Soil phosphorus status and natural growth of *Azolla* in irrigated lowland rice

Azolla is a genus of water fern that assimilates atmospheric nitrogen in symbiosis with the nitrogen fixing blue-green alga *Anabaena azollae* (that live in the cavities of *Azolla's* upper lobes). The *Azolla–Anabaena* complex offers potential for increasing yields of irrigated lowland rice, especially in situations where chemical nitrogen fertilizers are in short supply[1].

We have been conducting experiments since 1993 under irrigated lowland conditions at the Mbe (near Bouake) in Ivory Coast, located in the guinea savanna zone at 5°06'W, 7°52'N, to determine the status of mineral reserves in a lowland soil. Soil at the experimental site was an alfisol (pH 6.2, clay 320 g kg^{-1}; sand 240 g kg^{-1}; organic C 1.02%; CEC 8.9 cmol kg^{-1}; exchangeable K 0.2 cmol kg^{-1}; exchangeable Ca 1.02 cmol kg^{-1}; exchangeable Mg 0.67 cmol kg^{-1}; DTPA extractable Zn 0.8 mg kg^{-1}) clay loam in texture. Soil analysis was carried out using standard methods[2]. The experimental treatments included a complete fertilizer (CF) application (100 kg N ha^{-1} as urea, 100 kg P_2O_5 ha^{-1} as TSP, 100 kg K ha^{-1} as KCl, 50 kg Ca ha^{-1} as hydrated lime, 50 kg Mg ha^{-1} as $MgCO_3$ and 10 kg Zn ha^{-1} as $ZnSO_4$) and treatments in which N, P, K, Ca, Mg and Zn (CF–N, CF–P, CF–K, CF–Ca, 4CF–Mg and CF–Zn) were individually omitted. The treatments were arranged in a randomized complete block design with four replications. Each plot measured 15 m^2.

We observed a good growth of native population of *Azolla pinnata* var. africana in all plots that had received P application, but there was no growth of the fern in non P-amended plots. *Azolla* growth was due exclusively to natural inoculation. During the 1994 wet season (July–October), we quantified the biomass accumulated by *Azolla* under various plant nutrient treatments by collecting the fern from 1 m^2 area in each replication. The sampling of *Azolla* was done at 11 weeks after transplanting of the rice crop (cv Bouake 189).

Biomass production, expressed on a dry weight basis, in CF, CF–N and CF–K treatments was similar. There was no growth of *Azolla* in the CF–P treatment (Table 1). The biomass of *Azolla* in CF–Mg treatment was significantly lower than in other treatments. There was no significant difference in the biomass accumulation in other nutrient treatments. The elemental composition of *Azolla* dry matter for N, P, K and Zn contents was similar in various plant nutrient treatments (Table 1). The results were confirmed in the 1995 wet season: there was no growth of *Azolla* in CF– P treatment plots and the biomass of *Azolla* was significantly lower in CF–Mg treatment. The biomass of *Azolla* was similar in all other nutrient treatments.

Bray 1 extractable P (NH_4F–HCl solution) in soil in the treatments that had received fertilizer P was 14 mg P kg^{-1} soil compared to 6 mg P kg^{-1} soil Bray 1 P in the CF–P treatment. The content of water soluble P in the soil with added P was 0.038 mg P l^{-1} while no detectable amount of water-soluble P was found in the CF–P treatment.

The results underscore the importance of P nutrition for *Azolla* growth in the typical lowlands of West Africa deficient in available P. Among other plant nutrients, Mg seemed important.

Table 1. *Azolla* biomass (g m^{-2}) and its elemental composition under various plant nutrient treatments in a lowland Alfisol planted to rice at Mbe (near Bouake), Ivory Coast in 1994

Nutrient treatment	*Azolla* biomass (g dry wt m^{-2})	Nutrient content in *Azolla* (mg kg^{-1}) N	P	K	Zn
CF (all nutrients)	72	40600	4500	26600	38
CF–N	76	32400	4600	23600	39
CF–P	0	–	–	–	–
CF–K	80	42700	3900	22900	26
CF–Ca	92	41500	4250	25000	40
CF–Mg	35	39500	4350	24800	36
CF–Zn	87	42500	4600	24800	30
Mean	63				
LSD (0.05)	27.5				

1. Lumpkin, T. A. and Plucknett, D. L., *Azolla as a Green Manure: Use and Management in Crop Production*, Westview Press, Colorado, 1982, p. 230.
2. Page, A. L., Miller, R. H. and Keeney, D. R. (eds), *Methods of Soil Analysis*, Part 2, American Society of Agronomy, Wisconsin, 1982, p. 1159.

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