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Basal fertilizer effects on weed occurrence and rice yield in acid upland soil of West Africa at Bénin

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Abstract: Fertilizers application is required in order to improve rice production in low fertile soils of West Africa. This practice can also increase weed pressure in rice field, thereby reducing yield significantly. Chemotropism of weed was hypothesized to identify nutrient effects on weed abundance and biomass production as well as rice yield for suitable recommendation of basal fertilizer in *terre de barre* soil agro-ecology. Two years (2005 and 2006) fertilizer omission trial including nitrogen (N), potassium (K), phosphorus (P), calcium (Ca), magnesium (Mg) and zinc (Zn) was conducted in a randomized completed block design, with 4 replications at the Africa Rice Center experiment station, in Benin. The New Rice for Africa named NERICA 4 was sown. Weed dominance-abundance indices and biomass, as well as, rice grain yield were assessed. Results show that *Digitaria horizontalis* Wild and *Mariscus cylindristachyus* Steudel were the most dominant weed species in rainfed rice fields on *terre de barre* soils and the omission of Zn has ability to discriminate among weeds. Base on weed biomass (60.11 – 129.26 g m^{-2}) reduction by 36 – 53% in treatments with Ca, Mg and P omission, the application of N, K and Zn was recommendable for basal fertilizer as integrated weed management practice for boosting rice production on *terre de barre* soils in West Africa.

Keywords: Chemotropism, Fertilizer, Rainfed Rice, *Terre de Barre* Soil, Weeds

1. Introduction

Rice (*Oryza sativa* L.) is an important staple food in West Africa. It is largely grown on small-scale farms, usually of less than 1 ha in size [1]. About 57% of total rice area in West Africa is planted to upland rice under various cropping systems. Weeds are the major causes of yield loss in upland rice (48-100%), and control is labor intensive ([2], [3]). Smallholder farmers manage weeds in upland rice using hoes and machetes, but they face out high costs and labor shortages. Herbicides for weed control in upland rice are expensive and often not affordable to the majority of smallholder farmers. Furthermore, when available, farmers lack the required skills for the proper use of herbicides [4]. Although herbicide use is an alternative to labor in controlling weeds, misuse can result in health and environmental risks [5]. Reduced dependence on herbicides can lower crop production costs and retard weed resistance to herbicides [6].

Applying allelopathy concept ([7], [8], [9], [10]) based on toxins (terpenoids, monoterpens, sesquiterpenes, sesquiterpene lactones, triterpenes, benzoxazinones and fatty acids) secretion against weeds by cereals such as rice and rye (*Secale cereale* L.) could have been the best strategy in this context. However, allelopatic ability of African rice cultivars is not well established yet [11]. Moreover, fallow practice [12], planting methods [4] and crop rotation [13] as weed management methods are not widely adopted in West Africa for upland rice cultivation, because of labor, time, and land shortages ([14], [15], [16]).

A recent study conducted by Ekeleme *et al.* [17] identified some cultivars of New Rice for Africa (NERICA 1 and NERICA 4), that had highest weed competitive ability under upland conditions in West Africa. However, this performance was obtained with two hand weeding periods as conventional method, which was not fully adopted by farmers, due to time constraint [18]. Therefore, it is still important to investigate weed management strategies, especially for upland rice cultivation in West Africa. Fertilizer effects on weed species ([19], [20]), combined with NERICA performance can meet this requirement. In fact, fertilizer can affect weed-rice competition through rate and time of application [21], as well as the type of fertilizer [22]. However, there is limited data on such knowledge in Africa ecosystems and extrapolation can be risky, because of specific relationships between soil, vegetation and climate under tropical environments [23]. Hypothesizing weed chemotropism [24], nutrient exclusion from basal fertilizer may impair weed species abundance, reinforcing rice competitiveness at least before the tillering stage. This approach can be useful, especially in case involving micronutrients, which may have minimum effect on rice yield.

The present study was conducted in Benin to assess the effects of different compositions of basal fertilizer on weed occurrence and NERICA 4 yield on acid soil in a derived savannah zone of West Africa. More specifically, the study aims to identify specific fertilizers that can reduce weed pressure in rice fields, thereby allowing one hand weeding, instead of two and inducing high yield of rice.

