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Response of a weed community to organic and inorganic fertilization in peanut crop under Savannah zone of Senegal, West Africa

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ABSTRACT

Weeds are among the most harmful factors limiting crop production in savannah zone of Africa. However, they are crucial for biodiversity and ecosystems sustainable management. A field experiment was conducted in savannah zone of Senegal to determine the effect of organic and mineral fertilization on weed flora in peanut crop. The experiment was laid out in randomize complete block design with four replicates and four treatments (Control, Cattle manure, Compost, and Mineral fertilizer). Our findings show that weed density was not significantly affected by the type of fertilization. However, dry matter of grasses and broadleaf weeds was significantly affected by the treatment respectively in forty and sixty days after treatment. The highest dry weight of grasses was observed in forty days after sowing in cattle manure treatment followed by inorganic fertilizer with respectively 23.7 and 15.2 g/m^2. In sixty days after sowing, the highest dry matter of broadleaf weeds was recorded in cattle manure treatment with 4.5 g/m^2. It was noticed that *Digitaria horizontalis* and *Mesosphaerum suaveonlens* were the dominant species in all treatment. The biodiversity indices were not significantly influenced by the type of fertilization but the highest values of Shannon-Webber and Simpson indices was recorded in cattle manure treatment. Moreover, the linear correlation between grain yield and diversity indices revealed that Shannon index is highly correlated with the peanut yield.

Introduction

In Senegal, peanut is one of the most important rainy crop in terms of production and the first cash crop (ANSD, 2015). Thus, it plays an important role in household food and income security in

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farming systems. Despite this importance, their production has been decreasing over the years. Expect irregular rainfall, this situation is mainly due to weed infestation and low soil fertility (Noba et al. 2004). Soils in most parts of the Savanna agro-ecological zones of Senegal where peanut are cultivated have low fertility because of long time of exploitation. Farmers use mineral fertilizers for restoring soil fertility and improving crop production. However, several studies showed that continuous and unbalanced use of synthetic fertilizer degrades physicochemical and biological soil environment and health (Mahajan et al. 2007; Chauvel, 2014). In this context, it becomes necessary to promote sustainable and accessible farming fertilization economically viable and environmentally acceptable such as organic fertilization. However, several studies including Sary et al. (2009); Monaco et al. (2002); and Simarmata et al. (2016) reported the benefits of organic fertilization on weed diversity and growth. In tropics, weeds are a major biological constraint that limits 10-56 percent of agricultural production (Koch, 1982; Le Bourgeois and Marnotte, 2002). Weeds compete with crops for aerial and underground resources such as nutrients, water, space, atmospheric gases and light (Yildirim and Turna, 2016; Kaur et al. 2018). This competition is more aggressive in savannah zone where it growths faster than any other part of the world because of warm and moisture conditions (Merlier and Montégut, 1982). In Africa, manual weeding consumes more than half of the farmer's time and limits arable land extension (Le Bourgeois and Marnotte, 2002). Moreover, impurities reduce the crop quality and decrease the commercial value of the product (Chicouène, 2014). Therefore, every promoting or encouraged agronomic practices in savannah zone of Africa must integrate weed management for their adoption and viability. The purpose of this study was to evaluate the effects of different type of fertilization on weed density, weed species diversity and dry matter in peanut and yield of the crop, under savannah Africa conditions.

Materials and Methods

Experimental design

The district of Kolda (12 ° 53 'N, 14 ° 57'W) is located in Southern Senegal. The climate is Sudanian with alternating rainy season from June to October and a dry season for the rest of the year. Over the period 1981-2010, the normal climates are 959.3 mm. Cumulative rainfall is 1335.9 mm in 2017. Soil texture varies from sandy-clay to clay. The experiment was conducted at Kolda research station using a randomized complete block design (RCBD) with four replications and four treatments. The four kinds of amendments were: treatment without fertilizer as a control (T0); cattle manure treatment (T2: 5 tons per hectare), treatment with compost (T3: 5 tons per hectare) and mineral fertilizer treatment (T4: NPK, 6-10-20). The plot size was 7.875m^2 (3.5 × 2.25). Peanut seeds (*Arachis hypogea* L. variety '*Hative de Séfa'*) were sown by hand in rows 50 cm apart with 25 cm between plants. Finally, weed control carried out by hand hoeing at 20, 40 and 60 days after sowing. This practice is one of the basic weed control methods used in traditional cropping system in savannah zone of Senegal.

