NITROGEN USE EFFICIENCY OF SOIL AND FOLIAR APPLICATION OF ^{15}N LABELLED UREA WITH OR WITHOUT INOCULATION AND MICRONUTRIENTS BY GROUNDNUT *(Arachis hypogaea L)* IN A SEMI-ARID ENVIRONMENT

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ABSTRACT

The N use efficiency by groundnut (Arachis hypogaea L.) grown in the field on a sandy loam soil (Plinthaqualf) in Ghana was estimated using ^{15}N labelled urea applied to the soil at planting on one hand and urea in an NPKS nutrient solu- tion sprayed during the pod-filling stage of the crop on the other. The efficiency of the ^{15}N utilization *was low and ranged from 26.2 to 27.3% when the urea was applied to the soil, and 14.3 to 20.8% with the foliar spray. The results suggest active absorption of the applied N through the root system of the groundnut at the pod-filling stage. Seed inoculation and application of Mo significantly reduced the ^{15}N use efficiency.*

KEYWORDS: *Nitrogen use efficiency, foliar spray, urea, inoculation, boron, molybdenum, groundnut.*

INTRODUCTION

Groundnut is intensively grown on the light textured soils in the semi-arid zone of West Africa, where agroclimatic conditions are conducive to leaching and volatilization losses of soil applied nitrogen (N). The efficiency of applied N is, therefore, low. Ofori [18] reported a mean per cent N derived from fertilizer (% Ndff) by groundnut grown in the Guinea savanna zone of Ghana to be less than 30 even though as high as 120 kgN/ha was applied. An alternative method of applying the highly soluble N fertilizer to groundnut in the semi-arid zone of West Africa may be desirable. The results of experiments conducted on the effect of foliar fertilization with NPKS nutrient solution on soyabean during the period of pod-filling showed significant grain yield increase [8]. These authors observed that root activity decreased during pod-filling so that nutrient uptake was not sufficient enough to meet the crops demand to realize optimum yields. Foliar fertilization (FF) during pod-fill was suggested as a means of increasing N input without involving the root during this critcal period. There has been, since, increasing interest in elucidating the effect of FF on other crops [1, 10, 13, 22].

In India [19, 20] and Israel [9] yield increases of groundnut have been reported due to FF with N. In West Africa, however, there is no published information on the effect of FF of groundnut.

Although inoculation increases grain yield of legumes [3], farmers in West Africa rarely use inoculum. There are also reports indicating beneficial effects of boron (B) and molybdenum (Mo) on the growth and yield of groundnut [4, 15, 17], however, the influence of these micronutrients on groundnut in the sub-region is ill-defined.

In this paper, the effect of ^{15}N labelled urea, inoculation and micronutrients on grain yield of groundnut and fertilizer N use efficiency was evaluated.

MATERIALS AND METHODS

The experiment was carried out at the Crops Research Institute Experiment Station at Manga/Bawku (11°3' N, 0°19' W) in the Northeastern Sudan-Savanna zone of Ghana, West Africa. The annual rainfall and temperature of the experimental site range from 965 to 1092mm and 29.0 to 38.1°C, respectively. The distribution of rainfall is erratic; drought occurs frequently resulting in either low crop yield or complete crop failure. The soil (Varampere series), is a sandy loam of granitic origin and classified tentatively as Plinthaqualf. It is slight acidic (pH 6.2) inherently low in fertility: organic carbon 0.63%, total N 0.047%, NH_4-N 2.1 μg/g, NO_3-N 15.4 μg/g, Bray P1 4.5 μg/g [14]. Nine treatments arranged in a randomised complete block design with five replicates were used in the study.

1. Absolute Control (N_0T_0)
2. 15kg N*/ha at planting ($N_{15}T_0$ soil applied)
3. 40kg N*/ha in NPKS solution sprayed at pod-filling stage (N^*_{40} T_1)
4. 15kg N*/ha(T_0) + 40kg N/ha(T_1)
5. 15kg N/ha(T_0) + 40kg N*/ha(T_1)
6. 15kg N/ha(T_0) + soil inoculation + 40kg N*/ha(T_1)
7. 15kg N/ha(T_0) + seed inoculation + 40kg N*/ha(T_1)


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8. 15kg N/ha(T_O) + 0.6 μg/g M_O + 40kg N^*/ha(T_1)
9. 15Kg N/ha(T_O) + 0.11 μg/g B + 40kg N^*/ha(T_1)