2. Material and Methods

2.1. Site Description

The study was conducted during the cropping seasons of 2005 (June – September) and 2006 (May – August), at the Africa Rice Center (ex-WARDA) experiment station in Cotonou (6º 28 N; 2º 21 E, 15 m asl), Benin. The site is a derived savannah zone in the Dahomey gap of West Africa. The rainfall pattern was bimodal with 488.3 and 482.6 mm, during 2005 and 2006 cropping seasons respectively. The soil is locally referred to as *terre de barre*. It is a very deep (>10 m) Acrisol, free of morphological constraints (gravels, stones or hardpan) in the profile. Soil C (7.20 g kg^{-1}) and N (0.60 g kg^{-1}) contents were low in the topsoil (0 – 20 cm), but medium for P content (P-Bray I = 15 mg kg^{-1}). A wide variability of soil K, Ca and Mg contents were observed in a ranges of 0.07 – 0.73 cmol kg^{-1}, 1.97 – 1.25 cmol kg^{-1} and 0.70 – 0.81 cmol kg^{-1}, respectively. The texture was dominated by sand particles (126 g kg^{-1} of clay, 14 g kg^{-1} of silt and 860 g kg^{-1} of sand). The experiment was preceded by a 3- year bush fallow dominated by *Panicum* spp. and *Imperata cylindrica* (L.) Raeuschel mixed with *Mucuna pruriens* (L) DC.

2.2. Experimental Design

The area used for the experiment was cleared and tilled, using a tractor one month before the beginning of the experiment and a plot of about 1000 m^2 was manually re-tilled. Plant debris was raked up from the plot during land operations. In 2005 and 2006 a randomized-block design, with 8 treatments and 4 replications, was used : i) Complete fertilizer (Fc) composed of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and Zinc (Zn), ii) 6 incomplete fertilizers treatments, with a specific nutrient exclusion from Fc (Fc-N, Fc-P, Fc-K, Fc-Ca, Fc-Mg and Fc-Zn), iii) and a check with no fertilizer (0). The rates of 30 kg N ha^{-1} (urea), 100 kg P ha^{-1}(triple super phosphate), 100 kg K ha^{-1} (potassium chloride), 50 kg Ca ha^{-1} (calcium sulfate), 50 kg Mg ha^{-1} (magnesium sulfate) and 10 kg Zn ha^{-1} (zinc sulfate) were applied as basal fertilizer before sowing the rice [25]. Additional 35 kg ha^{-1} N rates, as urea, were applied at both tillering and panicle initiation stages respectively. Fertilizers were broadcasted and incorporated in 5 – 6 cm soil depth every year during the two-year period of the trial. The rice cultivar NERICA 4 (50 % of flowering at 70 days after emergence-DAE; maturity at 100 DAE) was sown at 3 grains per hill early. The hills were spaced within and between rows at 20 cm × 20 cm, in micro-plot of 5 m × 3 m size. Rice emergence occurred about 3-5 days after sowing. Manual weeding was done, once at 21 DAE. After harvest, the land was left in fallow until the next cropping season. The experiment was repeated every year in the same plot for respective treatment during the two-year period.

2.3. Data Collection

Weed abundance was recorded at 21 DAE and rice maturity stage using the dominant-abundance index (1= cover less than 1/20; 2 = cover between 1/20 – 1/4; 3 = cover between 1/4 – 1/2; 4 = cover between 1/2 – 3/4 and 5 = cover more than 3/4) of Braun-Blanquet, as described by Chicouene [26] for each micro-plot (15 m^2) of treatments. Weed absence was recorded as 0; aboveground -weed biomass was harvested within a 1 m^2 quadrat which was randomly placed 3 times in each subplot every time after recording species abundance index. Weed biomass was oven-dried at 70˚ C for 72 hrs and weighed. Mean weight of weed species biomass was reported for each treatment every year throughout the experiment. Rice grain was harvested at maturity within 8 m^2 plot, sun-dried and weighed after moisture content measurement. Grain yield was calculated at 14 % moisture content.

2.4. Statistical Analysis

Univariate procedure of descriptive statistic (SAS, version 8) was used to determine the average value of weed species abundance indexes per treatment for 75% (Q3) of observed cases. Across year variability of weed spectrum was shown according to cross-table analysis (SAS, version 8). Discriminant analysis (SPSS, version 9) was also used: The grouping variables were the eight treatments of the study while, the abundance indexes of encountered weed species (21) were the dependant variables. Moreover, analysis of variance (SAS version 8) was done to compare mean values of weed biomass, as well as for grain yield between treatments. The least significant difference (lsd) was used to test for means separation at α equal 0.05 regarding to the lack of significant difference obtained with other tests. Weed species were selected according to their significant Pearson correlation analysis (SAS version 8).