Sampling, measurements and methods

The number and dry weight of identified weeds were recorded before hoeing at 20, 40 and 60 days after sowing. A square quadrat (50 × 50 cm) was randomly placed three times in each plot and weeds in the square quadrat were counted for each species present. Then, weeds were cut and their roots discarded. The remaining material was placed in paper bags in an oven at 65°C during three days and dry matter was measured.

Weed population analysis

The diversity of weed species was evaluated by means of the Shannon-Weiner index (H') (Booth et al. 2003): H': $H' = -\Sigma$ (pi ln pi), where: *pi* is the proportion (n/N) of individuals of one particular species (n) divided by the total number of individuals (N), ln is the natural log, Σ is the sum of the calculations. Simpson index was also calculated (Krebs, 1978).

Simpson's index of dominance (D) $D = \Sigma pi^2$

This index detects the dominant species whereas Shannon index detects and counts the rarest species that can be found in a community. Beta diversity comparisons were done by using the Bray-Curtis dissimilarity index values (Bray and Curtis, 1957) in order to compare the dissimilarity between floristic compositions in treatment each other.

Statical analysis

An analysis of variance was conducted for all data and differences between treatment means were compared at the 5% level of significance using the Student-Newman-Keuls (SNK) test. Correlation coefficient between peanut yield and diversity indices was also estimated according to the linear equation. All statistical analyses were conducted using the R 3.5.0 software from R Development Core Team (2018) (Library Ade4, Agricolae and Vegan).

Results and Discussion

Weed recorded

The results showed that weed flora consisted of 28 species distributed in 23 genera and 9 families (Table). This flora was dominated by Cyperaceae and Poaceae families which together account for fifty percent of recorded species. Domination of Poaceae is a typical characteristic of weed flora under sudano-sahelian zone of Africa (Le Bourgeois and Marnotte, 2002; Noba et al. 2004; Touré et al. 2008; Ka et al., 2017a) and is mainly due to their high seed production capacity even under unfavorable conditions (Baskin and Baskin, 1998). High proportion of sedges reflected their adaptation on anthropic pressure and agricultural practices. For sedges, both sexual and vegetative mode of reproduction are operative for their proliferation (Ljevnaić Mašić et al. 2015). Monocotyledon was the most important form with 53.5 percent of recorded species. Also, the study showed except two perennial species (*Cyperus esculentus* and *Dichrostachys cinerea*), only annual species were encountered.

Table 1. List of weeds recorded in experimental plots.

Family name	Weed species	CT	Life forms	Leaf morphology
Amaranthaceae	*Celosia trigyna* L.	D	T	Broad-leaf
Commelinaceae	*Commelina gambiae* (C.B. Clarke)	M	T	Broad-leaf
Convolvulaceae	*Ipomoea eriocarpa* R. Br.	D	T	Broad-leaf
	Merremia pinnata (Hochst.) Hallier	D	T	Broad-leaf
Cyperaceae	*Bulbostylis barbata* (Rottb.) CB Clarke	M	T	Sedge
	Cyperus amabilis Vahl.	M	T	Sedge
	Cyperus cuspidatus Kunth.	M	T	Sedge
	Cyperus esculentus L.	M	G	Sedge
	Cyperus iria L.	M	T	Sedge
	Fimbristylis hispidula (Vahl) Kunth	M	T	Sedge
	Kyllinga squamulata Thon.et Vahl.	M	T	Sedge
	Mariscus hamulosus (M. Bieb.) Hooper	M	T	Sedge
Fabaceae	*Crotalaria retusa* L.	D	T	Broad-leaf
	Dichrostachys cinerea (L.) Wight et Am.	D	P	Broad-leaf
	Sesbania pachycarpa DC.	D	T	Broad-leaf
	Stylosanthes fruticosa (Retz.) Alston	D	T	Broad-leaf
Lamiaceae	*Mesosphaerum suaveolens* (L.) Poit.	D	T	Broad-leaf
Malvaceae	*Corchorus tridens* L.	D	T	Broad-leaf
	Hibiscus cannabinus Hook. F.	D	T	Broad-leaf
	Sida rhombifolia L.	D	T	Broad-leaf
Poaceae	*Cenchrus biflorus* Roxb.	M	T	Grass
	Cenchrus pedicellatus (Trin.) Morrone	M	T	Grass
	Dactyloctenium aegyptium Beauv.	M	T	Grass
	Digitaria exilis (Kippist) Stapf	M	T	Grass
	Digitaria horizontalis Willd.	M	T	Grass
	Eragrostis tremula Steud.	M	T	Grass
Rubiaceae	*Mitracarpus villosus* (Sw.) DC.	D	T	Broad-leaf
	Spermacoce stachydea DC.	D	T	Broad-leaf