N^* - N labelled as Urea

Each plot measured 12m x 2.8m. The site was harrowed to a depth of 23cm. The basal fertilizer consisted of 25kg P and 30kg K/ha as triple superphosphate and muriate of potash, respectively. These were broadcast together with 15kg N/ha as urea and incorporated at about 10cm deep at planting. In treatment 6, a composite peat-based inoculum, NC 92, was applied at a rate of 1.5 x 10^5 cells/g soil along the planting rows while in treatment 7 the seeds were inoculated. Treatments 8 and 9 received 0.6μg/g M_O and 0.11μg/g B as molybdate and borax, respectively applied at planting. The ^{15}N labelled urea at the rate of 15kgN/ha (4% ^{15}N atom excess) was broadcast and incorporated on a subplot of $3m^2$ at planting. A Senegalese groundnut (Arachis hypogaea L. cv 55-437) was planted on the flat spaced at 40cm between rows and 20cm within rows. The nutrient solution consisted of 80kg N as urea (2% ^{15}N atom excess), 10kg P, 26kg K as potassium polyphosphate, and 4.48kg S as potassium sulphate in 100 litres of water and contained 0.1% Tween as a surfactant. The foliar spray solution was applied at the rate of 250L/ha in two sprays spaced at 10 days beginning from the pod-filling stage (67 days after emergence - DAE) of the groudnut. Spraying was done in the windless early morning using a small hand sprayer. The rest of the plot outside the ^{15}N labelled sub-plot was sprayed with unlabelled NPKS solution using a knapsack sprayer while the control plots were sprayed with equivalent amount of water.

During the pod-filling stage of the crop 20 plants each from the outer rows per plot were sampled for the determination of total N. At the final harvest, grain, husk and haulm were sampled for total N determination to estimate total N uptake of the crop. Separate samples were collected from the ^{15}N labelled subplots for the determination of the amount of N derived from the applied fertilizer, which afforded the estimation of fertilizer N use efficiency by the crop. All plant samples were oven-dried at 65°C for 48 hours and finely ground in a Wiley Mill. The total N was determined by the Kjeldahl method [2] and the ^{15}N assay was carried out in the Seibersdorf Laboratory by the International Atomic Energy Agency, Vienna according to the method outlined in the Technical Report 121 [11]. The amount of N derived from the fertilizer and the N-fertilizer use efficiency were calculated using the following formulae according to Fried [7]:

% NDFF = %N derived from fertilizer.

$$= \frac{\text{\%N - atom excess of crop}}{\text{\%N - atom excess in fertilizer used}} \times 100$$

$$\text{and \%N-fertilizer efficiency} = \frac{\text{\%NDFF x total N in crop}}{\text{Rate of N applied}} \times 100$$

The experimental data were statistically analysed [21].

RESULTS AND DISCUSSION

Grain Yield

The application of urea at planting or sprayed at the pod-filling stage resulted in profuse vegetative growth compared with the control but in most cases the differences in haulm yield were not significant. However, urea applied in combination with molybdate significantly increased the haulm yield but yield was reduced in the presence of borax (Table 1). All the treatments reduced the grain yield except that incorporating borax. The increase in haulm and decrease in grain yields resulting from the application of M_O, and the decrease in haulm and increase in grain yields with the application of B suggests antagonism between each of the two micronutrients and the applied N at different growth stages of the groundnut. Judging from the low available N in the soil, the high grain yield obtained on the control plot (-N) suggests that the crop depended on fixable N. The declined grain yield on the inoculated plots suggests the presence of effective native rhizobia in the soil. The results of grain yield of groundnut obtained in this experiment following foliar fertilization are at variance with those reported by some researchers in India [19, 20] and on Soybean [8].

TABLE 1: Effect of foliar spraying of Urea-N on the yield of groundnut, kg/ha

Treatment	Haulm	Grain	Haulm/Grain Ratio
No To	2889ab*	918c*	3.15
N^*_{15} To	3251abc	569a	5.71
N^*_{40} T_1	3354bc	726b	4.62
N_{15} To + N^*_{40} T_1	3281abc	546a	6.01
N^*_{15} To + N_{40} T_1	3289abc	687b	4.79
N_{15} To + Inoc. SL + N^*_{40} T_1	3163abc	749b	4.22
N_{15} To + Inoc. SD + N^*_{40} T_1	3300abc	563a	5.86
N_{15} To + Mo + N^*_{40} T_1	3892c	709b	5.49
N_{15} To + B + N^*_{40} T_1	2541a	901c	2.82
S.E	± 336	± 41	± 0.58

Means in a column followed by the same letter are not significantly different at 5% level of probability.

Total N concentration and uptake

The total N concentration in the haulm and husk reduced after the pod-filling stage while it increased in the grain (Table 2) indicating transfer of N from the haulm and husk into the grain with age of the crop. The N concentration in the various plant parts was not significantly affected by either fertilization and/or inoculation.

