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N fixation and N transfer in Maize/Cowpea and Sorghum/Cowpea intercropping systems as determined by ^{15}N isotope dilution technique

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ABSTRACT

N fixation and N transfer in maize/cowpea and sorghum/cowpea intercropping systems, as determined by ^{15}N isotope dilution technique was studied in two field trials conducted at Bata-atha, in the dry zone of Sri Lanka. Two cvs. of cowpea *i.e*; Bombay and MI-35 were used in maize/cowpea intercropping system, with following combinations of treatments; maize/Bombay, maize/MI-35, Bombay (monocrop), MI-35 (monocrop) and maize (monocrop). A similar set of treatments was used in sorghum/cowpea intercropping system also. The ^{15}N atom excess, % Ndfa, total amount of N fixed, N yield and the total dry matter production were estimated. Maize/cowpea intercropping resulted in an increase in total dry matter production and total N yield compared to monocrop treatment. However the %Ndfa and total N fixed showed a decrease compared to monocrop stand. The %Ndfa was 60-65% in monocrop while the same was 45-50% in intercropped treatments.

Keywords: N fixation, N transfer, ^{15}N isotope dialution technique, %Ndff, %Ndfs, %Ndfa

INTRODUCTION

Intercropping cereals with legumes is practiced widely throughout the tropics (Ruthenbarg 1971; Okigbo and Greeenland 1976). Cereals deplete soil nitrogen and produce carbohydrates while legumes fix atmospheric nitrogen and produce protein. The cereal legume mixture improves the diet of tropical farmers as well as the soil of their farms (Tariah and Wahua 1985). Nitrogen is the most commonly exhausted nutrient in soil owing to high demand, whereas legumes can fix this element from the atmosphere. Cowpea, a legume, which matures simultaneously with maize and sorghum, is an ideal crop to grow between rows of maize and sorghum as an intercrop.

In view of the increasing prices and undesirable environmental effects of nitrogen fertilizers, concern has been expressed about the need to seek cost effective and environmentally acceptable sources of N. In this context, N fixed by legumes is assumed to be very important. Legumes are, therefore, being increasingly used in cereal-based intercropping systems (Ofori and Stern 1987). The level of N supplied by a legume to the associated crop in an intercropping system depends on the legume species (Bandyopadhay and De 1986; Senaratne *et al.* 1991). Studies conducted previously have also shown that the N fixation may vary considerably with genotype/variety (Eaglesham *et al.*1982; Graham and Temple 1984; Gillar *et al.* 1987; Awonaike *et al.* 1990). So, there may be a considerable genotypic variability in the N fixing and N supplying ability of legumes to the associated cereal crop in dual stand. Therefore, studies to determine the amount of N fixed by legumes and N transfer from legumes to associated cereals is important in improving and sustaining the productivity of low-input cropping systems practiced in the dry zone of Sri Lanka. This study was conducted to understand the N fixation of legumes and N supplying ability from cowpea to maize or sorghum in maize/cowpea and sorghum/cowpea intercropping systems as affected by cowpea cultivar.

MATERIALS AND METHODS

The study was conducted in a field at Bata-atha ($6^{0}.15'$N, $80^{0}.54'$ E, 5m amsl) in low country dry zone of Sri Lanka. The soil of the area was Reddish Brown

Earth classified as Rhodosulfs. Maize cv. Badra and sorghum cv. IS-2941 were grown in monocrop and intercrop stands with two cvs. of cowpea; Bombay and MI-35 as separate experiments. In addition to that, monocrop stands of cowpea cvs. Bombay and MI-35 were also included. Both experiments were laid out in a 5x4 Randomized Complete Block Design with four replicates using 3.6x2.1 m plots separated by 40cm wide drains. Blocking was done against the direction of soil gradient. Treatments used in the Experiment 1 were; maize/Bombay intercrop, maize/MI-35 intercrop, Bombay monocrop and maize monocrop. The treaments of Experiment 2 were sorghum/Bombay intercrop, sorghum/ MI-35 intercrop, Bombay monocrop, MI-35 monocrop and sorghum monocrop.

