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SHORT COMMUNICATION

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Influence of arbuscular mycorrhizal fungi in sugarcane productivity under semiarid tropical agro ecosystem in India

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Abstract

Impact of Arbuscular mycorrhizal fungi (AMF) in sugarcane productivity was assessed through a field experiment from plant and ratoon sugarcane in Tamil Nadu, India. Control, 12.5 and 18.75 kg ha^{-1} of AMF along with 75% and 100% of phosphorous application were triedas treatments. 18.75 kg ha^{-1} AMF applied plots showed significant difference in germination percentage, tiller number, internode thickness and ultimately in cane yield in both plant and ratoon crop comprising two seasons. Quality parameters such as Pure Obtainable Cane Sugar and brix% of sugarcane were also significantly improved with the application of AMF, compared to control. The yield and post harvest soil fertility data showed that there is considerable statistically significant difference between AMF applied plots and control plots. These results suggest that the application of AMF will assist in improving the profitability of the farmers through higher sugarcane productivity and sustaining soil fertility. Besides, the quantity of phosphorus fertilizer application can also be reduced by 25% and application of AMF as a biofertilizer to sugarcane is good boon for millers since it has a direct impact on the quality of sugarcane juice.

Keywords: Biofertilizer; Phosphorus; Sugarcane; Yield and sugar content.

Introduction

The ability to take advantage of the natural resources is a major step towards economic prosperity for a country like India as usage of chemical fertilizers for crop production is expensive, mainly because of shortfall in availability and the problems of environmental pollution. Scientists are currently interested in developing alternative technology to minimize the dependence on chemical fertilizers and encourage the use of bio-fertilizers on a large scale by the farming communities. Sugarcane (*Saccharum spp*.) is a tropical and subtropical crop, which produces a large amount of biomass and requires substantial inputs of both water and nutrients to produce maximum yield. The soil fertility has also declined in many sugarcane growing areas due to improper and distorted fertilizer schedules adopted over the years under intensive cultivation of the crop. On average, sugarcane crop yielding 100 t ha^{-1} would remove 200-250 kg of N, 120-150 kg of P and 175-225 kg of K from soil (Surendran and Murugappan, 2006). Our study area (Command area of Pettavaithalai) is also deficit in N, medium in P and deficit in other micronutrients. Among all the micro nutrients, zinc and iron deficiencies are very high; 91.5 and 68% soils in our command area are deficit in zinc and iron, respectively (Surendran et al., 2007). At this juncture, we planned to study the impact of bio fertilizer *viz*., Arbuscular Mycorrhiza Fungi (AMF) on the yield and quality of sugarcane as an option to use bio fertilizers. Because of dwindling phosphate reserves and soaring prices for phosphate fertilizer (Van Vuuren et al., 2010), there is a renewed interest in the capability of AMF to efficiently supply plant-available phosphorous in agricultural production systems, especially for sugarcane, since P application has a direct impact on the quality of sugarcane juice.

The term vesicular-arbuscular mycorrhiza (VAM) was originally applied to symbiotic associations formed by all fungi in the Glomales, but because a major suborder lacks the ability to form vesicles in roots, AMF is now the preferred form of writing. Globally mycorrhiza occurs in 83% of dicots and 79% monocots. Mycorrhiza is undoubtedly of extraordinary importance in plant production, plant and soil ecology and plays a key role in sustainable agriculture. Infection of crop roots with AM fungi can improve their uptake of nutrients, particularly of phosphorus and increase crop production (Joner, 2000; Atimanav and Adholeya, 2002).