CT= cotyledon type; D= dicotyledons; G= geophyte; M= monocotyledons; P= phaneropyte; T= therophyte

Effect of different treatments on density (weed/m²) and dry weight (g/m²)

The study revealed that there was no significant difference regarding density and dry weight except for grasses and broadleaf weeds dry weight respectively at forty and sixty days after sowing (Table and Table). The highest dry weight was recorded at 40 DAS using cattle manure (T2) followed by inorganic fertilizer (T4). For broadleaf weeds a significant difference was observed at 60 DAS where the highest dry weight was recorded in cattle manure treatment. In general the highest weed density and dry weight were recorded in cattle manure treatment.

Table 2. Density of weeds in experimental plots.

Treatment	20DAS			40DAS			60DAS		
	Broad-leaf	Grasses	Sedges	Broad-leaf	Grasses	Sedges	Broad-leaf	Grasses	Sedges
Control	61.2	61.0	13.0	58.2	53.0	17.7	4.2	4.7	2.5
Cattle manure	38.2	102.5	16.0	35.7	70.2	38.0	9.2	6.2	5.0
Compost	83.2	94.8	49.0	42.0	53.0	30.5	3.0	6.0	1.2
Mineral fertilizer	21.0	86.5	13.7	14.2	40.2	11.7	4.7	6.7	2.7
Mean	50.9	86.2	22.9	37.6	54.1	24.5	5.3	5.9	2.9
Pr (>F)	0.503^{ns}	0.377^{ns}	0.421^{ns}	0.597^{ns}	0.105^{ns}	0.156^{ns}	0.174^{ns}	0.96^{ns}	0.438^{ns}

Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1.

Table 3. Dry matter of weeds in experimental plots.

Treatment	20DAS			40DAS			60DAS		
	Broad-leaf	Grasses	Sedges	Broad-leaf	Grasses	Sedges	Broad-leaf	Grasses	Sedges
Control	6.5	58.0	1.5	3.5	10.7^{b}	4.5	2.5^{ab}	1.7	0.1
Cattle manure	4.5	92.2	2.2	4.2	23.7^{a}	9.2	4.5^{a}	2.2	0.3
Compost	5.0	81.5	2.5	5.5	12.0^{b}	5.2	0.1^{b}	1.7	0.1
Inorganic fertilizer	2.0	114.7	1.2	3.0	15.2^{ab}	1.2	2.5^{ab}	1.2	0.3
Mean	4.5	86.6	0.616	4.1	15.4	5.1	2.4	1.7	0.2
Pr (>F)	0.34^{ns}	0.67^{ns}	1.9^{ns}	0.794^{ns}	0.033*	0.096^{ns}	0.068	0.811^{ns}	0.429^{ns}

Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1.

