SOIL FERTILITY AND NERICA RICE NUTRITION

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Background information

Studies on soil characterization of rice ecologies in West Africa carried out by Africa Rice Center showed that in the upland production systems, the magnitude of nitrogen (N) deficiency increases from the humid forest to the semi-arid zone, whereas phosphorus (P) deficiency is highest in the humid forest but slight in the semi-arid (Oikeh *et al*., 2006a). On soils developed from sandstones, all three macronutrients N, P and potassium (K) are deficient. Therefore, to optimize NERICA production in these soils will require the application of chemical fertilizers.

NERICA varieties have greater yield potential and respond strongly to the use of inputs such as fertilizers.

Agronomy and Integrated Soil Fertility Management

What is the optimum fertilizer rate required for the released NERICA varieties in the humid forest and savanna agroecosystems?

Can we identify rice varieties (NERICA and *Oryza sativa*) that are more efficient in the use of fertilizer?

Methodology

- NERICA1, 2, 4 and 6 were used
- Experimental site under fallow for 3 years
- Different combinations of NPK

Unit 1 – Rate and time of fertilizer application and NERICA response to nutrients

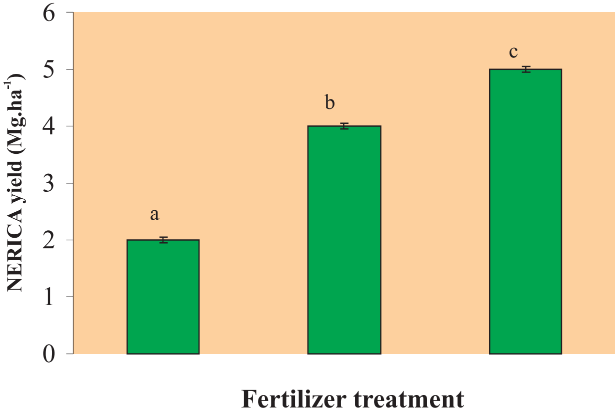
What is the optimum fertilizer rate required for the NERICA varieties under various input cropping systems?

The following fertilizer combinations are recommended for NERICA rice cropping systems in Benin. Please refer to country-specific recommendations for relevant site-specific fertilizer application.

- Combination of 60 kg N, 13 kg P and 25 kg K per ha (low to moderate input) has proved sufficient to double grain yield to *ca*. 4 tonnes per hectare as compared to zero fertilizer application.

- Doubling the levels of N and P at the same K level increases grain yield by 25% over a moderate NPK level.

- 120 kg N, 26 kg P and 25 kg K per ha (appropriate for high input farmers) generates 145% more grain yield compared to no NPK fertilizer application.



N60-P13-K25= 60 kg N, 13 kg P and 25 kg K per ha
N120-P26-K25= 120 kg N, 26 kg P and 25 kg K per ha

Figure 19. NERICA response to fertilizer application in the humid forest zone of West Africa.

- Application of 120 kg N ha^{-1} to NERICA varieties delays maturity by 4 days compared to zero-N fertilizer application.

- With the application of 120 kg N ha^{-1}, NERICA3 matures up to 5 days earlier than the other interspecifics, while the same dose of the same N-fertilizer prolongs the cycle of NERICA2 by about 3 days.

- The above information is important as the short growth cycle of the NERICA varieties is an important trait for drought escape and weed competitiveness, and may enable the farmers to diversify their cropping systems through intercropping or rotations.

- Oikeh *et al.,* (2006b) recommend the use of 60 kg N, 13 kg P and 25 kg K per ha for smallholder farmers with basal application of P and K at sowing and top dressing with one-third urea at the beginning of tillering, and the remaining two-thirds at about panicle initiation.

- Phosphorus is the second most important nutrient after N for rice production, because chemical fertilizers are not readily available nor affordable to smallholder farmers.

In West Africa, Rock-P is locally available in Mali and other neighbouring countries, including Burkina Faso, Mali, Niger, Nigeria, Senegal and Togo.

On the Ultisols (Ferralsols) of the humid forest agro-ecosystem of Côte d'Ivoire, West Africa, Diatta *et al.* (unpublished data) recommend a dose of 150 kg per hectare of rock-P from Mali applied every four years at NERICA rice planting.

Fertilizer requirements for other agro-ecosystems and the development of integrated soil fertility management packages for the different agro-ecosystems in West Africa are in progress.