As AM fungi improve crop health and soil quality, it would be desirable to exploit further the symbiosis for agriculture (Miller and Jastrow, 1992). However, it is not known how to take best advantage of the AM fungal communities indigenous to cultivated soils and so far, inoculation of field-grown crops has yielded variable results. For example, considerable yield increase was noticed after inoculation of field-grown maize and leeks, respectively (Furlan, 1993). However, Hamel (1996) found no significant effect of inoculation of field-grown maize and soybean, unless the soil was fumigated before seeding. It must be recognized that AM inoculation is still largely restricted to experimental plots even if commercial inoculums has been available since 1984 in the United States and 1991 in Canada. In another study it has been stated that the presence of AMF fungi in long-term sugarcane growing fields associated with yield decline led to the supposition that AMF may be responsible for the poor yields. However, the published data from such holistic studies are often difficult to interpret and to compare (Martinez and Johnson, 2010). Phosphorus solubilising biofertilizers solubilise the unavailable phosphorus to available P form and increase the P use efficiency. Inclusion of biofertilizers in the nutrient management programme has found to increase the yield of sugarcane by 5-10%, besides increasing the nutrient use efficiency (Ramesh et al., 2004). More results are needed for clear trends to emerge and to decide whether we can go for large scale application of AMF by farmers in semi arid tropical agro ecosystem in India. The present investigation was aimed out to assess the effect of AMF on growth, yield and quality of sugarcane and to promote the application of AMF to sustain the soil fertility in the command area, if it is giving profitability to farmers.

Materials and Methods

The field experiment was conducted at Research and Development farm of EID Parry located at Vishwanath apuram (10^{o} 53’ 57 N, 78^{o} 29’ 35 E, elevation 276 ft) of Petta vaithalai, in the Tamil nadu state of India in the special season (July planting). The study was done as a 2 years field experiment (one sugarcane plant crop and one sugarcane ratoon crop) along with multi location experiment during 1 year. Hence the entire study period was more than 3 years (40 months). The climate of the experimental site is semi-arid, subtropical with hot dry summers and cold winters. The average annual rainfall is 648 mm and nearly 80% of the rainfall is received from northeast monsoons during September to December. Initial soil samples were collected from the experimental plots and the samples were analyzed for its chemical properties using standard analytical procedures. The soils are red soils of Irugur Soil series with USDA taxonomical class of *Kaolinite; Isomegathermic deep*; *Typic Ustorthents*. The soils are sandy loam with 62% sand, 20% silt and 18% clay. Chemically, soils had pH of

7.72, Organic matter content of 0.47%, Phosphorus 16.5 kg ha^{-1}, Potassium 490.1 kg ha^{-1}, Nitrogen 137.8 kg ha^{-1}, Calcium 475.4 mg kg^{-1}, Magnesium 134.5 mg kg^{-1} and Zinc 0.97 mg kg^{-1}. Source of water in the R & D farm is from open well and it is having a pH of 7.42 and EC of 2.16 dSm^{-1}. The design was randomised block design with four replications having a plot size of 72 m^2 (10 m × 6 rows × 1.2 m). Sugarcane plant crop trial was initiated during July 2007-08 (special season). Co 86-032 was the selected variety because which occupies more than 60% of the command area. AMF was applied as control (without AMF-0), 12.5 and 18.75 kg ha^{-1} along with 75% and 100% of recommended P were tried as treatments. Commercially available AMF biofertilizer certified by Tamil Nadu Agricultural University was applied as basal in the soil after 5 days of planting (during establishment of roots). Nitrogen, Phosphorus and Potassium were applied as per the recommended dose, of 275, 150 and 150 kg ha^{-1}, respectively. All the cultural and management practices are followed uniformly to all plots as per the sugarcane growth calendar published by R & D centre, EID Parry (Crop Calendar, 2006). The growth parameters such as Germination count, tiller number, cane girth, mill able cane, agronomic desirability and cane yield were recorded by adopting standard procedures. Small Mill Test (SMT) samples were collected at 12^{th} month and quality parameters such as brix, pol%, purity, fibre and Pure Obtainable Cane Sugar (POCS) and sugar yield was worked out using the standard procedures. The crop was allowed for rationing (second crop) and the same procedure was repeated again. Post harvest soil samples were collected from the field and analysed for the nutrient characteristics and AMF colonization. Plant roots and rhizosphere soil samples were collected from the AMF applied plot and control plots. The samples were analyzed at the PG Department of Plant Science, Government College Karaikal for the root colonization and spore count of AMF. Mycorrhizal chitin was stained with lactic-trypan-blue according to the procedure as described by Philips and Hayman (1970). The root infection percentages (colonization) were calculated from number of infected segments out of total root showed segments during their examination microscopically on a glass slide. Economic profitability is calculated using the standard procedures. Data from this experiment was subjected to statistical analysis using AGRES software of Tamil Nadu Agricultural University.