These results support Sary et al. (2009); Monaco et al. (2002); Simarmata et al. (2016) who observed that the use of manure can enhance the growth of weeds because some weed seeds remain viable in the manure, such as seeds from Cyperaceae and Poaceae families. This domination is more important at early stage as suggested by Chowdhury et al. (2014) who showed that grasses and sedges were most dominating weed species during the early stages and broadleaf weeds during later stages. Also, both density and dry matter of weeds decreased from earlier stage to harvesting.

Effect of different treatments on dominant species

Digitaria horizontalis and *Mesosphaerum suaveonlens* were the dominant species (Figure). *Digitaria horizontalis* represents 43%, 36% and 20% of total emerged species respectively in 20, 40 and 60 days after sowing. This species is characterized by an early emergence, an important number of seeds production and a short cycle (Le Bourgeois and Marnotte, 2002).

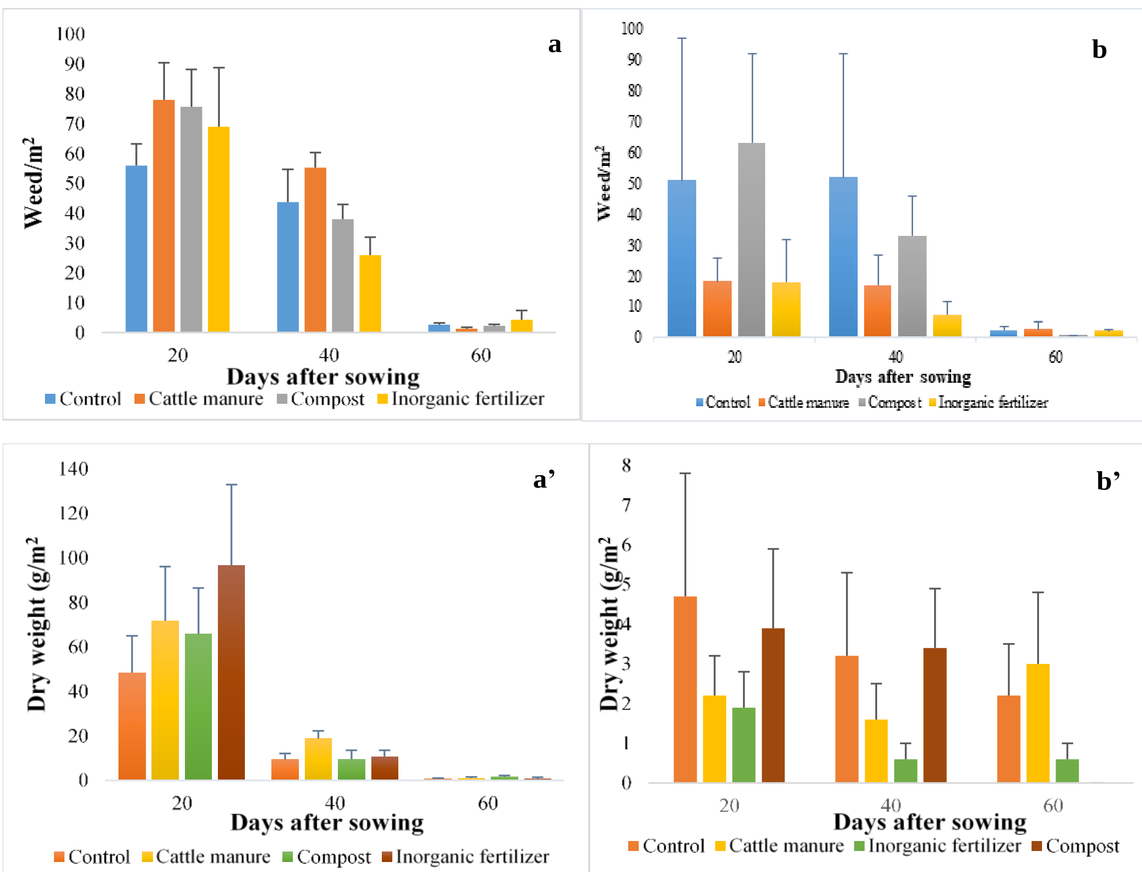

Figure 1. Density and dry weight of *Digitaria horizontalis* (a; a') and *Mesosphaerum suaveonlens* (b; b').

