The utilization of Azolla as a source of nitrogen for rice production in Ghana

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SUMMARY

The performance of the local strain of Azolla, *Azolla pinnata* var. *africana*, as a green manure for rice was compared with inoganic nitrogen alone and a combination of Azolla and inoganic nitrogen. The Azolla was incorporated under therice crop (cv. GRUG 7) grown under irrigation on the vertisol. Within a period of 4 weeks and a doubling time of 5 days, a total biomass of 18 t/ha of Azolla, equivalent to 25 kg N/ha was produced. This is 28 per cent of the optimum recommended nitrogen rate (90 kg N/ha) for rice cultivation on the vertisols of the Accra Plains. Azolla, in combination with 40 kg N/ha ammonium sulphate fertilizer, gave significantly higher grain yields than Azolla only, 60 kg N/ha ammonium sulphate fertilizer and the control plot. No significant grain yield differences were observed between the single and double Azolla incorporations, but the double incorporation of Azolla only gave a yield equivalent to that obtained under 60 kg N/ha ammonium sulphate while a lower yield was observed for the single incorporation. The grain yields were 4.8, 3.5, 2.7 and 1.8 t/ha for the Azolla plus N-fertilizer, 60 kg N/ha, Azolla only and the control plot respeectively.

Research and development note. Received 10 Oct 89; revised 1 Dec 96.

RÉSUMÉ

NYALEMEGBE, K., OTENG, J.W. & AHIABU, R. K.: L' *Utilisation d' Azolla en tant que source d' azote pour la production du riz au Ghana.* La performance de la lignée locale d' Azolla: *Azolla pinnata* var. *africana*, en tant qu' engrais vert pour le riz était comparé à l'azote inorganique unique et une combinaison d' Azolla à l'azote inorganique. L' Azolla équivalent à 25 kg/ha (A=azote) était incorporé sous culture du riz cultivé sous l' irrigation sur le vertisol. Dans une période de 4 semaines et un temps doublant de 5 jours, une biomasse totale de 18 t/ha d' Azolla, équivalent à 25 kA/ha (A=azote) était produite. Ceci est 28 pour cent de la proportion optimum d' azote recommandée (90 kg A/ha) pour la culture du riz sur les vertisols des plaines d' Accra. Azolla en combinaison à 40 kg A/ha d'engrais de sulfate d'ammonium donnait des rendement de grains considérablement plus élevés qu' Azolla unique, 60 kg A/ha d'engrais de sulfate d' ammonium et le lot contrôle. Aucune différence considérable de rendement de graine n' était observée entre les incorporations d' Azolla unique et double, mais l' incoporation double d' Azolla donnait un rendement equivalent à celui obtenu sous 60 kg A/ha de sulfate d' ammonium alors qu' un rendement plus bas était observé pour l'incorporation unique. Les rendements de graine étaient 4.8, 3.5, 2.7 et 1.8 t/ha pour Azolla plus l' engrais-A, 60 kg A/ha, Azolla unique et la lot de contrôle respectivement.

Introduction

Azolla is a small floating freshwater fern found in lowland rice fields and in stagnant waters. The upper lobe of the Azolla leaflet contains a large leaf cavity inhabited by the blue-green alga, *Anabaena azollae*, which contains about 15-20 per cent nitrogen-fixing cells (heterocyst) as compared to 5 per cent in free living *Anabaena* species. In this symbiotic association, Azolla serves as the host plant while the alga fixes nitrogen, using molecular nitrogen from the atmosphere. The fixed nitrogen is utilized by the Azolla plant for growth, but is released when the fern dies and decomposes (Singh & Singh, 1989).

The *Azolla-Anabaena* association can fix from 100 to 150 kg of nitrogen per ha per year in approximately 40-60 t of biomass. Azolla as a biofertilizer has been extensively used to great advantage by many Asian countries notably China, Thailand, Indonesia, India and the Philippines. On the other hand, the impact of Azolla on rice culture in West Africa is very little. However, studies carried out by WARDA (West Africa Rice Development Association) in Richard Toll (Senegal) and Rokupr (Sierra Leone) show great potential for the use of Azolla as a green manure in rice culture (WARDA, 1980, 1988, 1993).

The rice crop has a high N requirement, and studies on the Akuse soil, the vertisol on which this study was conducted (Oteng & Asuming-Brempong, 1985), shows that 90 kg N/ha is required to obtain an optimum yield of 6.4 t/ha for a medium duration (130 days) rice variety. To sustain rice production in lowland ecologies (swamps, hydromorphic and irrigated lands) in many developing countries where farmers are unable to afford the cost of agro-inputs, it is imperative to look at cheaper organic sources of fertilizer as alternative or supplement to inorganic fertilizers. Azolla is a good alternative source of N in rice production in most tropical countries (Singh & Singh, 1989).