Results and Discussion

Germination per cent and tiller number was significantly influenced by the application of AMF and it was statistically significant against the control plot (without AMF applied plot). Tiller number was higher with 100% of recommended dose of P along with AMF 18.75 kg ha^{-1} applied plot (T_6) (Table 1). There is a slight difference in agronomic desirability in the AMF applied and control plot, however, it was not so significant (data not shown). Yield attributes was higher with 100% of recommended dose of P along with AMF 18.75 kg ha^{-1} applied plot (T_6). However it was on par with that of T_5, T_2 and T_3 treatments. The average yield of one plant and ratoon data showed that the highest yield was recorded in 100% of recommended dose of P along with AMF 18.75 kg ha^{-1} applied plot (T_6). Similar to the crop growth traits and yield attributes, this is also on par with that of T_5 and T_3 treatments. In general AMF applied plot performed better than the control plot. Similarly root length and weight of the AMF applied plots were higher than the control plots (data not shown). The possible reason may be the volume of soil exploited by plant roots can be greatly increased by the external mycelium of arbuscular mycorrhizal (AM) fungi (Bolan, 1991; Marschner and Romheld, 1998). The likely cause for influence of AMF is that they are able to grow beyond the depletion zones around the plant roots and they are able to increase the uptake of immobile nutrients such as P and also micronutrients, resulting in the enhanced growth of sugarcane and related yield parameters (Hodge et al., 2001; Hodge et al., 2010). Application of AMF significantly influenced the quality parameters of sugarcane juice *viz*., Brix, Purity, Fibre content, Pure Obtainable Cane Sugar (POCS) and Commercial Cane Sugar (CCS) contents (data not shown). Highest POCS recorded in AMF (18.75 Kg) applied plot compared to other plots (T_6) and it is good for millers since it has a direct impact on the profitability. Post harvest soil fertility status also proved that the fertility is being sustained in the case of AMF applied plots. The available N and P status in AMF applied plots has been statistically significant than the control plots, where as K it is non significant (Table 2). The colonization with AMF was positively correlated to sugarcane plant height, at the first cutting. These post harvest soil fertility status confirms that 25% of P fertilizer can be reduced in medium P soils, without affecting the sugarcane yield and sustainability of soil fertility. Similar findings have been reported by Kelly et al. (2001), in which application of P fertilizer is not necessary for sugarcane when acid-extractable P<30 mg kg^{-1} if sufficient VAM propagules are present. The possible reasons for improvement in cane yield and quality might be due to the improved rooting and plant establishment; improved uptake of low mobile ions such as P, improved nutrient cycling; enhanced plant tolerance to stress (biotic and abiotic) and improved quality of soil structure. The AMF have a high-affinity P-uptake mechanism that enhances P nutrition in plants. The AMF are able to scavenge the available P through their hyphae that have large surface areas on which the extra radical hyphae act as a bridge between the soil and sugarcane roots (Liu et al., 2000; Kelly et al., 2001). AMF colonization results showed that AMF applied plot had higher amount of AM spores indicating the multiplication of AMF at higher rate which might have assisted in solubilization of nutrients, when compared to the control plot. In control sample the average number of AM spores present was 150 AM spores whereas in AMF applied plot it was 1014 AM spores. Root colonization per cent was higher in AMF applied plot to the tune of 97%. Root colonization of AM spores is high in AMF applied plot, which indicates that upon colonization, the mycelium of the VAM increases the nutrient absorbing surface area of the root by symbiosis, enhances exploration of a larger soil volume and thereby increases nutrient uptake (Figure 1) and finally resulted in higher sugarcane yield.

