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Cultivation Systems Using Vegetation Cover Improves Sustainable Production and Nutritional Quality of New Rice for Africa in the Tropics

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Abstract: Little is known about the impact of direct sowing under vegetation cover on the production and quality of New Rice for Africa (NERICA) on poor oxisol. In this study, two NERICA varieties (NERICA 3 and NERICA 8) were grown under tropical oxisol soil with very low nutrient contents. Four cultivation systems were used in completely randomized block design, including plowing (control), unplowed soil with dead vegetation cover (DVC), unplowed soil with live vegetation cover (LVC) and unplowed soil with mixed vegetation cover (MVC). DVC significantly improved the exponential growth of NERICAs. NERICA 3 was the more productive (2.16–3.05 t/hm^2) compared with NERICA 8 (0.71–1.21 t/hm^2). Cultivation systems improved the nutritional quality of NERICAs. The total protein content of NERICA 3 under DVC and MVC was 84.8% and 75.0% higher than control, respectively. The total soluble carbohydrate contents of NERICA 8 under LVC and MVC was 73.2% and 57.3% higher than control, respectively. These results suggested that conservative approach like direct sowing on unplowed soil with vegetation cover systems can improve the nutritional quality of rainfed NERICAs and their sustainable production under poor oxisol soil in sub-Saharan Africa.

Key words: direct sowing; sustainable production; nutritional quality; rice; vegetation cover; yield; protein; soluble carbohydrate content

The world's population will hit 9 billion by 2050 (Dubois, 2011). In order to feed this escalating population, the world requires a global revolution and cereal production potential must increase by more than 80% in sub-Saharan Africa countries (van Ittersum et al, 2016). Sustainable food production and agriculture play an important role in the economy in these countries. Rice (*Oryza sativa* L.) is the staple food of more than 60% of the world's population and provides up to 50% of the dietary caloric supply for millions living in poverty (Muthayya et al, 2014). Rice annual deficit is estimated to increase from 400 000 t in 2016 to 800 000 t by 2030 (Thirze, 2016). To overcome this deficit, new more productive upland rice varieties called NERICA (New Rice for Africa) have been developed by crossing *O. sativa* L. with *O. glaberrima* Steud. However, the nutritional quality is highly variable and its production does not yet satisfy the expected potentials in conditions of very low biophysical soil suitability (Yengoh and Ardö, 2014). Three types of rice cultivation systems (irrigated, rainfed lowland and rainfed upland) are known and practiced, of which rainfed upland rice (over 68% of rice cultivation area)

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is known for its high yield gap (van Ittersum et al, 2016). Most of the farmers inadequately apply fertilizers above the recommended rates/doses to increase the yields, leading to long-term increase in soil acidity and degradation of its physical status (Tonfack et al, 2009). It has been reported that the usual tillage practice significantly decreases soil organic matter (Mohammed et al, 2013) and increases leaching which decreases the nutrient content of the soil (Pimentel et al, 2013). Nutrient deficit does not only affect the growth and development but also the nutritional quality in plants (Shaon, 2014). Direct planting systems under vegetation cover (DPSVC) have been developed worldwide to cope with this phenomenon. These systems constitute an innovative approach to agriculture, making it possible to avoid plowing, leading to the positive effects of mulching plants on organic matter enrichment of the surface horizon (Corbeels et al, 2006), improvement of soil nitrogen and moisture retentions through reduced evaporation (Davidson et al, 2015; Kaur and Brar, 2016), and improvement of soil fertility (Rakotoarisoa et al, 2010). DPSVC are based on three principles: absence of tillage, permanent cover of the soil, and succession or judicious crop rotation in association with cover crops (AFD, 2006). The adoption of these approaches is still low in several sub-Saharan African countries because of farmers' habits and the competitiveness of livestock production for crop residues in agro-pastoral areas (M'Biandoun et al, 2009). Moreover, perennial leguminous crops recommended in DPSVC are twining plants and are not adequate for rice production. This study aimed to pave way for the use of DPSVC as an agricultural approach, making it possible to improve the NERICA quality in terms of total soluble carbohydrates (TSCs) and protein content.