The positive attribute of Azolla as a biofertilizer for rice cultivation is in its high nitrogen-fixing capacity, rapid multiplication in waterlogged rice fields, rapid decomposition and relatively easy availability of its N to the standing crop, and its non-interference with normal cultivation practices and crop development (Singh, 1989). Lumpkin & Plucknett (1980, 1982) have all indicated positive contributions of Azolla to grain yield in rice. Singh (1989), in a review of studies conducted in India, China, Vietnam and Thailand, revealed that grain yield increases due to Azolla were equivalent to that of about 30 kg N/ha of urea.

The present study was aimed at determining the efficiency of the local strain of *Azolla pinnata* var. *africana*, grown as a green manure or dual crop supplement N for rice production under irrigated conditions in Ghana.

Materials and methods

The experiment was laid out in a randomized complete block design with four replicates. There were six treatments:

N_0 Control; no N fertilizer applied.

N_1 Application of 60 kg N/ha as ammonium sulphate in three equal splits (at transplanting, tillering and panicle initiation stages).

N_2 Single incorporation of Azolla 25 days after transplanting (DAT), when Azolla was in-oculated from the nurseries 5 days before transplanting (DBT).

N_3 Double incorporation of Azolla 25 and 50 DAT, when Azolla was inoculated from the nurseries 5 days after transplanting rice.

N_4 Single incorporation of Azolla 25 DAT when Azolla was inoculated from the nurseries 5 days after transplanting and 40 kg N/ha in two equal splits, 20 kg N/ha at tillering and 20 kg N/ha at panicle nitiation stage.

N_5 Double incorporation of Azolla 25 and 50 DAT, when Azolla has been inoculated from the nurseries 5 DAT and 40 kg N/ha as ammonium sulphate in two equal split doses as in N_4.

The rice seedlings were transplated two per hill, at a spacing of 20 cm × 20 cm in 3 m 4 m bunded basins. There was a basal application f P at 45 kg P_2O_5 and K at 35 kg K_2O_5 per hectare. Fradan was applied at the rate of 25 kg/ha to control insects on both rice and Azolla. Azolla was inoculated at a rate of 0.25 kg m^2. To measure the amount of biomass produced, Azolla was sampled in 10 cm × 10 cm quadrats and, at the same time, a portion was set aside for N, P and K determinations. Nitrogen content was determined by the wet digestion Kjeldhal method and was followed by titration. Phosphorus was measured by the colorimetric method proposed by Watanabe & Olsen (1965), and potassium was determined by flame photometry. The number of tillers and panicles per hill, filled grains, 1000-grain weight, straw and average grain yields were determined for rice, using standard methods.

Results and discussion

The results of the soil chemical analysis (Table) indicated that the levels of nitrogen (0.07%), Olsen P (18 ppm) and exchangeable K (0.27 me/100 g) were low. There was thus the need for basal applicati

TABLE 1

Some Chemical Characteristics of the Akuse Soils Series (Vertisol)

Property	*Chemical value*
pH (Water)	7.30
Percent N	0.07
P (Olsen's)	18.0 ppm
K (available)	0.27 me/100 g
Exchangeable K	1.2 me/100 g
Exchangeable Mg	9.5 me/100 g
Exchangeable Ca	23.8 me/100 g
CEC	35.0 me/100 g
Clay mineralogy: Dominant clay	Montmorillonite 90-95 per cent

of P and K in this experiment, in conformity with the observations by Watanabe, Berja & Del Rosario (1980) that there is need for application of good quantities of P and K to induce rapid growth of Azolla.

The N content of the Azolla crop varied between 2.6 per cent and 2.9 per cent and averaged 2.8 per cent (Table 2). This was evidently lower than the value of 3 - 5 per cent reported for the exotic strains (Moore, 1969; Watanabe, 1982). The low N content in the indigenous Azolla strains was attributed to the low heterocyst count (Asuming-Brempong, 1987 - Private communication). The biomass of Azolla produced during the early growth of the rice crop, dropped by 50 per cent under full rice canopy (Table 2), as shown by the biomas of the first and second Azolla incorporations.

Grain yield

The grain yield of rice correlated significantly (r = 0.92 at 1 % level) with applied nitrogen (Fig. 1). The treatments with Azolla plus ammonium sulphate fertilizer, N_4 and N_5, produced the highest grain yields (4.8 and 4.7 t/ha respectively), and there was no significant yield difference between the two treatments (Table 3). The double incorporation of Azolla, therefore, did not show any grain yield advantage over the single incorporation. Similarly, in the Azolla incorporations only, no significant yield difference was obtained between the single and double incorporations (N_2 and N_3). In spite of this the 60 kg N/ha ammonium sulphate fertilizer treatment (N_1) had greater yield than N_2, but did not differ from N_3. Grain yields in N_2, N_3 and N_1 were 2.7, 2.8 and 3.5 t/ha respectively. This indicates a slight yield advantage in the double Azolla incorporation, when there is no inorganic N supplement. The significantly