3. Results

3.1. Weed Occurrence According to the Treatments and Years

Table 1 shows average values of weed species abundance indexes per treatment, for 75 % of observed cases. The indexes ranked from 0 to a maximum of 3 with dominant weed species in rice field identified as: *Digitaria horizontalis* Willd., *Passiflora foetida* L., *Hyptis suaveolens* Poit., *Croton lobatus* L., *Mariscus cylindristachyus* , *Tridax procumbens* L., *Talinum triangulare* (Jacq.) Willd, *Cleome viscosa* L., *Phyllanthus amarus* Schum. & Thonn., *Boerhavia erecta* L., *Ipomoea involucrata* P. Beauv., *Diodia radula* Cham. & Chltdl., *Pupalia orbiculare* Forssk.f. and *Rottboellia cochinchinensis* (Lour.) W. Clayton.

However, only *D. horizontalis*, *P. foetida*, *C. lobatus*, *M. cylindristachyus* and *T. procumbens* had highest (>1) values of dominance index, especially for *D. horizontalis* and *M. cylindristachyus*. Indeed, *D. horizontalis* had highest (3) abundance index in all treatments. Similar observations were made for *M. cylindristachyus,* except in treatments Fc-K, Fc-Mg and Fc-Zn having significantly lower frequency. Besides *D. horizontalis* and *M. cylindristachyus*, the 0-fertilizer treatment induced also a significant high abundance (2) of *P. foetida*, *H. suaveolensis* and *D. radula*. Greater reduction of weed spectrum was observed in the treatments Fc-Mg and the control with the absence of 4 weed species including *T. triangulare* and *I. involucrata*. Although Fc treatment induced abundance index value of 2 for *P. orbiculare*, this species and *I. involucrata* were often absent according to the treatments.

Furthermore, annual variation of weed occurrence was shown in Table 2: *H. suaveolens* and *D. radula* encountered in 2005 were significantly absent (100%) in the field during the trial in 2006. Meanwhile, significant occurrence of additional species (*Kyllinga erecta*, *Croton hirtus* and *Paspalum scrobiculatum*) was noticed in the last year (2006).

3.2. Fertilizers Ability to Discriminate Weeds Groups

Three factors (F1, F2 and F3) were identified to be able to discriminate weed occurrence significantly according to the treatments with 73.6% of total information (Table 3). The abundance indexes of eight (Dh, Pf, Be, Po, Mc, Tt, Tp and Cv) of the identified weed species characterized the factors according to the higher values of their respective standardized coefficients as illustrated in figures 1, 2 and 3.

***Table 1.** Mean values (2005 and 2006) of weed species abundance indice per treatment at 75 % (Q3) of case observed*

Treatment	Dh	Pf	Hs	Cl	Mc	Tp	Tt	Cd	Pa	Be	Cv	Ii	Dr	Po	Rc
0	3**	2*	2*	1**	3**	1*	0	0	1*	1	0	0	2	1	1
Fc	3**	2*	1*	1**	3**	2*	1	1*	1*	0	1**	1	1	2	0
Fc-P	3**	1*	2*	1**	3**	2**	1	1	1	0	2	0	0	1*	1*
Fc-N	3**	2**	1	2**	3**	2**	1	1	1*	1	0	0	1	1	1
Fc-Ca	3*	1**	1*	2**	3**	2**	1*	0	1*	1	1	1	1*	0	0
Fc-K	3*	2**	1*	2**	2**	2*	1*	1	1*	1*	1	1	1	0	1
Fc-Mg	3*	2**	1*	2**	2**	2*	0	1	1*	0	1**	0	1*	0	1
Fc-Zn	3*	2**	2**	2**	2**	1*	1*	0	1*	2	2	0	1	0	1

Highly significant (P>| t| = < 0.01) : ** ; Significant (P> | t| = < 0.05): *
Dh: *Digitaria horizontalis*, Pf: *Passiflora foetida*, HS: *Hyptis suaveolens*, Cl: *Croton lobatus*, Mc: *Mariscus cylindristachyus*, Tp: *Tridax procumbens* , Tt:*Talinum triangulare*, Cd: *Commelina diffusa*, Pa : *Phyllanthus amarus*, Be: *Boerhavia erecta*, Cv: *Cleome viscosa*, Ii: *Ipomoea involucrata*, Dr : *Diodia radula* ,Po: *Pupalia orbiculare*; Rc: *Rottboellia cohinchinensis*.

