Measuring N_{2}- fixation by some varieties of groundnut and their residual effect on subsequent sorghum crop using ^{15}N methodology

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ABSTRACT

Five varieties of groundnuts were studied for their exact amount of nitrogen fixation effect on subsequent sorghum crop. The ^{15}N methodology was used with a non-nodulating groundnut isoline as the reference crop. Six months after the groundnut harvest, sorghum was sown to study the presence of any residual N from fixation and/or soils own conserved N. The non-nodulating groundnut as a reference crop could detect N fixation (Ndfa) as amounting to 60% —70% of the crops need, i.e., 20%-30% more than the 40% -50% detected using sesame as the reference crop. The N derived from soil (Ndfs) was reduced from 50%-60% to 30%-40% which is much closer to what the low N (300ppm) Gezira soil can provide. Subsequent sorghum was positively affected by the preceding groundnut varieties but only variety Medani gave significant straw and total biological yields over the non-nodulating isoline. There was, therefore, an indication of residual N represented by the higher parameters recorded for the varieties. Groundnut is thus a good preceding crop for cereals though more research work is needed in the area of biological nitrogen fixation.

INTRODUCTION

The land endowment of the Sudan is estimated at 96 million hectares arable land with only about 11.5 million hectares under cultivation. The Gezira is the largest irrigated scheme (0.84 million ha) in the country. It contributes a big share in food provision. A defined crop rotation is practiced in the scheme including cotton، wheat , groundnuts , sorghum and fallow in this order. Limited areas are grown to horticultural crops and forages

Groundnut was introduced as a legume in the rotation for soil fertility preservation but it proved to be a good food in the form of cooking oil, animal feed as cake concentrates and as an export crop only second to cotton for fetching hard currency.

Research in biological nitrogen fixation (BNF) by groundnuts has received good attention since its introduction in the country, in the early 1950's. The studies conducted defined the problems encountered in the field of improving BNF by groundnuts. One of these problems is the belief that the crop is not a good N_2-fixing legume inspite of the fact that sorghum grown following groundnuts gave better yields compared to sorghum after cereals, cotton and other crops at Rahad research station (Fadil A/Rahman, personal communication). Also soil analysis immediately after the harvest of a number of crops showed that available N03-N was double under groundnut compared to maize and sorghum at Kenana research station (Mukhtar, 1973).

Nitrogen fixation was always measured by the conventional N difference method (Musa, 1974; Hadad, 1984). An experiment using ^{15}N methodology gave the best fixation as about 50% of the crop's N need with sesame as the reference crop (Mukhtar, 1993 Many experiments showed that the crop responded neither to combined nitrogen nor to seed inoculation with rhizobia (Musa, 1974; Mukhar, 1982)a fact that clearly showed the 50% fixation recorded was very low. In addition to that, a crop of groundnut yields about 180kg N/ha meaning that at least 90 kg of N are provided from the soil which is already known to be low in N (300 ppm). Considering reports of 64%, %78 and 92% N-fixed by this crop (Boddey et al., 1990; Gilla et al., 1987, and Nurhayati et al., 1991), it is clear that N-fixation by groundnuts is not well tapped here. The major factor in studying exart N-fixation using ^{15}N methodology is the reference crop used (Danso, 1988). Sesame which was used as a reference crop in earlier studies was replaced by a non-nodulating groundnut isoline in the present work.

The objectives of this study are: a) to determine the exact N fixation by five groundnut varieties that already showed differences in nodulation (Adlan and Mukhtar, 1998) using a non-nodulating groundnut as a reference crop, b) to investigate the effect of preceding groundnut varieties on subsequent sorghum production through N residual effect.

