ORGANIC FORAGE PRODUCTION : RESPONSES OF *LOXODERA LEDERMANNII* GROWN UNDER THE COMPOST APPLICATION IN SUBEQUATORIAL BENIN

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ABSTRACT

This study examines biological and agronomic responses of *Loxodera ledermannii* to the compost application. A complete random block of 3 treatments (0 t/ha, 5 t/ha and 10 t/ha of organic fertilizer in 3 replicates was designed. Each plot (1.5 m x 2 m) is seeded 24 tussocks acclimated in the Botanical Garden of the UAC from 2011 to 2013. Leaf morphometric, ecophysiological and agronomic measurements are subjected to ANOVA with STATISTICA 9.0. Results showed that organic fertilization significantly affects the tillers production, Specific Leaf Area (SLA) and aboveground biomass. SLA are the highest under compost (SLA >208.61±10.81 $cm^2.g^{-1}$) and the lowest with the controls (153.33 $cm^2.g^{-1}$ ≤ SLA ≤ 169.05 $cm^2.g^{-1}$). The leaves of *L. ledermannii* accumulate naturally more biomass per area unit and have a long lifespan. The compost application increases significantly SLA by 25% ($P< 0.01$). This increase implies a low accumulation of biomass per area unit, indicating that compost would impoverish the leaves of *L. ledermannii* in carbon reducing by the way its life expectancy. The controls produced 10.33 t $DM.ha^{-1}$, which was 46% other than production under 5 to 10 t per hectare of compost. SLA is positively correlated to the leaf dry matter content ($R = 0.88$; $p< 0.01$) and negatively to the leaf water content ($R = -0.89$; $P< 0.01$). These results suggest that *L. ledermannii* is a slow-growing species and the organic fertilization tends to disrupt its development. Its utilization in ecological farming requires knowledge on strategies and functional status of this species.

Keywords: *Loxodera ledermannii*, organic fertilizer, agronomic traits, correlation, southern Benin

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RÉSUMÉ

PRODUCTION FOURRAGÈRE BIOLOGIQUE : RÉPONSES DE *LOXODERA LEDERMANNII* CULTIVÉE SOUS ADJONCTION DU COMPOST EN ZONE SUBÉQUATORIALE DU BÉNIN

Cette étude examine les réponses biologiques et agronomiques de *Loxodera ledermannii* à l'apport du compost. Le dispositif expérimental est un bloc aléatoire complet de trois traitements [0t/ha (témoin), 5t/ha et 10t/ha de compost] en 3 répétitions. Sur chaque placette de 1,5m x 2m ensemencée de 24 souches, sont échantillonnées 5 souches provenant du Parc W et acclimatés au Jardin Botanique de l'UAC de 2011 à 2013. Des mensurations morphométriques, écophysiologiques et agronomiques sont soumises à l'Analyse de Variances sous STATISTICA 9.0. Les résultats montrent que la fertilisation organique affecte significativement la production de talles, la surface foliaire spécifique (SFS) et la biomasse aérienne. Les SFS sont les plus élevées sous traitements (SFS > 208,61±10,81 $cm^2.g^{-1}$) et les plus faibles chez les témoins (153,33 $cm^2.g^{-1} \leq$ SFS $\leq$ 169,05 $cm^2.g^{-1}$). Les feuilles accumulent naturellement plus de biomasse par unité de surface et ont une longue durée de vie. L'apport du compost accroit la surface foliaire spécifique de 25 % (P<0,01). Cette augmentation qui implique une faible accumulation de biomasse par unité de surface, indique que le compost appauvrirait les feuilles de *L. ledermannii* en carbone, diminuant ainsi leur durée de vie. Les plants témoins ont produit 10,33 t de $MS.ha^{-1}$, soit 46 % de moins que la production sous 5 à 10 t/ha de compost. La SFS est corrélée positivement à la teneur en matière sèche foliaire (R=0,88 ; p < 0,01) et négativement à la teneur en eau (R = - 0,89 ; P < 0,01). Ces résultats suggèrent que *L. ledermannii* est une espèce à croissance lente et la fertilisation organique tende à perturber son développement. Son utilisation en agriculture écologique nécessite plus de connaissances sur ses stratégies fonctionnelles.