Table 1. Impact of AMF on growth and yield attributes of sugarcane*.

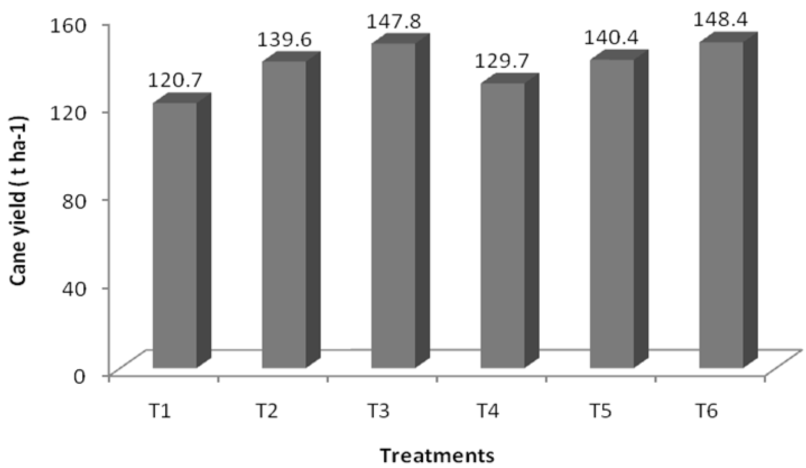
Treatments	Germination%	Tiller Number (lakh ha^{-1})	Internode Thickness (cm)	Cane Length (cm)	Single Cane Weight (kg)	Cane yield (kg ha^{-1})
T_1: 75% of P	57.29	1.67	8.25	2.35	3.40	120.7
T_2: 75% of P + 12.5 kg ha^{-1} of AMF	77.88	3.02	8.98	2.95	3.65	139.6
T_3: 75% of P + 18.5 kg ha^{-1} of AMF	66.67	3.09	9.00	2.66	3.40	147.8
T_4: 100% of P	58.33	1.67	8.50	2.25	3.10	129.7
T_5: 100% of P + 12.5 kg ha^{-1} of AMF	71.25	3.21	9.75	2.81	3.30	140.4
T_6: 100% of P + 18.5 kg ha^{-1} of AMF	67.71	3.47	10.13	3.03	3.90	148.4
CD 5%	9.99	0.49	1.16	0.25	0.10	8.22
F value	5.24	24.18	3.64	14.54	53.00	12.31
CV	9.98	12.13	8.46	6.22	2.20	10.46

* Mean value of two crops-one plant cane and one ration cane.

Table 2. Post harvest soil fertility status (Mean of two seasons).

Treatments	Quality POCS*%	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
T_1: 75% of P	12.27	142.4	14.88	486.2
T_2: 75% of P + 12.5 kg ha^{-1} of AMF	13.51	148.6	15.50	496.4
T_3: 75% of P + 18.5 kg ha^{-1} of AMF	13.75	152.0	16.56	485.5
T_4: 100% of P	12.56	146.6	16.31	492.4
T_5: 100% of P + 12.5 kg ha^{-1} of AMF	13.55	151.5	17.85	491.6
T_6: 100% of P + 18.5 kg ha^{-1} of AMF	13.84	154.5	18.72	485.6
CD (P=0.05)	0.598	6.71	1.60	NS
CV%	3.000	6.08	4.56	5.96

* POCS-Pure Obtainable Cane Sugar.



CD (P=0.05)-8.22

Figure 1. Impact of AMF on yield of sugarcane (Mean value of two seasons).

Conclusion

The field experiment with AMF confirmed that AMF applied plots showed significant difference in germination percentage, tiller number, inter node thickness and cane yield. Besides, quality parameters such as POCS and brix% of sugarcane also significantly improved with the application of AMF, compared to control. 25% of P fertilizer can be reduced in medium P soils, without affecting the sugarcane yield and sustainability of soil fertility. These results from the field experiment helped us to promote the large scale adoption of application of AMF in sugarcane growing soils. It resulted in improving the profitability of the farmers and it is good for millers since it has a direct impact on the quality of sugarcane juice.

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