Impact of Effective Microorganisms on Nitrogen Utilisation in Food Crops

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Abstract : *Organic farming utilises different crop residues to maintain soil fertility and sustainability. However, the effectiveness of different crop residues to supply required nutrients to crops is determined by their C:N ratios. Studies using microbial solutions, including Effective Micro-organisms (EM) have illustrated greater nutrient use efficiencies of crops with the addition of such inoculants to organic matter. This enhancement could result from crops absorbing nutrients from organic matter or soil. Hence a study was conducted using 15N labelled crop residues of corn and mungbean to determine the influence of two types of microbial inoculants, EM and a slurry of cattle manure on N use efficiencies of cowpea (*Vigna unguiculata Walp*) grown in an organic system.*

Application of microbial inoculants enhanced 15N enrichment of cowpea, confirming the usefulness of inoculants in promoting nutrient availability from organic matter. A comparison of the inoculants clearly provided evidence of greater 15N enrichment in cowpea grown with EM. The impact was greater with mungbean residue, which has a lower C:N ratio. The effects of dilutions was also observed and maximum uptake was observed at a dilution ratio of 1:500. Germination and plant growth was also promoted by EM at a dilution of 1:500, when compared to plants grown with a slurry of cattle manure. The prospects of using EM as an inoculant for enhanced N utilisation from organic matter, which is a problem in most tropical organic farming systems is presented.

Introduction

Organic agriculture has received increasing attention in the past few decades, as it offers some solutions to the defects of modern intensive agricultural systems. Hence, organic farming has the potential of providing benefits in terms of environmental protection, conservation of non renewable resources, improved food quality and reorientation of agriculture (Lampkin, 1994). However, in the developing countries, where food quantity rather than the quality is the key factor, the intensive development of organic farming has not made much progress. Most organic farms practise traditional agriculture, using available organic matter from the hinterlands. Hence productivity of these farms is low. This is attributed to the lower concentrations of nutrients of the organic matter and the degraded environments used by tropical smallholder farmers for crop production (Chen and Avnimelech, 1986). Hence productivity of these farming systems is low, although the countries need to enhance yields of their agricultural sectors (RAPA, 1993).

Traditional organic farmers apply solid organic matter to soils and cultivate crops. The time taken for decomposition of the organic matter and release of nutrients for crop growth is affected by many factors. Furthermore, nutrient use patterns could also be affected by these factors. Hence application of slurries made from organic matter has enhanced the efficiency of applied organic matter, especially animal manures (Stein-Bachinger and Werner, 1997). This process would also improve the microbial biomass of soils.

In the recent past, solutions of Effective Micro-organisms (EM), developed in Japan have been used to enhance productivity of organic farming systems (Parr et al, 1996). The benefits of applying the solutions of EM range from more rapid release of nutrients from organic matter for vigorous crop growth. Due to the small quantity required in comparison to organic slurries, application of EM would be easily accommodated into conventional organic farming systems. Comparative studies under field conditions (e.g. Sangakkara et al, 1998) have shown that the application of EM or slurries of cattle manure enhance phosphorus and potassium uptake by crops, where the beneficial impact of EM was observed to be greater. However, nitrogen is considered the most limiting nutrient in tropical systems, especially in organic farming as shown recently by Hodtke et al, (1999). Thus a field study was carried out to determine the impact of EM or slurry of cattle manure on nitrogen utilisation patterns from crop residues labelled with 15N.

Materials And Methods

The experiments were carried out at the University farm, located 20 km from the main campus, over the period May – August, 1997 to encompass the normal dry seasonal cultivation of the country. The mean rainfall received at the site over the experimental period was 422 mm and the mean temperature ranged between 29° - 32°C over the year.

The soil of the site was an Alfisol with a pH (1:2.5 H_2O) of 6.21 $\pm$ 0.16 and an organic carbon content of 0.98 percent. The available nitrogen content was 0.54 percent.