***Table 2.** Frequency (%) of total weed species encountered according to their absence in 2005 and 2006*

Weed species	Frequency (%) of species absence		χ^2-Probability
	2005	2006	
D. horizontalis	28.13	37.50	0.037
P. foetida	15.63	84.38	<0.0001
H. suaveolens	72.00	100	0.005
C. lobatus	9.38	72.00	<0.0001
M. cylindristachyus	87.00	32.00	0.343
T. procumbens	50.00	37.50	0.032
T. triangulare	78.00	69.00	0.363
C. diffusa	97.00	100	0.313
P. amarus	56.25	43.75	0.059
B. erecta	97.00	100	0.313
C. viscose	78.10	66.00	0.090

Weed species	Frequency (%) of species absence		χ^2-Probability
	2005	2006	
I. involucrate	97.00	87.500	0.340
D. radula	81.25	100	0.010
P. orbiculare	94.00	100	0.150
R. cohinchinensis	97.00	97.00	1.000
M. oppositifolia	100	97.5	0118
C. hirtus	100	56.25	0.056
K. erecta	100	71	0.028
I. cylindrica	100	81.25	0.250
P. scrobiculatum	100	31.25	0.0001
M. peltata	100	94	0.150

Table 3. *Characteristic of weed canonical discrimination functions according to the eight treatments use as grouping variable*

Fonction	Eigenvalue	Variance (%)	Cumulative (%)	Canonical Correlation
F1	1.096	33.3	33.3	0.723
F2	0.741	22.5	55.8	0.65
F3	0.583	17.7	73.6	0.607
F4	0.380	11.5	85.1	0.525
F5	0.302	9.2	94.3	0.482
F6	0.152	4.6	98.9	0.363
F7	0.036	1.1	100	0.187
	Wilks' Lambda	χ2	Df	Significance Probability
F1 through F7	**0.081**	**129.61**	**105**	**0.05**
F2 through F7	**0.169**	**91.51**	**84**	**0.27**
F3 through F7	**0.295**	**62.95**	**65**	**0.54**

Factors F1 and F2 have significantly discriminated two groups of weed by the effect of the treatments Fc-Zn and Fc-Mg (Figure 1).

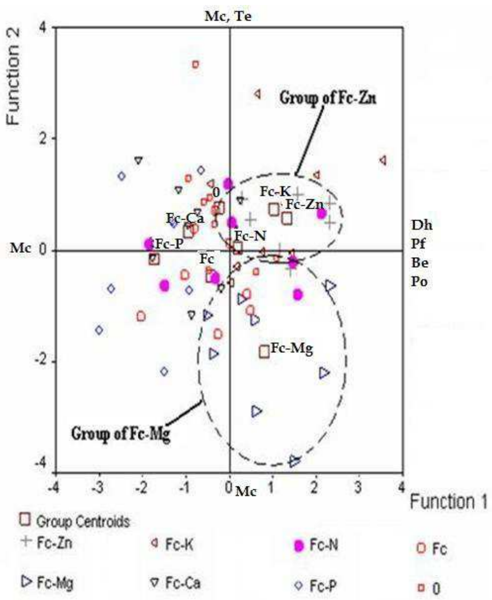

Figure 1. *Groups of weed discriminated by the factors 1 and 2 according to fertilizer treatments (Dh: Digitaria horizontalis; Pf: Passiflora foetida; Be: Boerhavia erecta; Po: Pupalia orbiculare; Mc: Mariscus cylindristachyus; Tt: Talinum triangulare; Tp: Tridax procumbens).*