However, the application of SN and M_O supplemented with two foliar sprays (FS) significantly increased the N uptake by the haulm while the N reduced significantly by the application of B. Contrary to expectation, the application of M_O reduced the N uptake by the grain and the husk while it increased in the same components but not significantly when B was applied.

TABLE 2: The content of total N in groundnut at different growth stages.(%)

Treatment	At pod-filling			At maturity		
	Leaves + stems	Husk	Grain	Leaves + stems	Husk	Grain
No To (Control)	2.34	2.14	3.54	1.70 (-27.3)*	1.77 (-17.3)	4.20 (+18.6)
N_{15} To	2.08	2.34	3.44	1.77 (-14.9)	1.77 (-24.3)	4.14 (+20.3)
N_{15} To + soil inoculation	2.18	2.41	3.70	1.74 (-20.2)	1.74 (-27.8)	4.20 (+13.5)
N_{15} To + Seed inoculation	2.12	2.21	3.74	1.79 (-15.6)	1.86 (-15.8)	3.98 (+6.4)
N_{15} To + Mo	2.23	2.57	3.78	1.68 (-24.7)	1.74 (-32.3)	3.84 (+6.0)
N_{15} To + B	2.03	2.23	3.52	1.66 (-18.2)	1.58 (-29.1)	4.17 (+18.5)
S.E. ±	0.29	0.36	0.30	0.25	0.23	0.25
LSD 5%	NS	NS	NS	NS	NS	NS

* Figures in parenthesis represent decrease (-) or increase (+) in total N various plant parts relative to its content at the pod-filling stage.

The results in Table 3 shows that the application of ^{15}N urea alone to the soil or ^{15}N urea in an NPKS nutrient solution sprayed at the pod-filling stage of the groundnut plant had no significant effect on the total N uptake by the different plant parts or the whole plant.

TABLE 3: Total N uptake by groundnut at maturity (kg/ha)

Treatment	Haulm	Husk	Grain	Total
No To	49.1bc**	3.8ab	38.6b	91.5ab
N^*_{15} To	57.5abc	3.2ab	23.6ab	84.3ab
N^*_{40} T_1	56.0abc	3.4ab	25.9ab	85.3ab
N_{15} To + N^*_{40} T_1	59.1ab	2.8b	19.9a	81.8b
N^*_{15} To + N_{40} T_1	61.2ab	3.1ab	28.0ab	92.3ab
N_{15} To + Inoc. SL + N^*_{40} T_1	55.0abc	3.7ab	31.5ab	90.2ab
N_{15} To + Inoc. SD + N^*_{40} T_1	59.1ab	3.6ab	22.4a	85.1ab
N_{15} To + Mo + N^*_{40} T_1	65.4a	3.2ab	27.2ab	95.8a
N_{15} To + B + N^*_{40} T_1	42.2c	4.0a	37.6b	83.8b
S.E	± 6.8	± 0.46	± 6.5	± 4.8

** Means in a column followed by the same letter are not significantly different at the 5% level of probability.

This observation is difficult to explain in view of the positive contribution of M_O to the nutrition and growth of the groundnut. This might be due to imbalance between not only M_O and N after the FS but also between N and other nutrients such as K and Ca which influence the uptake of N by plants. The declined N uptake by the haulm on the B treated plot could be connected with antagonism between B and N. The total N uptake by the haulm ranged from 47.7 to 70.3 per cent of the total plant N while the grain N varied from 26.2 to 45.5 per cent at full maturity. The results indicate an underestimation of the total N uptake by the groundnut crop when compared with the findings of Musa and Burhan [16]. Two reasons may be responsible for the low N uptake. Firstly, the fallen leaves were not collected during harvest and this would lead to substantial loss of N. Secondly, immobilization of both soil and applied N would reduce the amount of N taken up by the crop through the root system while volatilization of the foliar spray urea solution could also reduce N absorption through the leaves.

Percent N derived from fertilizer (%Ndff)

The percent N derived from the fertilizer (%Ndff) in the different plant parts were essentially the same (Table 4). Although the %Ndff by the haulm and the grain was higher with the FF than when the N fertilizer was applied to the soil but not directly proportional to the amount of N applied in the NPKS nutrient solution. The higher %Ndff obtained with the application of the urea solution is thought to be associated with the higher rate of N (40 kgN/ha) than the SN (15 kgN/ha) applied to the soil. Ofori, [18] in Ghana found increasing %Ndff by groundnut as the rate of N increased from 20 to 120 kgN/ha. The %Ndff in the haulm was not significantly affected by inoculation, however, it was significantly reduced in the grain. The observation seems to confirm the presence of adequate and effective rhizobial strains in the soil. There was also a significant decrease in the %Ndff in the haulm and the grain when M_O was applied in combination with N indicating that the contribution of M_O to the high N uptake reported in Table 2 was due to its effect on the soil and biologically fixed N.