With the onset of rains in late April, land was tilled and plots of dimensions 2 x 2 m were prepared. Thereafter, crop residues of corn (*Zea mays* L – - Enrichment 2.04 percent, N 1.98 per cent) and mungbean (*Vigna radiata* L Wilczek - Enrichment 3.96 per cent, N 2.36 per cent) obtained from another experiment which used 10 per cent enriched NH_4SO_4 was applied to separate plots. The rate was equivalent to 8 MT per ha (800 g of fresh crop residue per m^2)) and the materials were incorporated into the soils. Thereafter, a solution of EM or a slurry made with fresh cattle manure was applied onto the plots containing the different crop residues at dilutions of 1:100, 1:500 or 1:1000, at a rate equivalent to 4 litres of the concentrated solution per ha. Thus, the experiment, which had six treatments (2 microbial solutions at three dilutions) was laid out in a randomised block design with three replicates per treatments. Utmost care was taken to avoid contamination between EM treated and non treated plots.

Uniform seeds of Cowpea (*Vigna unguiculata* L Walp) were planted at a spacing of 25 x 10 cm in the plots two weeks after the application of microbial solutions. The time for 70 per cent germination was recorded and the plots weeded manually on two occasions. No fertilisers were applied and the plots were irrigated in the absence of rainfall for four consecutive days. The slurries of cattle manure or the solution of EM were applied onto the same plots at V1, V4 and V8 growth stages at the same dilutions and rates.

At the onset of flowering (R1 growth stage) three plants from each plot were carefully uprooted, washed and dried at 80^{o}C for 24 hours. The samples were weighed and ground for 15N analysis by emission spectrometry, with selected samples analysed at the International Atomic Energy Agency, Vienna for comparison of errors.

At crop maturity, seed yields (corrected to 10 per cent moisture content) were determined on 8 plants per plot.

The data was subjected to statistical analysis using a General Linear Model to identify the significance of observed differences.

Results and Discussion

Nitrogen Uptake from Crop Residue

Application of EM to both types of residues induced greater levels of 15N enrichment in cowpea plants than when cattle manure was applied as a slurry (Table 1). This phenomenon was evident at all dilutions of the microbial inoculants. This suggests that EM through its fermentative process (Higa, 1996), has a greater impact in releasing N from crop residues. The lower rates of 15N release from organic matter to which cattle manure slurry was added could be due to microbial utilisation or more rapid decomposition, thereby removing N from the rhizosphere. This warrants further study.

Cowpea grown with mungbean residue had higher levels of enrichment. The impact of EM was also greater in increasing the 15N enrichment of cowpea than cattle manure slurry. However, this suggests that the microbial additives release greater quantities of N from crop residues having low C:N ratios. This in turn implies the benefits of using crop residues with low C:N ratios, especially with a microbial inoculant, to obtain greater quantities of N, an element that is generally deficient in tropical organic farming systems. The use of EM enhances this effect rather than cattle manure.

Application of both types of inoculants at a dilution of 1:500 produces the highest level of enrichment in cowpea. While the values of enrichment are greater with EM, the consistent trend seen with both inoculants suggests that high concentrations of these solutions could lower N availability from residues. This could be attributed to the immobilisation of N or microbial consumption. A dilution of 1:1000 produces similar levels of enrichment obtained with 1:500, although in some instances the differences are significant. Hence a dilution of 1:500 could be considered a useful guideline for the application of both EM and slurry of cattle manure.

Table 1. Impact of Microbial Solutions on Nitrogen Uptake from Different Crop Residues by Cowpea at the R1 Growth Stage

Crop Residue	Microbial Solution	Dilution	% N Excess	% NdfR	% N Use Efficiency
Corn	Slurry of Cattle Manure	1:100	0.241	16.4	14.1
		1:500	0.262	18.9	24.2
		1:1000	0.255	18.2	20.5
	Effective Microbes	1:100	0.206	17.5	19.8
		1:500	0.242	22.4	28.7
		1:1000	0.240	19.6	25.4
Mungbean	Slurry of Cattle Manure	1:100	0.194	18.8	17.4
		1:500	0.301	20.5	21.8
		1:1000	0.295	20.1	21.4
	Effective Microbes	1:100	0.224	19.5	20.8
		1:500	0.342	23.8	26.1
		1:1000	0.338	22.1	25.4
Sx (mean)			0.052	1.580	2.247
Probability	Residue x Solution		0.004	0.027	0.042
	Residue x Dilution		0.584	0.140	0.221
	Solution x Dilution		0.041	0.008	0.035
	Residue x Solution x Dilution		0.068	0.451	0.552