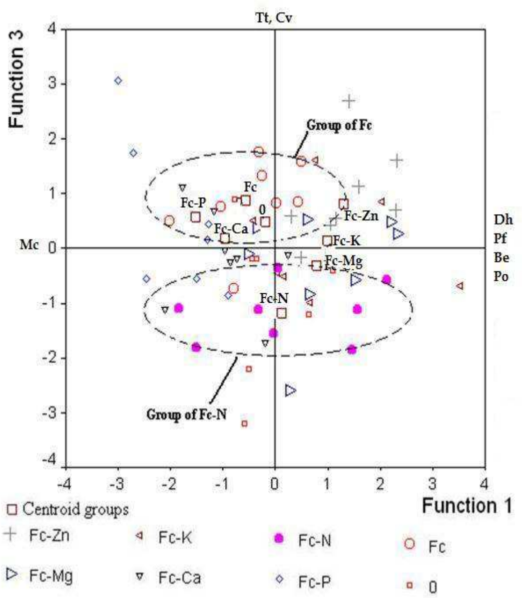

Figure 2. *Groups of weed discriminated by the factors 1 and 3 according to fertilizer treatments (Dh: Digitaria horizontalis; Pf: Passiflora foetida; Be: Boerhavia erecta; Po: Pupalia orbiculare; Mc: Mariscus cylindristachyus; Tt: Talinum triangulare; Cv: Cleome viscose).*

In figures 2 and 3, treatments Fc and Fc-N have also discriminated two groups of weed species. But species within the group are widely spread referring to the centroid group position, which often showed confusion between the different groups. These observations were confirmed by the cross validation matrix showing non-alignment of the highest coefficient values across the diagonal in Table 4. However, it was revealed that 20.3% to 56.3 % of the original cases could be correctly classified by treatment effects. Indeed, the group of treatment Fc-Zn was confirmed by cross-validation to be well- classified, with a highest coefficient value in the predicted group contrasting with other groups (0, Fc, Fc-Mg and Fc-N) that were confused.

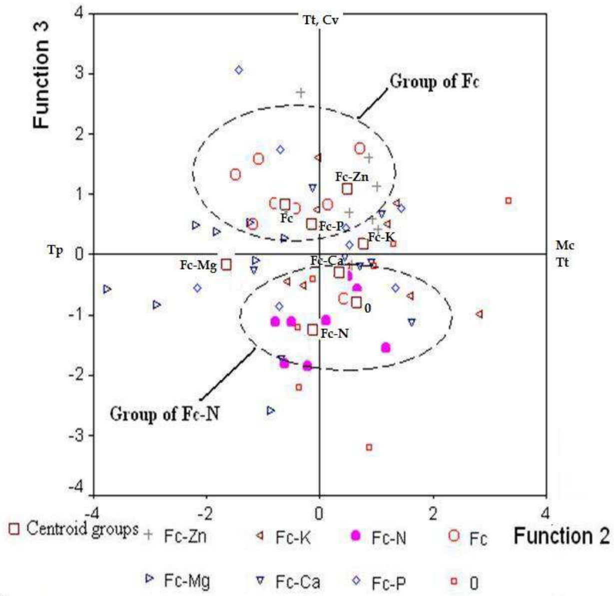

Figure 3. *Groups of weed discriminated by the factors 2 and 3 according to fertilizer treatments (Mc: Mariscus cylindristachyus; Tp: Tridax procumbens; Tt: Talinum triangulare; Cv: Cleome viscose).*

3.3. Weed Biomass and Rice Grain Yield

Significant differences of grain yield were observed between mean values obtained in 2006 and the average grain yield values of the two years (Table 5). The mean values of rice grain yield were lower in 2005 than in 2006 ranging from 0.23 t ha^{-1} to 1.93 t ha^{-1}. But, no significant difference was observed between the mean values of weed biomass (60.11 – 129.26 gm^{-2}) according to the treatments from 2005 to 2006. However, weed biomass was significantly depressed in 0 (check) and Fc-P treatments in both years. The 0-fertilizer treatment has also depressed rice grain yield significantly in 2006 and for the across year average yields. On the contrary, rice grain yield was not significantly depressed in Fc-P treatments, contrasting with weed biomass.

Similar effects were observed for the across year mean values, while Fc-K treatments induced depression of weed biomass and rice grain yield. Higher values of weed biomass and rice grain yield were observed in Fc-Zn treatment. The grain yield obtained for Fc-Ca (0.92 t ha^{-1}), Fc-Mg (1.03 t ha^{-1}) and Fc-P (0.85 t ha^{-1}) treatments did not differ significantly from the highest yield value observed in Fc (1.09 t ha^{-1}). However, these treatments induced significant lower weed biomass also depending on rainfall (Figure 4).