During the rainy season, the species can be propagated by cuttings from the fragments of the stems that are rooted at the nodes (Le Bourgeois and Merlier, 1995). The presence of

Mesosphaerum suaveonlens was 24, 26.5 and 13.2 per cent respectively at 20, 40 and 60 days after sowing. For both species, the highest density and dry matter were obtained at 20 days after sowing. Despite their abundance, the broadleaf *Mesosphaerum suaveonlens* dry weight remains low and never exceeds 8 g/m^2. As recently reported by some authors (Bassène et al. 2014; Ka et al. 2017a; Ka et al. 2017b), *Mesosphaerum suaveonlens* become the main constraint in farmer's field on Sudanian zone of Senegal. Their infestation seems related to soil degradation and a lowest palatability. In control, compost and inorganic fertilizer treatments, the highest dry weight was obtained at the earlier stage. However, in cattle manure treatment, the biomass increased from the earlier stage until the end of the experiment for *Mesosphaerum suaveonlens*.

Effect of fertilization on weed diversity and abundance

The study revealed that diversity indices (Shannon and Simpson) were not significantly influenced by the type of fertilization (Table). However, Shannon index was higher in cattle manure treatment followed by compost treatment. Furthermore, it was observed that Simpson index was dominant in cattle manure and compost treatments. Several studies reported the increase of weed emergence in manure because some weed seeds remain viable in the manure (Sary et al. 2009; Monaco et al. 2002, Bilalis et al. 2012; Kakabouki et al. 2015). Even weed emergence may be attributed to the germination enhancement of weed seed already in the soil, some of seed come from weed grazed by cattle (Kakabouki et al. 2015). Nevertheless, rainfall and some other environmental factors, such as mean annual temperature may also affect the structural variability of the weed community (Tang et al. 2014). The study of Bray–Curtis dissimilarity index revealed that the larger distance was noticed between the treatment with inorganic fertilizer to others (Table). In general, diversity indices remained low in mineral fertilizer (Table).

Table 4. Effect of fertilization on weed diversity.

Treatment	Diversity indices	
	Shannon	Simpson
Inorganic fertilizer	1.59	0.71
Cattle manure	1.89	0.75
Compost	1.76	0.75
Control	1.48	0.66
Mean	1.68	0.71
CV (%)	15.16	11.59
Probability	0.165^{ns}	0.383^{ns}

Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1.

Table 5. Effect of fertilization on dissimilarity index.

Bray-Curtis coefficient	Control	Cattle manure	Compost	Inorganic fertilizer
Control	0	0.37	0.20	0.45
Cattle manure		0	0.25	0.44
Compost			0	0.52
Inorganic fertilizer				0

Effect of fertilization on peanut yield and yield components

Peanut yield, height and dry matter were significantly affected by the treatment. The highest values of plant height and dry matter were recorded in plots sown with inorganic fertilization followed by cattle manure and compost. The greatest yield (0.48 kg/m^2) were recorded in plots treated with cattle manure while the lowest yield (0.27 kg/m^2) obtained in plots receiving inorganic fertilizer (Table). In a previous study, Bilalis et al. (2009) have shown that growth and yield in cow manure plots was significantly higher than those in conventional plots.

Table 6. Effect of fertilization on peanut yield and yield components.

Treatment	Peanut parameters		
	Height (cm)	Dry matter (kg/m^2)	Yield (kg/m^2)
Inorganic fertilizer	43.9^a	1.83^a	0.27^b
Cattle manure	35.8^b	1.56^a	0.48^a
Compost	27.1^c	0.87^b	0.42^{ab}
Control	22.2^c	0.77^b	0.39^{ab}
Mean	32.2	1.26	0.39
CV (%)	10.2	2.5	21.0
Probability	<0.001***	<0.001***	0.022*

Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1.

Correlation between yields and diversity indices

Shannon index was highly correlated with peanut yield while the correlation between Simpson index and peanut yield remain low. Also, the study of linear correlation between the diversity indices and the peanut dry weight showed a decreasing of dry matter with the increase of diversity and *vice-versa* (Figure).