Percent Ndfr = Percentage nitrogen derived from fertilizer (crop residue)

Table 2. Germination and Yield of Cowpea as Affected by Crop Residue, Microbial Solutions and their Dilutions

Crop Residue	Microbial Solution	Dilution	% Germination	Dry matter (g/plant)	Seed Yield (g/plant)
Corn	Slurry of Cattle Manure	1:100	48	6.89	1.43
		1:500	84	9.24	2.96
		1:1000	85	8.15	2.64
	Effective Microbes	1:100	52	7.18	2.35
		1:500	91	10.42	3.99
		1:1000	88	9.15	3.80
Mungbean	Slurry of Cattle Manure	1:100	36	9.24	2.62
		1:500	78	12.94	3.87
		1:1000	74	12.91	3.48
	Effective Microbes	1:100	49	11.85	3.41
		1:500	84	14.46	4.19
		1:1000	82	14.03	4.12
Sx (mean)			8.15	2.47	0.52
Probability	Residue x Solution		0.019	0.040	0.023
	Residue x Dilution		0.441	0.841	0.210
	Solution x Dilution		0.009	0.011	0.046
	Residue x Solution x Dilution		0.552	0.088	

The percentage N derived from residues (per cent NdfR) and N use efficiencies (Table 1) are based on N contents of plants, supplied residues and enrichment. Hence these values follow the same trend as that of per cent N excess. However the data of these two parameters also show clearly that EM increases NdfR significantly, thus developing higher N use efficiencies. This is especially true with enriched mungbean residues, when EM is added at a dilution of 1:500.

Crop Growth and Yield

Application of EM and cattle manure slurry at a dilution of 1:100 reduced germination (Table 2). This clearly suggests a toxic effect of the high concentrations of microbial inoculants. In contrast, the supply of the inoculants at dilutions of 1:500 or 1000 increased germination significantly. The synergistic effects of the inoculants could be considered the causal factor.

The addition of EM increased germination than when cattle manure slurries were used at all dilutions. This is especially true with mungbean, a small seeded crop. Hence, the toxic effect of EM is less on the process of germination, which is a very favourable factor in organic farming.

Plant growth and more importantly yields of plants are enhanced by the use of EM. This again suggests the beneficial impact of this inoculant when compared with cattle manure slurries. The use of a dilution of 1:500 produces the highest growth and yields in cowpea, irrespective of the type of organic matter and inoculant. The use of a dilution of 1:1000 also produces high plant dry weights and yields. This again implies the use of lower concentrations of inoculants to avoid toxic effects.

The use of residues with a low C:N ratio (mungbean) produced greater yields than when corn residues were used. This could be a direct effect of greater availability of nitrogen from the residues and the other benefits of such high quality organic matter. This again suggests the benefits of using organic matter with low C:N ratios for organic farming, and the use of EM produces the best effects.

Conclusions

The field study carried out to determine the benefits of using EM or slurry of cattle manure in increasing productivity of organic systems clearly present the benefits of using a microbial inoculant. The use of EM increases the utility value of crop residues, as shown by the 15N enrichment of cowpea, when compared to cattle manure. This results in better crop growth and yields. Germination is also less hampered by EM. The rates of application could vary from 1:500 to 1:1000, although the former is more beneficial.

Most organic farming systems recommend the use of microbial slurries, especially from material such as cattle manure. The process of preparation of such inoculants is cumbersome and transport is difficult. In contrast, EM, which is now available in many countries and is made from microbes found within each country is easy to use, with much less problems. The cost of procuring EM especially in the developing world could be considered negligible when compared to the problems associated with using slurries of material such as cattle manure. The benefits of using EM accrue from better utilisation of organic material, resulting in greater efficiencies and higher yields on a sustainable basis from organic systems.

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