Maize/sorghum seeds were planted in rows at the rate of two seeds/hill with the spacing of 60x30 cm and thinned out to a single plant per hill, two weeks after planting. Three rows of cowpea were planted by replacing each alternative row of maize/sorghum in intercropped plots. Cowpea seeds were planted at 30x15cm spacing. Maize/sorghum rows were established in east-west direction to avoid shading effect on cowpea by maize/sorghum plants. Before the establishment of crops, 1mx1m micro-plots were demarcated for the application of ^{15}N labeled fertilizer. Basal N was applied before the crop establishment at the rate of 20kg N ha^{-1}, using ammonium sulphate. ^{15}N labeled ammonium sulphate was applied at the same rate (20kg N ha^{-1}). In addition to that, 50kg of P ha^{-1}as concentrated super phosphate (46% P_2O_5) and 75kg ha^{-1} of K as muriate of potash (60% K_2O) were applied to all plots and incorporated into soil.

During the experimental period, irrigation, weeding and spraying against pests and diseases were done as and when necessary. At physiological maturity of maize, sorghum and cowpea, above ground parts of the plants were harvested, separated into pods and stover, dried to a constant weight at 80°C, and dry weights were recorded. Samples were ground finely and used for the determination of N by Kjeldhal method (Bremner and Mulvaney 1982) and ^{15}N atom excess by mass spectrometry (Fielder and Proksch 1975). The amount of N derived by cowpea was determined by the isotope dilution technique (Fried and Middleeboe 1977).

RESULTS AND DISCUSSION

Experiment 1: Maize/cowpea intercropping

Effect of intercropping on % ^{15}N atom excess, % Ndfa and N_2 fixation of cowpea

Percent ^{15}N a.e. values were significantly higher in intercropped cowpea compared to monocropped stand with slightly higher rates in maize/Bombay treatment (Table 1). This indicates that the two cowpea cvs. used for the experiment derived more of their N requirement from atmosphere when they were monocropped than intercropped, as shown by diluted % ^{15}N a.e. by fixed N in monocropped cowpea. This trend was further confirmed by % Ndfa and total fixed N_2 values also. Tthe % Ndfa was significantly higher in monocropped cowpea (62-67%) than intercropped stand (48-53%). This is expected as the plant density of legume component is reduced under intercropping. Of the two cvs. of cowpea used, variety MI-35 derived a significantly higher amount of N from the atmosphere while the lowest value of % Ndfa was recorded from the maize/Bombay intercrop. Total N fixed by monocropped cowpea was also significantly higher (71-110kg ha^{-1}) than intercropped cowpea (27-73kg ha^{-1}) and the highest N fixation was recorded in the Bombay monocrop (Table1).

Table 1. Effect of intercropping on % ^{15}N a.e., % Ndfa and N_2 fixation of cowpea

Species/variety	^{15}N a.e. (%)	Ndfa (%)	N_2 fixed (kg ha^{-1})
Maize/Bombay	0.37^a	47.7^d	72.6^b
Maize/MI-35	0.33^a	53.3^c	26.7^c
Bombay (monocrop)	0.27^b	61.8^b	109.9^a
MI-35 (monocrop)	0.23^b	67.4^a	70.8^b

Values within columns with the same letter are not significantly different (P<0.5)

Effect of cowpea variety on % ^{15}N a.e. in intercropped maize

Maize intercropped with either of the varieties of cowpea was not significantly different from monocropped maize in terms of ^{15}N enrichment (Table 2). This suggests that the transfer fixed N_2 from the legume component to the cereal has not taken place in any significant amount. Thus, the present results do not support the earlier observations (Bandyopadhay and De 1986; Senaratne *et al.* 1991), where legumes have supplied fixed N to the intercropped cereals.

Table 2: Effect of cowpea genotype on the % ^{15}N a. ex. in intercropped maize

Crop	% ^{15}N a.e. in maize
Maize (monocrop)	0.707^a
Maize/ Bombay	0.614^a
Maize/ MI-35	0.661^a

Values within the column with the same letter are not significantly different (P<0.05)

Effect of intercropping on dry matter yield and N yield of component crops

The highest total dry matter production was obtained with monocrop maize followed by maize/Bombay intercrop and maize/MI-35 intercrop (Table 3). In contrast, the significantly highest N yield was observed with maize/Bombay, which accumulated 127% more N than did monocropped maize and 13% more N than monocropped Bombay while significantly lowest value of N yield was recorded from maize monocrop (Table 3).