MATERIALS AND METHODS

Five groundnut varieties, MH383, Medani, Ahmedi, Kiriv, and Virginia Red together with a non-nodulating isoline were sown at the Gezira Research Farm, Wad Medani, Sudan, on 15 of June 1999 in micro-plots of 2.4m^2 situated at one end of a macro-plot of 4x6 m^2. The nitrogen fixing varieties were given the equivalent of 20 kg N/ha in the form of urea with 5.4% ^{15}N atom excess (excess over the natural ^{15}N abundance) while the isoline was given 100kg N/ha at 1.0% ^{15}N atom excess. All plots were arranged in a randomized complete block design (RCBD) replicated four times. The crop was sown in a spacing of 60x15cm with two seeds per hole.. Watering was effected every 14 days.

Fresh weight dry matter, nodulation and pod yield were the parameters studied from the main plot while data for N-flxation was collected form a sampling) area of I x 2m^2- within the microplot. Nodule counts and dry weight were measured 72 days after sowing. Ten plants were randomly taken at harvest from the center of the microplots for the ^{14}N/ 15N analysis. Plant tissue samples together with the diluted ^{15}N used were sent to the International Atomic Energy Agency (IAEA) laboratories at Sibersdorf, Vienna, for ^{14}N/ ^{15} N analysis by the emission spectrometer.

After the harvest of groundnuts, all the experimental plots were sown to sorghum (var. Ingaz) after the lapse of period of 6 months. The plots were used with minimum tillage so as not to lose their boundaries. Samples of sorghum from microplots taken at harvest were subjected to ^{15}N analysis and grain yield and its components were estimated under each genotype from the macro-plots. The data were subjected to analysis of variance procedure and mean separation done using Duncan's Multiple Range Test (DVIRT).

RESULTS AND DISCUSSION

No significant differences were obtained for the N percent, %^{15}N atom excess and nodule number per plant among the varieties (Table l). Virginia Red, however, gave significantly more nodule dry weight over the others. While Kiriz gave significantly the lowest biomass, Medani gave the highest biomass. This could be an indication of better N fixation (Rochester *et al.*, 1998). Kiriz, again, gave the least total nitrogen compared to the highest one produced by Medani (Table 2).

Table l. %N, % BN at01n excess, nodule number/plant and dry plant and the total biomass of five groundnut varieties.

Varieties	%N	%^{15}N atom excess	Nodule number/plant	Nodule dry weight (g/plant)	Total Biomass (kg/ha)
MH 383	2.14a	0.103a	457a	0.615b	8663 a
Kiriz	2.10a	0.115a	295a	0.580b	5295 h
Medani	2.16a	0.096a	298a	0.500b	8723 a
Ahmedi	2.32a	0.080a	423a	0.625b	7630 a
V. Red	2.03a	0.108a	532a	0.040a	7794 a

Means followed by the same letter(s) in each column are not significantly different according to Duncan's Multiple Range Test (DMRT) .

Table 2. Total plant N, %N derived from soil and air and kg N/ha fixed and/or taken from the soil.

Varieties	Total Plant N (kg/ha)	Ndfa Fix (%)	Ndfs (kg N/ha)	Ndfs Kg N/ha)	Ndfs (%)
MH 383	185.6 a	65.0 a	120.5 a	61.5 a	33.0 a
Kiriz	111.5b	59.7 a	68.7 b	40.5 a	38.1 a
Medani	187.9 a	660 a	124.3 a	60B a	32.2 a
Ahmedi	177.9 a	72.4 a	128.0 a	47.3 a	26.1 a
V. Red	158.1 a	61.6 a	98.0 ab	569 a	36.4 a

Means followed by the same letter (s) in each column are not significant different according to Duncan's Multiple Range Test (DMRT)

The %N derived from the atmosphere (Ndfa) was lowest for Kiriz and highest for Ahmedi (Table 2). The non-nodulating reference has therefore, attained 60%/-70%/ fixation which was far higher and within good fixation limits compared to the 40% - 49% shown before (Mukhtar, 1993) using sesame as the reference crop, i.e., fixation had risen 20%. On the other hand, nitrogen derived from soil (NDFS) dropped from 90 kg N/ha (for a 180 kg/ha total uptake) to 40-60 kg N/ha (Table 2) much closer figures, though still higher, to what the Gezira soil could provide.