In Uganda, East Africa, T. Tsuboi (personal communication, 2006) recommends for soils that are sufficient in K, the use of 55:23:0 NPK kg ha^{-1} in the form of 50 kg ha^{-1} di-ammonium phosphate [DAP, 18:46:0 ($NP_2O_5K_2O$)] at 15 to 20 days after germination (DAG, i.e. allowing 5 days between sowing and emergence), and 50 kg ha^{-1} of urea (46% N) each at 15 to 25 DAS and 55 to 65 DAG. But for soils that are low in K, the use of 62:26:26 NPK in the form of 150 kg ha^{-1} of NPK 17:17:17 and 15 to 20 DAS with additional top dressing with 30 kg ha^{-1} urea at 15 to 20 DAG and 50 kg ha^{-1} at 55 to 65 DAG are recommended.

Performance of interspecific lines (*Oryza glaberrima* × *O. sativa*) under aluminium-toxicity growing conditions

Background information

About two thirds of the West African upland rice is produced in the humid forest zone on highly weathered phosphorus (P)-deficient acidic soils. Aluminum (Al) toxicity is very serious on this type of soil and causes other abiotic stresses, resulting in reduction of rice yields. However, information is limited on Al tolerance in NERICA lines.

The objective of the reported study conducted at the Experimental Station in Nakhon Nayok, Thailand, was to evaluate Al tolerance in several interspecific lines, including the NERICA rice (WARDA, 2006 Joint Interspecific Hybridization Project Progress report 2003–2005, pp. 135–140).

Forty-five interspecific lines, including 33 WAB450-derived and 12 WAB1159-derived lines, and 14 check lines, including 12 sativa and two glaberrima lines, were used. Germinated seeds were placed in a sand nursery bed in a greenhouse and the seedlings were grown for two weeks with Yoshida nutrient solution adjusted to pH 5.3. The nutrient solution was renewed every 2 days. The seedlings were transplanted on a plate of Styrofoam floated in a container (90 x 90 x 50 cm) filled with Yoshida culture solution at pH 3.5, and grown for 14 days after transplanting. The Al concentration in the nutrient solution was changed by adding 0.15, 0.3, 0.6, and 1.2 mM aluminum chloride ($AlCl_3 . 6H_2O$). The plants were harvested 14 days after the initiation of the treatment and served for the determination of the dry weight and Al content in the shoots and roots.

Highlights

Among the 45 interspecific lines, 12 showed better growth in Al-treated conditions than any check lines except IR53650 and CG14 in terms of dry matter weight and hematoxylin staining characteristics (Figure 20; Table 17). From the results of hematoxylin and dry weight determination, the tested interspecific lines were classified into seven groups. The Al-tolerant groups, which are derived from WAB450 (10 lines) and WAB1159 (2 lines), revealed higher dry weight than Al-intolerant groups in such high Al concentrations as 0.6 mM and 1.2 mM (Table 17). The analysis of the distribution of Al in the shoots and roots showed the accumulated Al in the belowground biomass was approximately 10-fold higher than in the aboveground biomass, irrespective of the groups (Figure 20). There was no significant difference between tolerant and intolerant groups in the Al accumulation in the roots. However, in the shoots, a significant difference in Al accumulation was found between tolerant and intolerant groups. When the plants were grown in low Al concentrations (0.15 mM or 0.3 mM), the Al contents in the shoots was higher in glaberrima (2 lines) than in all the other lines. When the plants were grown in high Al concentrations (0.6 mM or 1.2 mM), Al contents in the shoots were lower in the three tolerant groups than in glaberrima and the 3 intolerant groups. The WAB450-derived tolerant group showed the lowest Al accumulation in the shoot, followed by WAB1159-derived tolerant, sativa tolerant, glaberrima, WAB450-derived intolerant, WAB1159-derived intolerant, and sativa intolerant group.

This study identified two lines in the WAB450-derived tolerant group, namely WAB450-I-B-P-69-HB and WAB450-I-B-P-82-1-1, which have extremely strong tolerance against Al treatment (Figure 21), implying that these two interspecific lines can be a useful genetic resource for Al tolerance in rice.

Table 17. Difference in dry matter production of rice groups, including interspecific lines grown for 14 days in various Al-treated solutions

Shoot	Absolute basis					Normalized basis*				
	Dry weight of shoot (mg plant-1)					(%)				
	Low pH	0.15mM Al	0.3mM Al	0.6mM Al	1.2mM Al	Low pH	0.15mM Al	0.3mM Al	0.6mM Al	1.2mM Al
glaberrima	165±26	118±10	98±16	98±16	93±16	100	71	59	59	56
S.T**	203±7	133±16	118±10	115±12	105±12	100	65	58	57	52
S.Int	115±10	70±7	45±4	43±4	38±4	100	61	39	37	33
WAB450. T	192±8	157±8	138±6	133±6	112±7	100	82	72	69	58
WAB450. Int	137±5	92±3	75±3	65±2	60±2	100	67	55	47	44
WAB1159. T	105±6	105±3	98±7	98±7	88±13	100	100	93	93	83
WAB1159. Int	113±9	84±6	61±6	56±5	47±5	100	75	54	50	42
Root										
glaberrima	43±10	33±4	30±6	30±6	26±5	100	76	71	71	62
S.T	45±3	33±4	30±3	28±4	25±3	100	72	67	61	56
S.Int	34±3	21±2	13±2	11±1	8±1	100	61	39	31	24
WAB450. T	47±2	41±2	39±2	39±1	37±1	100	87	83	82	78
WAB450. Int	40±1	30±2	26±1	21±1	20±1	100	76	66	54	51
WAB1159. T	35±0	35±0	30±3	30±3	23±1	100	100	86	86	64
WAB1159. Int	29±1	23±2	18±1	16±2	12±1	100	79	62	53	41