TABLE 4: Effect of foliar spray of ^{15} NPKS solution on %Ndff by groundnut.

Treatment	Haulm	Husk	Grain
Control (0 kgN/ha)	-	-	-
N^*_{15} To, soil applied	4.6a**	5.2a	5.5ab
N^*_{40} T_1	7.8ab	6.0a	7.3bc
N_{15} To + N^*_{40} T_1	10.9b	6.3a	8.7c
N^*_{15} To + N_{40} T_1	4.1a	5.5a	4.5a
N_{15} To + Inoc. SL + N^*_{40} T_1	7.5ab	4.8a	6.9b
N_{15} To + Inoc. SD + N^*_{40} T_1	6.9ab	4.5a	6.6b
N_{15} To + Mo + N^*_{40} T_1	6.0a	5.1a	5.7ab
N_{15} To + B + N^*_{40} T_1	8.0ab	5.3a	7.3bc
S.E ±	1.3	1.2	1.0

** Means in a column followed by the same letter are not significantly different at the 5% level of probability.

Fertilizer - N use efficiency

The percentage ^{15}N use efficiency of the soil applied urea by the whole plant was superior to the FF at the pod-filling stage (Table 5). Generally, there was a reduction (22-47%) in the fertilizer - N efficiency when the N was sprayed at the pod-filling stage, the decrease on the seed inoculated and M_O treated plots being significant. This is an evidence of active absorption of the soil - applied ^{15}N and fixed N by the roots of the groundnut. According to Witter et al. [24], a bean leaf absorbed 50 per cent of urea that was to be taken up within 1 to 6 hours when urea solution was applied. Since there was no rainfall two days following the foliar application of the fertilizer to the groundnut leaves it can be assumed that maximum amount of the urea-N was absorbed during the first day of application. The low percentage fertilizer use efficiency of the foliar applied ^{15}N could be due to rapid volatilization of the urea solution from the leaf surface. This is supported by the fact that urea is absorbed into the leaf molecularly intact [24] and that urea hydrolysis [6] and subsequent volatilization as ammonia [5] increase with increasing temperatures. Also, the efficiency of foliar uptake depends on the wettability of the leaf surface among other factors [12]. In the Sudan-Savanna environment with high solar radiation intensity, the morning foliar spray exposed the urea solution on the leaf surface to hotter afternoon temperatures leading to more N loss through volatilization as earlier observed by Vasilas et al. [23]. Inoculation and the application of B or M_O did not significantly influence the ^{15}N recovery. The percentage N use efficiency of the ^{15}N urea was highest in the haulm followed by the grain and least in the husk. Of the 15 kgN/ha applied to the soil at planting, 26 to 27 per cent was taken up by the groundnut. Although the percentage N use efficiency of the ^{15}N foliar spray at the rate of 40 kgN/ha drastically reduced in comparison with soil applied N, the decreases were compensated by N uptake from the soil and fixed N. Consequently, the total N uptake was maintained. The decreased N use efficiency by groundnut resulting from inoculation suggests that the soil abounds in active rhizobial strains capable of forming nodules on the groundnut roots and thus contributing to N fixation.

TABLE 5: Percentage recovery of ^{15}N in an NPKS nutrient solution by groundnut at maturity.

KgN/ha applied	Haulm	Husk	Grain	Whole plant
N^*_{15} To	17.6a**	1.1a	8.6a	27.3a
N^*_{40} T_1	10.9ab	0.5b	4.7ab	16.1ab
N_{15} To + N^*_{40} T_1	16.1ab	0.4b	4.3ab	20.8ab
N^*_{15} To + N_{40} T_1	16.7a	1.1a	8.4a	26.2ab
N_{15} To + Inoc. SL + N^*_{40} T_1	10.3ab	0.5b	5.4ab	16.2ab
N_{15} To + Inoc. SD + N^*_{40} T_1	10.2ab	0.4b	3.7b	14.3b
N_{15} To + Mo + N^*_{40} T_1	9.8ab	0.4b	4.5ab	14.7b
N_{15} To + B + N^*_{40} T_1	8.4b	0.5b	6.9ab	15.8ab
S.E	±3.65	±0.25	±1.91	±5.22

** Means in a column followed by the same letter are not significantly different at the 5% level of probability.

The higher ^{15}N use efficiency by the groundnut plant on the plots where the fertilizer was applied to the soil suggests active root absorption of this nutrient at the pod-filling stage and after.

CONCLUSION

It is concluded that foliar fertilization of urea in an NPKS solution at the pod-filling stage of groundnut on the Sudan-Savanna soil proved inferior to the application of solid urea to the soil in terms of N use efficiency.

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