The difference in BNF, %N derived from air between the highest value recorded by Ahmedi and the lowest attained by Kiriz was about 14.7%. Nitrogen derived from soil (Ndfs) was lowest for Ahmedi and f highest for Kirjz Significant differences in BMF were observed among the genotypes with Kiriz fixing the least and Ahmedi the most (Table 2), but there were no significant differences in Ndfs among the genotypes.

Though residual nitrogen is better studied after the incorporation of legume residue, stover removal causes net removal of N from the soil (Eaglesham et al., 1982; Senaratne and Hardarson, 1988). Yet the results without stover incorporation revealed significant differences for the effect of the preceding Medani groundnut variety on the straw and total biomass yields of the subsequent sorghum over those of Kiriz and the non-nodulating cultivars while MH 383, Ahmedi and V. Red all gave significantly more sorghum straw than Kiriz only, but they exceeded the non-nodulating isoline by 16%, 25% and 21%, respectively (Table 3).

Table 3. Effect of different preceding groundnut varieties on seed and straw yields and total biomass of subsequent sorghum

Varieties	Seed yield (kg/ha)	Straw yield (hg/ha)	Total Hiomass (kg/ha)
MH383	2151 a	13402 ab	15555 ab
Non-nodutlating isoline	2138 a	11544 bc	13682 bc
Kiriz	1783 a	10277 c	12060 c
Medani	2189 a	15920 a	18109 a
Ahmedi	1944 a	14403 ab	16347 ab
V. Red	2238 a	13970 ab	16208 ab

Means followed by the same letter(s) in each column are not significantly different according to Duncan's Multiple Range Test (DMRT).

Total biomass gave the same results as those for the straw yield. Sorghum seed yield, however, did not show any significant residual genotype effect. Seed yield, %N and total N yield were not affected by any residual N while the % ^{15}N atom excess showed significant differences for the sorghum following the different variety (Table4). Ahmedi and Virigina Red had the highest %^{15}N atom excess while the lowest %^{15}N atom excess was recorded for the non-nodulating isoline followed by Kiriz, Medani and then MH 383.

Table 4. Effect of different preceding groundnut varieties on %N, total N uptake and % ^{15}N atom excess of subsequent sorghum.

Varieties	%N	Total N uptake (kg/ha)	%^{15}N atom excess
MH383	0.832a	128.8a	0.026a
Non-nodulating isoline	0.850a	117.7a	0.022b
Kiriz	0.830a	100.3a	0.024ab
Medani	0.800a	145.0a	0.025ab
Ahmedi	0.715a	116.7a	0.031a
V. Red	0.725a	116.5a	0.031a

Means followed by the same letter(s) in each column are not significantly different according to Duncan's Multiple Range Test (DMRT).

It was expected that the lowest %^{15} N atom excess should indicate the highest residual nitrogen expressed in total N-uptake, biomass and seed production, but this was not the case. Such results were obtained when stover of non-labeled legume was added to dilute ^{15}N atom excess of the residual soil nitrogen (Senaratne and Hardarson, 1988). In this study, the erratic results were due to the dependence of the sorghum crop on the labeled nitrogen that was left over by the previous legume crops. Here again the non-nodulating crop which was previously given 100 kg N/ha at 1.0% ^{15}N atom excess gave the lowest %^{15} N atom excess for sorghum. A result which conformity with the total nitrogen uptake where the least total N was taken up by the non-nodulating groundnut isoline. The latter was not significantly different under the different genotypes, though MH 383 and Medani produced much more total N and total biomass, respectively compared to total N and biomass produced by the non-nodulating isoline.

There was, however, an indication of residual N as many varieties significantly out-yielded the non-nodulating isoline in straw and total biomass production.

In conclusion, groundnut was a good fixing crop. It could fix up to 72% of it's N requirement. Furthermore, the varieties tested showed genotypic differences in N —fixation, effect on subsequent sorghum production and residual N. Residual N could, however, come from the two sources of fixed and non-fixed and components (Chalk, 1998).

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