* Normalized basis = percentage ratio of the Low pH.
**Abbreviation: S.T = sativa-tolerant; S.Int = sativa-intolerant; WAB450.T = WAB450-derived tolerant; WAB450.Int. = WAB450-derived intolerant; WAB1159.T = WAB1159-derived tolerant; WAB1159.Int = WAB1159-derived -intolerant.

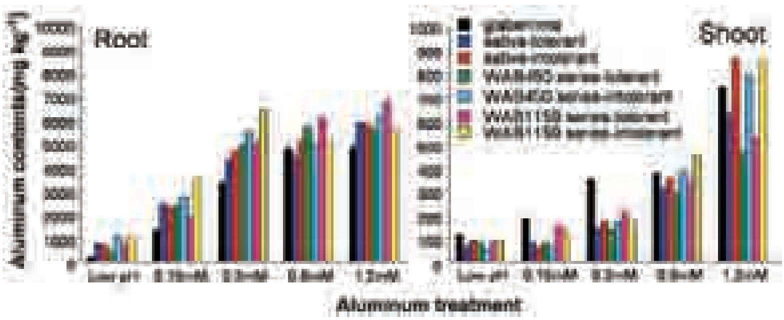


Figure 20. Aluminum accumulation in roots and shoots grown for 14 days in different Al-treated solution conditions (pH 3.5).

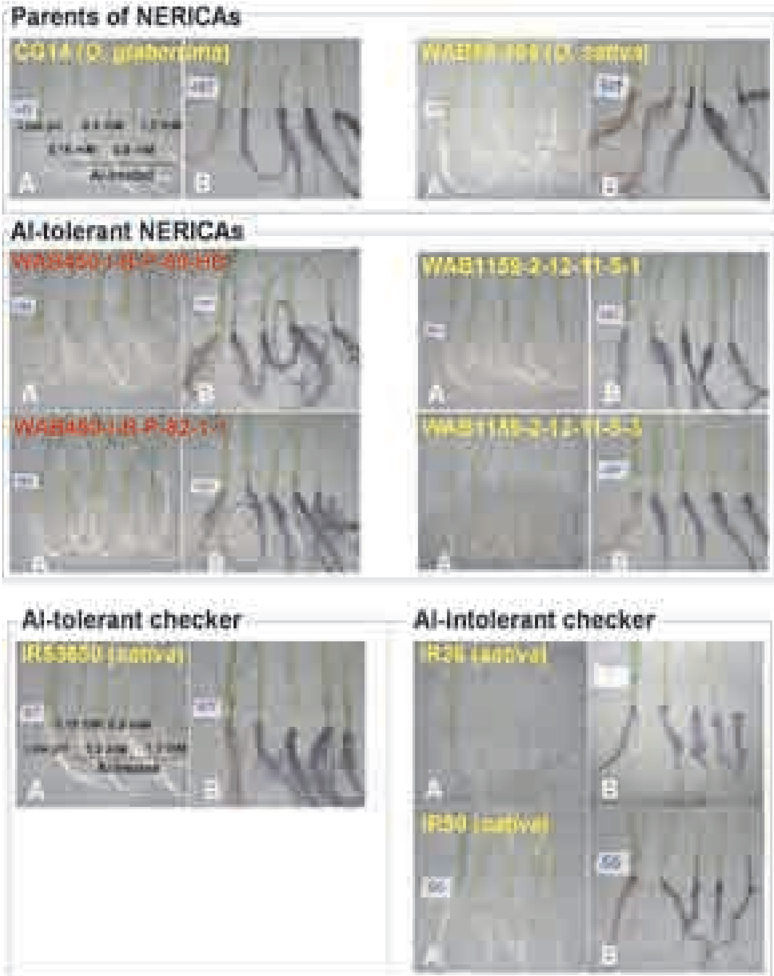


Figure 21. Phenotypic analysis of Al tolerance: Comparisons of root volume and hematoxylin staining in Al-tolerant vs. Al-intolerant rice: (A) Visual symptoms of Al toxicity in the roots; (B) Hematoxylin staining patterns showing differential Al accumulation in the roots.