Table 3. Dry mater and N yield when maize intercropped with cowpea

Treatment	Total dry matter (kg ha^{-1})	N yield (kg ha^{-1})
Maize/Bombay	13720^{a}	202^{a}
Maize/MI-35	11090^{ab}	105^{c}
Bombay	6560^{bc}	178^{b}
MI-35	4980^{c}	103^{c}
Maize	14560^{a}	89^{d}

Values within a column with the same letter are not significantly different ($P<0.05$)

Experiment 2. Sorghum/cowpea intercropping

Effect of intercropping on % ^{15}N a.e., % Ndfa and N fixation of cowpea as affected by cowpea genotype

The highest % ^{15}N a.e. value was recorded in MI-35 monocrop compared to the intercropped cowpea as well as monocrop Bombay. The monocrop cowpea derived a higher %Ndfa compared to the intercropped cowpea (both intercropped Bombay and MI-35). The significantly highest amount of fixed N (31kg ha^{-1}) was recorded from the monocrop cowpea var. Bombay while the significantly lowest fixed N (8.2kg ha^{-1}) was recorded from the intercropped MI-35 with sorghum (Table 4).

Table 4. Effect of intercropping on % ^{15}N a.e., % Ndfa and N fixation of cowpea

Treatment	^{15}N a.e. (%)	N dfa(%)	N_2 fixed (kg ha^{-1})
Sorghum/Bombay	0.186^{a}	25.8^{a}	22.9^{b}
Sorghum/MI-35	0.152^{a}	12.7^{b}	8.2^{d}
Bombay	0.149^{a}	28.6^{a}	30.9^{a}
MI-35	0.213^{b}	30.0^{a}	15.6^{c}
Sorghum	0.152^{a}		

Values within a column with the same letter are not significantly different ($P<0.05$)

As in maize/cowpea experiment, intercropping did not significantly affect the % ^{15}N a.e. of sorghum, suggesting that cowpea did not transfer fixed N to sorghum (Table 5).

Table 5. Effect of cowpea cultivars on the % ^{15}N a.e. in intercropped sorghum

Crop	% ^{15}N a.e. in sorghum
Sorghum monocrop	0.44^{a}
Sorghum/ Bombay	0.33^{a}
Sorghum/ MI-35	0.36^{a}

Values within a column with the same letter are not significantly different ($P<0.05$)

A significantly higher total dry matter production was noted when cowpea var. Bombay was intercropped with sorghum compared to the cowpea var. MI-35 intercropped with sorghum as well as monocrop sorghum and monocrop cowpea. But there is no significant difference between dry matter yield of intercropped cowpea var. Bombay and MI-35 (Table 6). The significantly highest total dry matter production was noted in sorghum/Bombay intercropping treatment while the significantly highest total N yield was recorded in monocropped Bombay. The total N yield was significantly higher in monocropped cowpea compared to the respective intercropped cowpea treatments.

Table 6. Effect of intercropping on dry matter and total N yield of cowpea

Treatment	Total dry matter (kg ha^{-1})	Total N (kg ha^{-1})
Sorghum/Bombay	5180^{a}	98.6^{b}
Sorghum/MI-35	5160^{a}	75.9^{c}
Bombay	3980^{ab}	107.9^{a}
MI-35	2460^{b}	51.9^{d}
Sorghum	2960^{b}	15.9^{e}

Values within a column with the same letter are not significantly different ($P<0.05$)

CONCLUSIONS

The used varieties of cowpea; Bombay and MI-35 are capable of producing higher dry mater yields when intercropped with maize than sorghum. Both varieties of cowpea are capable of fixing higher amounts of N when intercropped with maize than with sorghum. The % Ndfa value was higher under monocropped cowpea compared to intercropped stands in both maize-cowpea and sorghum-cowpea intercropping. The % ^{15}N a.e. of cowpea has not changed significantly according to the cropping stands suggesting the fixed N by cowpea did not transfer to the associated maize or sorghum except in sorghum/MI-35 treatment, which recorded significantly lower % ^{15}N a.e. value compared to the monocrop MI-35. This suggests that a certain amount of N fixed by MI-35 may have been transferred to the associated sorghum crop. Thus it can be concluded that intercropping maize with cowpea resulted in greater efficiency of crop production compared to intercropping sorghum with cowpea although ^{15}N enrichment data did not suggest direct N transfer from the legume component to the cereal component.

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