MATERIALS AND METHODS

Culture condition, experimental design and land preparation

The experiment was performed in an open field with two short cylcle (95–100 d) rainfed hybrid rice varieties (*O. sativa* × *O. glaberrima* cvs. NERICA 3 and NERICA 8) from Africa Rice and a bean (*Phaseolus vulgaris* cv. 'Nitu' offered by the Institute of Agricultural Research for Development) in Yaounde, Cameroon (35º12′ N, 11º27′ E, alt: 717 m) in March 2015. An average rainfall of 1 700 mm and an average temperature of 26 ºC ± 2 ºC were recorded during the experimental period. Soil sample was collected all over the 260 m^2 and analyzed as previously described (Tonfack et al, 2013).

The experimental design consisted of four completely randomized blocks, each with eight experimental plots of six square meter. The treatments, in four replicates, consisted of two rice varieties (NERICA 3 and NERICA 8) and four cropping systems (Fig. 1): Control or conventional plowing system, unplowed soil with sowing under dead vegetation cover (DVC) of *Chromolaena odorata*, unplowed soil with sowing under live vegetation cover (LVC) of *Phaseolus vulgaris* and unplowed soil with sowing under mixed (live and dead) vegetation cover (MVC).

The experimental field was cleaned and herb was hoed off. The control plots were thoroughly hand-plowed at 15–20 cm deep and leveled. One week before sowing, the removed dead plant (*C. odorata*) was weighted and used as mulching layer at 7 t/hm^2 to cover the soil on DVC and MVC plots.

Sowing, amendment and management

Dry seeds were manually broadcasted onto the soil surface and then incorporated by harrowing while the soil was still dry. Rice seeds were sown in early March (6 seeds per hole) following a 30 cm × 30 cm pattern at a depth of about 3 cm. In LVC and MVC experimental plots, beans were sown (three seeds per hole), following the same pattern between the rice lines (Fig. 1). After emergence, four rice seedlings and two bean seedlings were preserved per hole with others discarded. Mineral fertilizer [N:P:K] [20:10:10] was applied at 300 kg/hm^2 on experimental plots. During tilling (from end March to early April) and stem elongation (from end April to early May), urea (46% N) was applied at 50 kg/hm^2.

During the experiment, hand weeding was done when necessary, avoiding to harm rice plants. No pesticide application was done.

Evaluation of plant sprouting, growth, development and yield

At two weeks after sowing, the number of pits with seedlings were counted on different plots and the effect of cultivation system on seeds sprouting was assessed as follows:

Rate of sprouting (%) = No. of pits with seedlings / No. of sown pits × 100

The plant height (from the base to the tip) and the number of leaves per plant were recorded at seven days interval, from three weeks up to ten weeks after sowing, on tagged plants. The kinetic curves were used to generate regression equations and R^2 of plant height and number of leaves per plant.

At harvest (by middle June, when the plant turned brown

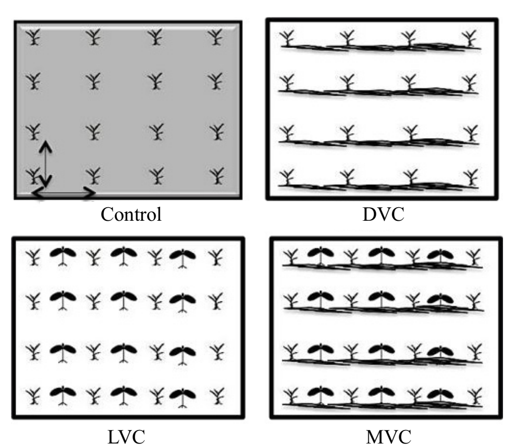

Fig. 1. Different sowing patterns in the experimental design.

Control, Plowed soil without vegetation cover; DVC, Unplowed soil with dead vegetation cover; LVC, Unplowed soil with live vegetation cover; MVC, Unplowed soil with mixed vegetation cover.