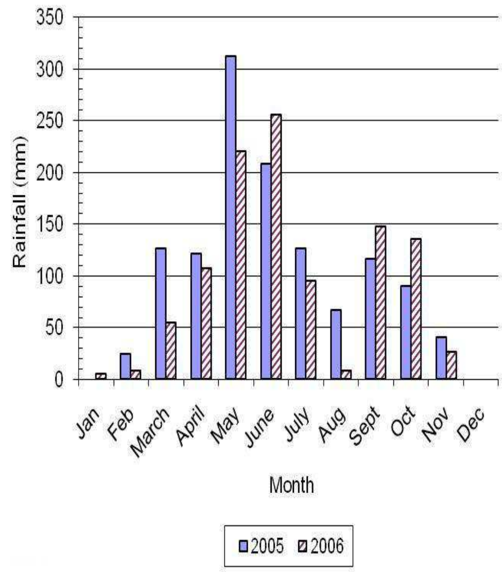

Figure 4*. Monthly rainfall in 2005 and 2006 at the experimental site.*

Table 4. *Confusion matrice of the eight groups classification*

		Predicted groups							
Original groups		0	Fc	Fc-P	Fc-N	Fc-Ca	Fc-K	Fc-Mg	Fc-Zn
Validation	0 (%)	37.5	0.0	0.0	50.0	12.5	0.0	0.0	0.0
	Fc (%)	12.5	75.0	12.5	0.0	0.0	0.0	0.0	0.0
	Fc-P (%)	0.0	0.0	75.0	0.0	12.5	0.0	12.5	0.0
	Fc-N (%)	12.5	0.0	12.5	37.5	12.5	0.0	12.5	2.5
	Fc-Ca (%)	0.0	0.0	12.5	12.5	75.0	0.0	0.0	0.0
	Fc-K (%)	12.5	0.0	0.0	0.0	25.0	37.5	0.0	25.0
	Fc-Mg (%)	0.0	12.5	0.0	12.5	12.5	0.0	50	12.5
	Fc-Zn (%)	12.5	0.0	0.0	0.0	0.00	25.0	0.0	62.5
Case of original group correctly classified							**56.3 %**		

Original groups		Predicted groups 0	Fc	Fc-P	Fc-N	Fc-Ca	Fc-K	Fc-Mg	Fc-Zn
Cross-validation	0 (%)	12.5	25.0	0.0	50.0	12.5	0.0	0.0	0.0
	Fc (%)	12.5	12.5	25.0	0.0	0.0	25.0	12.5	12.5
	Fc-P (%)	12.5	25.0	12.5	12.5	12.5	0.0	12.5	12.5
	Fc-N (%)	25.0	0.0	25.0	0.0	12.5	0.0	12.5	25.0
	Fc-Ca (%)	12.5	12.5	12.5	0.0	25.0	12.5	25.0	0.0
	Fc-K (%)	0.0	12.5	0.0	12.5	25.0	25.0	0.0	25.0
	Fc-Mg (%)	0.0	25.0	0.0	25.0	12.5	0.0	12.5	25.0
	Fc-Zn (%)	12.5	0.0	0.0	0.0	0.0	25.0	0.0	62.5
Case of cross-validated group correctly classified								**20.3 %**	

Table 5. *Weed biomass (WB) and rice grain yield (RGY) per year as induced by treatments.*

	2005		2006		Mean	
Treatments	**WB ($g.m^{-2}$)**	**RGY ($t\ ha^{-1}$)**	**WB ($g.m^{-2}$)**	**RGY ($t\ ha^{-1}$)**	**WB ($g.m^{-2}$)**	**RGY ($t\ ha^{-1}$)**
Fc	98.23abA	0.25aB	101.20abA	1.93aA	99.71ab	1.09a
Fc-Ca	80.80abA	0.26aB	84.21abA	1.58abA	82.50b	0.92abc
Fc-K	83.64abA	0.20aB	86.80abA	1.30bcA	85.20b	0.75bc
Fc-Mg	78.95abA	0.25aB	81.46abA	1.81abA	80.20b	1.03ab
Fc-N	98.70abA	0.34aB	100abA	1.26bcA	99.35ab	0.80abc
Fc-P	59.58bA	0.23aB	60.64Ba	1.48abcA	60.11b	0.85abc
Fc-Zn	123.81aA	0.32aB	134.71Aa	1.39abcA	129.26a	0.85abc
0	67.05bA	0.25aB	60.64Ba	1.02cA	68.00b	0.63c
Mean Lsd.05 *Pr>F*	86.34 55.11 0.362	0.26 0.171 0.972	89.73 59.00 0.253	1.47 0.606 0.665	88.05 39.86 0.024	0.86 0.326 0.147