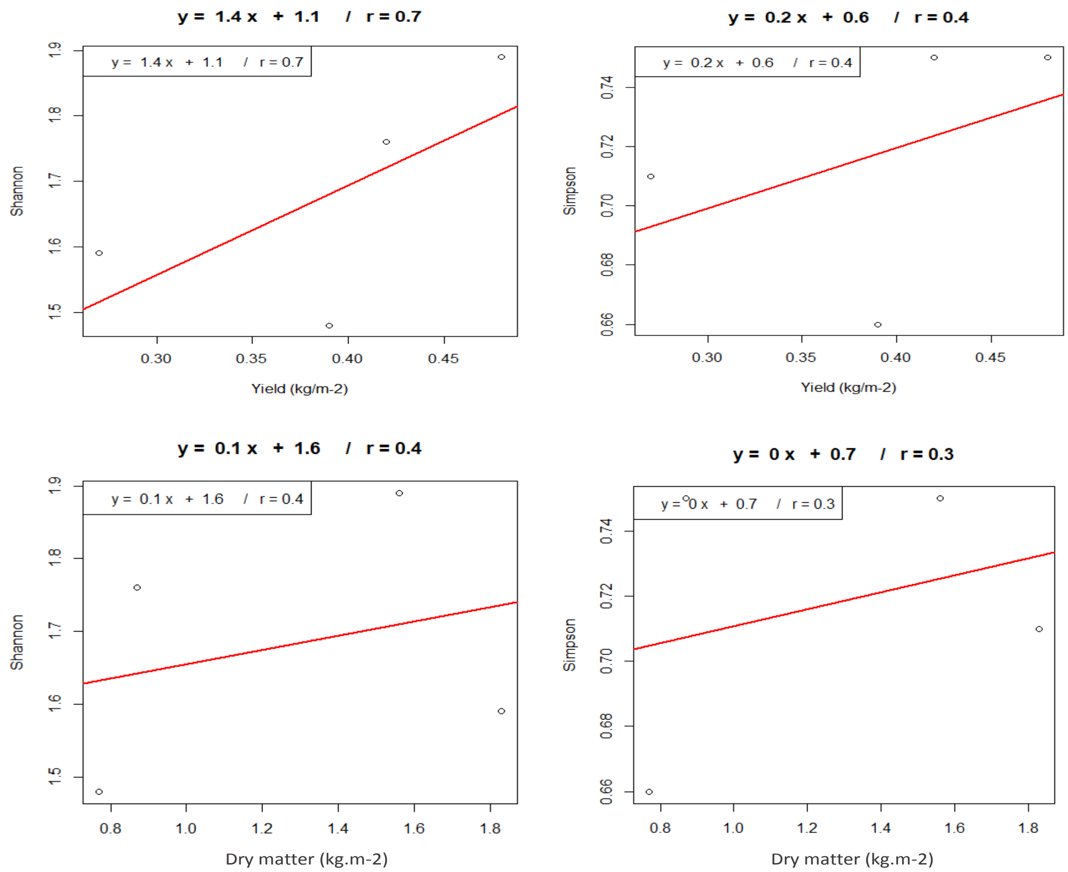

Figure 2. Correlation between peanut yield/dry matter and diversity indices.

Conclusion

Based on these results, it could be concluded that biodiversity indices (Shannon-Webber and Simpson) were not significantly affected by the type of fertilization even the higher values of Shannon-Webber and Simpson were recorded in cattle manure treatment. However, dry weight of weeds was significantly affected by the type of fertilization. In particular, the high dry weight of broadleaf weeds and grasses were recorded in cattle manure treatment. Regarding peanut yield, this research demonstrates that organic fertilizers can be used as an alternative of inorganic fertilizers. However, more studies should be conducted to fill the gap weeds-fertilization-environment interactions which are crucial for promoting sustainable agriculture production in savannah zone of Africa.

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Conflict of Interest

Authors declare no conflict of interest.

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