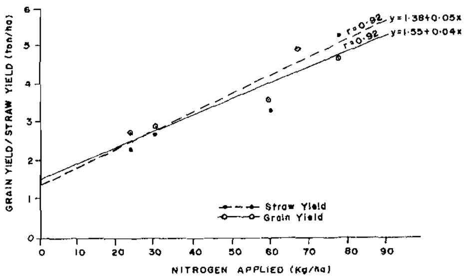

Fig. 1. Correlation of applied nitrogen vrs grain yield/ straw yield

TABLE 2

Fresh Weight, Dry Weight and NPK Content of Azolla pinnata *var.* africa *Produced and Incorporated in Rice Field*

Treatment	*Fresh weight of Azolla incorporated (t/ha)*		*Total fresh weight incorporated (t/ha)*	*Total dry weight incorp. (t/ha)*	*Total N incorp. (kg/ha)*	*NPK content (%)*		
	1st incorp.	*2nd incorp.*				*N*	*P*	*K*
N_2	18.3	-	18.3	0.92	25.0	2.6	0.13	1.11
N_3	14.2	8.4	22.5	1.13	31.2	2.9	0.14	1.37
N_4	18.1	-	18.1	0.97	26.8	2.9	0.12	1.18
N_5	17.2	8.8	26.4	1.32	36.4	2.7	0.12	1.23

TABLE 3

The Effect of Azolla and N Fertilizer on Rice Yield and Yield Components

Treatment	*Av. tiller no. per hill*	*Av. productive panicles per hill*	*Weight of straw (t/ha)*	*Per cent filled grains*	*Grain/Straw ratio*	*1000-grain weight (g)*	*Grain yield (t/ha)*
N_0	9.0bc	6.0b	1.7c	83a	0.9a	26.6b	1.8d
N_1	9.0bc	12.0a	3.3bc	77a	1.1a	27.5a	3.5b
N_2	8.0c	7.0b	2.3c	87a	1.2a	28.3a	2.7c
N_3	8.0c	7.0b	2.7bc	84a	1.1a	27.9a	2.8bc
N_4	13.0ab	12.0a	5.4a	93a	1.1a	28.1a	4.8a
N_5	12.0ab	12.0a	5.3ab	94a	0.9a	27.7a	4.7a

Values in the same column, followed by the same letter are not significantly different by the DMRT at the 5 per cent level of probability.

higher grain yields of the N_4 and N_5 treatments over the N_2, N_3 and N_1 are in agreement with results obtained by Singh & Singh (1986), which indicated that a combination of chemical N fertilizer and Azolla performs better than either alone.

Yield components

The 1000-grain weight (test weight) did not differ significantly between treatments, but for the control (N_0) which was significantly lower than all the other treatments (Table 3). On the other hand, although the number of filled grains per panicle showed no significant difference between treatments, N_4 and N_5 appeared to have higher number of filled grains. This is an indication that the high N availability in N_4 and N_5 led to greater number of filled grains while the individual grain weights showed little difference.

The treatments with higher levels of nitrogen (N_4 and N_5) showed higher tiller numbers and productive panicles per hill than those with lower levels of N, i.e. N_0, N_1, N_2 and N_3 (Table 3). The positive effects of increasing nitrogen levels on tillering, productive tiller numbers, per cent filled grains and grain yield have been observed by Matsushima (1957), Ishizuka & Tanaka (1963), and Oteng & Andoh (1984). These advantages were effectively translated into significant grain yield differences between the highest and lowest N treatments.

There was no significant difference between grain-straw (G/S) ratios of the various treatments, even at the highest N levels, i.e. N_4 and N_5 (Table 3). The G/S ratio remained fairly close to 1 in all treatments, which is a standard for improved varieties (Yoshida, 1981).

The number of panicles per hill were significantly higher in treatments N_1, N_4 and N_5 than N_2 and N_3 (Table 3). The greater N availability in the former treatments supported a greater number of panicles as observed by Matsushima (1957) and Ishizuka & Tanaka (1963). The Azolla incorporation might have been late and the rice crop might not have benefitted fully from it, especially from the second incorporation. This also explains the lack of differences in tillering between treatments. Tillering, according to Matsushima (1957) and Ishizuka & Tanaka (1963), attains its highest value about one month after transplanting.

Conclusion

Azolla pinnata var. *africana*, cultivated under irrigated rice and incorporated into the soil, provided 28 per cent of the N requirement of the crop. The greatest yield was obtained when the N from Azolla was supplemented by inorganic N ferilizer. The usefulness of the inorganic N supplement may lie in the need for N during the period when the Azolla is decomposing.

Azolla multiplies rapidly in paddy fields and does not interfere with the rice crop. The plant also appeared to decompose rapidly thus releasing N readily to the crop. It is, however, necessary to study the critical time to incorporate the Azolla so that the growing crop could derive maximum benefit from the nitrogen released. The results indicate that an incorporation before transplanting and another soon after establishment could provide the requirement of the rice crop during the critical growth stages viz: (1) vegetative and tillering stage and (2) the panicle initiation and grain filling stage.

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