a, b and c are indicating mean values that are significantly different in a column; A and B are indicating mean values with significant difference in line for WB and RGY respectively.

4. Discussion

4.1. Weed Species in Upland Rice Field

The most encountered weed species in upland rice-based systems in West Africa, were listed as *R. cochinchinensis*, *D. horizontalis*, *A. conyzoides* and *T. procumbens* [4]. Only *A. conyzoides* was not recorded in actual study, whereas *P. foetida, M. cylindristachyus, T. triangulare* and *C. lobatus* were also revealed as dominant weed species. *R. cochinchinensis* was found to be less abundant in rice field, contrary to earlier reports. Differences in soil fertility level can account for these analyses regarding the variability in *R. cochinchinensis* abundance (Table 1). These data restate the complexity of site specific characterizations, in terms of weed occurrence in agro-ecological zones, because of temporal and spatial variability in weed species occurrence. Weed seed dormancy [12], land use [27] and local climate, as well as soil conditions [28] can contribute to the difference observed between actual result and previous knowledge. Consequently, there is limited ability to predict weed species occurrence in a cultivated field. Indeed, annual variability of weed species occurrence was also observed from 2005 to 2006 (Table 2) as reported by Armengot *et al.* [29] to be a consequence of land-use in cereal field.

The occurrence of *P. scrobiculatum* in 2006 was a typical illustration of land-use effect according to Heuzé *et al.* [30]. Therefore, we confirm that the continuous cropping can induce changes in weed communities as asserted by Liebman and Robichaux [31]. Hence, we assume that families or taxonomic groups of weeds can be more appropriate for predicting weed occurrence in order to plan a weed management strategy. Such missing knowledge can also explain the error reported by Major *et al*. [32] in various works related to soil fertility effect on weed species abundance in agricultural systems. Long-term multi-location studies of weed community spatial variability, under continuous rice cultivation can provide more consistent data for predicting weed occurrence and improving weed integrated management strategies for rice cultivation. Nevertheless, our study revealed the possibility of weed discrimination by treatment Fc-Zn (Table 4). In this condition (Zn-deficient soils), more abundance of *D. horizontalis*, *P. foetida*, *C. lobatus* and *M. cylindristachyus* can be predicted (Table 1). This finding reinforces the knowledge of Zn influence on weed occurrence as reported by Udoh *et al.* [33] and confirms the occurrence of *Digitaria* sp. in Southern Guinea savanna agro-ecological zones of West Africa [34].

4.2. Fertilizer Effect on Rice Production and Weed Species Occurrence

The lower rice grain yield (<0.5 t ha^{-1}) observed in 2005 can be attributed to the late sowing date, at the end of June, hence rice reproduction stage (flowering) coincided with the mid-season drought that occurred in August (66.2 mm). In 2006, sowing was done earlier, in May. Therefore, the mid-season drought occurred in August (8 mm) coincided with the maturity stage of rice (Figure 4). As result, rice reproduction process was more disturbed [35] in 2005, whereas the mid-season drought effect was partially escaped in 2006. However, there was no significant difference of weed biomass from 2005 to 2006 (Table 5) according to the treatments in spite of the widest spectrum of weed species recorded in 2006 (Table 2). In fact, except for *P. scrobiculatum*, the new species appeared in less than 50% of the studied plots in 2006 while some old species has disappeared.

