first leaf emergence of greater yam with *Rhizophagus irregularis* and Nitrogen Fixing Azotobacter.

In the investigation, it was noted that no leaves (30 DAE) number of sprouts per tuber are increased. One possible explanation could be related to the morphology of *D. alata* cultivars (Orkwor et al., 1998). Vine length 45 DAE and vine length at harvest, the initial growth of vines is dependent on the food reserves of planted setts, with established root system which starts absorbing nutrients from the soil, shoot growth and canopy development become faster, and this phase necessitates proper trailing of vines to expose the canopy to sunlight (Sunitha et al., 2020). Tuber length (cm) is increased by applying the treatment results obtained with other species of bacteria in yam crops report similar results (Swain et al., 2007).

Rhizophagus irregularis (arbuscular mycorrhiza fungi) and Nitrogen Fixing Azotobacter can potentially interact synergistically; consequently, the plants live in mutualistic harmony (Ordoñez et al., 2016). Therefore, AMF and Azotobactor can interact synergistically when these nutrients are applied. In addition, the treatment in combination with chemical fertilizers proved to be better for the diameter of tuber (cm) stem girth (cm).

This study shows that inoculation by AM fungi and Azotobacter significantly changes the yield and composition of greater yam for starch content (g/100gm) ascorbic acid (mg/100gm), the similar results were findings on eggplant and potato by Sharma et al. (2021) and Saini et al. (2021). The joint application of mycorrhizae with Azotobacter allows the fixed amounts of atmospheric nitrogen to be more remarkable because the fixing bacteria have a greater amount of available phosphorus (an essential element for the fixation of nitrogen), supplied by the activity of the solubilizing organisms was reported by Dixon and Kahn (2004). The treatments in combination with chemical fertilizers proved to be better for total phenol (mg/100 g), one possible explanation of total phenol (mg/100 g) may be attributable to different factors such as genetic, climate, and environmental conditions (Paul et al., 2020). The use of anthocyanin as a food colouring in ice cream, lemon juice, and hard candy in the food business highlights the significance of this antioxidant.

Furthermore, the arbuscular mycorrhiza fungi have emerged as an essential component of the soil's ecosystem, and inoculation with these fungi has resulted in significant increases in the devel-

opment of plants when they are exposed to them. Such bacterial populations could be significant in developing diverse agricultural ecosystems (Wei et al., 2018). In this respect, some reports indicate that Azotobacter might positively influence the growth and yield of some plants, not only due to the contributions in nitrogen but also due to the production of a series of hormones, in particular auxins, gibberellins, and cytokinins (Noumavo et al., 2013).

This confirms our findings that 70 %CF + RI + AC showed the best growth, reported similar results and increased them to grow without external sources. However, isolation of AMF differs in their sensitivity to soil and plant levels, and therefore, fertilizer application may alter the activity of the symbiosis (Sylvia and Schenck, 1983). These microorganisms, also known as Plant Growth-Promoting Rhizobacteria (PGPR) and Rhizophagus irregularis (arbuscular mycorrhiza fungi), are often regarded as very helpful for nitrogen fertilizer replacement programs in key crop species (Russelle et al., 2008; Norman and Friesen, 2017; Rodrigues et al., 2018). For instance, plants characters are treated with chemical fertilizers, 70% chemical fertilizer, 70% chemical fertilizer + RI, 70% chemical fertilizer + AC, and 75% CF + RI + AC had shown enhanced effect because the microbial population makes the absorption of the nutrients easy as compared to those which were treated with less amount of 70% chemical fertilizer (Ramirez-Villanueva et al., 2015). We found that 75% CF + RI + AC, 70% chemical fertilizer + AC, 70% chemical fertilizer + RI and chemical fertilizer were suitable treatments out of all treatments.

5. Conclusion

Greater yam (*D. alata* L.) cultivation with a higher dosage of chemical fertilizers add a sufficient amount of nutrients required by the plant and allow the growth of the same vegetable plants in the same area. Plant bioinoculants, such as AMF and Azotobacter, have been studied for their efficacy in crops to reduce the need for chemical fertilizers in agriculture. As a result of our research, we discovered that bioinoculants' appropriate and sensible application provides sufficient nutrients and other substances to the host greater yam, resulting in improved development, nutritional value, and yield of the greater yam in question. The combined application of these AMF and Azotobacter biofertilizers could reduce the overuse of full chemical fertilizers in more outstanding yam production while maintaining or improving the physiology and yield. Overall use of above treatment enhances the agronomical and biochemicals traits of greater yam. From the results, it is suggested that *Rhizophagus irregularis* and nitrogen fixing Azotobacter form strong interaction for nutrient and revealed that they influence yield.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Declaration of Competing Interest/Competing interests

The authors have no conflicts of interest to declare.

Ethics approval

Not applicable.

Consent to participate

All authors consent to participate in the manuscript publication.

Consent for publication

All authors approved the manuscript to be published.

Availability of data and material

The data supporting the conclusions of this article are included within the article. Any queries regarding these data may be directed to the corresponding author.

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Author Contributions

AK and SDYN designed the research and edited the manuscript; PK and AK helped in Methodology and Project administration; AK and SDYN conducted experiments; EK, MA, and PA analyzed the data., BNS and PK revised the manuscript to the present from.

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