The study also showed that the exclusions of P, Ca and Mg from basal fertilizer had reduced weed biomass without affecting significantly rice yield. Therefore, these nutrients are not recommended for rice production in *terre de barre* soils. The rice yield and weed biomass were significantly decreased by K exclusion justifying the use of this nutrient in basal fertilizer. Although not significantly reduced, the yield loss induced in treatments Fc-N and Fc-Zn reached 27% and 22% respectively in relation with the high weed biomass recorded. Beside this yield loss that could be of interest for smallholder, the weed biomass induced can be a labor threat for them. Consequently, the basal fertilizer should also include N and Zn. Finally, the composition of basal fertilizer (N, K and Zn) concerned the nutrients already identified as deficient in *terre de barre* soils ([25], [37]) whereas, soil contents of P, Ca and Mg are known to be moderate or suitable for crops. Therefore, it is likely that correcting nutrient deficiency in soil can be crucial in determining basal fertilizer components for both crop production and weed management. Otherwise, supplement available nutrients can be more profitable for weed than crop [37]. However, weed assemblage can be of interest in determining their competitive ability with rice as illustrated in treatment Fc-Zn (Tables 1 and 5):

Rice yield was not significantly decreased in spite of the higher weed biomass probably because of a reduced spectrum of weed species compared with treatment Fc-K. Furthermore (Table 6), no significant relationship was observed in Fc-Zn for *P. foetida* and *C. lobatus* that have negative relationship with rice yield in treatments Fc-Ca (-0.92), Fc-N (-0.85) and Fc-K (-0.63) respectively. In contrast, a positive correlation (0.66) was observed for *P. scrobiculatum* in the treatment Fc-Zn for a significant level of 0.10. However, there is a need of more investigation to clarify such positive relationship in rice field.

Our data showed 36 to 53 % of weed biomass reduction through fertilizer treatments and probably because of soil covered by rice canopy. In the case of 53 % of weed biomass reduction, we can assume that weeding operation can be also reduced to one instead of two before rice tillering stage.

Deepening of such knowledge (fertilizer effect × number of weeding) can help to develop more affordable weed management strategies through labor and fertilizer cost reduction, with positive socio-economical consequences [38] that can boost rice production in West Africa.

Table 6. *Significant (P) Pearson correlations (R) observed between weed abundance index and rice grain yield according to the treatments.*

	Fc		**Fc-Ca**		**Fc-K**		**Fc-Mg**		**Fc-N**		**Fc-P**		**Fc-Zn**		**0**	
Weeds	**R**	**P**	R	P	**R**	**P**	R	P	**R**	**P**	R	P	**R**	**P**	R	P
Cl	-0.89	0.002	-0.24	0.550	-0.63	0.090	-0.04	0.915	-0.30	0.460	-0.74	0.030	-0.02	0.959	-0.59	0.153
Pa	0.16	0.700	0.64	0.080	0.32	0.435	0.33	0.421	0.37	0.359	0.35	0.399	0.13	0.752	-0.01	0.977
Ps	0.38	0.342	0.29	0.481	0.63	0.080	0.71	0.040	0.75	0.030	0.51	0.191	0.66	0.071	0.35	0.388
Dh	-0.52	0.183	0.49	0.212	0.17	0.678	0.63	0.090	-0.03	0.944	0.22	0.605	0.09	0.228	0.07	0.858
Cv	-0.52	0.183	0.48	0.222	0.65	0.081	0.65	0.080	0.54	0.167	0.28	0.493	0.15	0.715	0.85	0.007
Pf	-0.28	0.488	-0.92	0.001	-0.46	0.254	0.33	0.411	-0.85	0.006	-0.60	0.114	-0.62	0.102	-0.56	0.147
Ic	-----	-----	0.28	0.495	0.37	0.365	0.30	0.466	0.64	0.08	-----	-----	-----	-----	0.07	0.870

Cl: *Croton lobatus*, Pa : *Phyllanthus amarus*, Ps :*Paspalum scrobiculatum*, Dh: *Digitaria horizontalis*, Cv: *Cleome viscosa*, Pf: *Passiflora foetida*, Ic : *Imperata cylindrica* ; ------ : not calculated

5. Conclusion

Weeds such as *D. horizontalis*, *M. cylindristachyus*, *P. foetida*, *C. lobatus* and *T. procumbens* were found to be abundant species in rice field in *terre de barre* soils. Nutrient deficiency in soil was revealed to be the basic concept of weed control through chemotropism. Zinc deficiency in studied soil was also revealed to have the ability to discriminate between groups of weed species. Applying N, K and Zn, as basal fertilizer, was recommended in the reduction of weed pressure in rice fields and increase rice grain yield. The use of fertilizer for weed control was considered to be a good strategy for boosting rice production in West Africa.

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