Mots clés : *Loxodera ledermannii*, compost, traits agronomiques, Corrélations, Sud-Bénin

INTRODUCTION

Ruminants production is globally limited by the unavailability of forage (Peter & Lascano, 2003 ; Carr *et al*., 2005). Organic farmers in the subequatorial Benin are facing a great challenge of self-sufficiency, in order to reduce as much as possible external fodder purchase. Thus, new strategies to maximize forage production are required that are not detrimental to sustainability. Research in organic farming is demanding more holistic approaches, by linking as many components of the agroecosystem as possible (Isart & Llerena, 1999). Useful agronomic results obtained from organic farming studies may be considered from a wider ecophysiological perspective, by taking into account the complex interactions among crop growth, soil and climate (Lambers *et al*., 1998). In this work, we tested soil fertilization methods to improve organic forage productions in the Guinean zones and propose an ecophysiological approach to the organic production of *Loxodera ledermannii* swards. Indeed, *Loxodera ledermannii* (Pilger) WD Clayton ex Launert is tropical forage grass, dominant of pastures in Northern Benin (Sinsin *et al*., 1989), monocot Angiosperms (Brunel *et al.,* 1984), perennial evergreen herbage up to 1 m high; banded basal leaves (Sinsin, 1993). The species is typical of burned savannah where human pressures are low and where the suffrutex geophytes mostly dominated rootstock buried in the ground (Sinsin, 1993). It offers advantages on the livestock feed, as it grows well in the drought period. Flowering quickly and produces good quality forage (Brunel *et al.,* 1984 ; Sinsin 1994), it contributes to the high forage biomass production in West Africa (Sinsin, 1993). Recent work has shown that the species is rich in minerals, very appetite despite its high silica content (Kindomihou *et al.,* 2012) and being an indicator of little disturbed environment (Sinsin & Owolabi, 2001 ; Kindomihou *et al.,* 2009). Generally, the best way to improve the composition of pastures (i.e. getting higher producing grasses established) is to completely re-sow. Recent research has shown re-sowing pastures which usually offer increased production, though results can vary depending on the technique that is used. In this study, we evaluated biological and agronomic responses of *L. ledermannii* to the compost application in Southern Benin.

MATERIALS AND METHODS

A forage crop was started on the experimental garden of the Faculty of Agronomic Sciences, University of Abomey-Calavi in Southern Benin (6° 26' 55''N ; 2° 21' 20''E), from july 2013 to february 2014. The site is located in the Guinean zone. Climate is subequatorial with two dry seasons : mid-july to mid-september, and mid-november to mid-march. Annual precipitation reached 1200 mm in 2012, with 856 mm for the main rain season. Monthly average temperatures ranged from 25.9°C to 30°C. Sunny periods added up to 2330 hours a year and the annual average relative humidity ranged between 78 and 85 %. The potential evapotranspiration of Penman averaged 1650 mm (ASECNA, 2012). Precipitations were abnormally low in the study period and plots were well watered. Vegetation of the experimental site environment is the prairie type, and soil ranges from alluvial to sandy of the littoral (Assan *et al.*, 1994). The soil in the garden of FSA/UAC is ferralitic, relatively acid, poor in exchangeable bases, nitrogen and phosphorus, but with appreciable sodium concentration; C/N mass ratio is 10.6 (Kindomihou *et al.,* 2006, 2009). The commercial organic compost "APCB" used is composed by Carbon: 37.08 % - DM : 50 %; Nitrogen : 2.34 % ; Phosphorus (P_2O_5) : 0.30 % ; Potassium (K_2O) : 0.96 % ; Magnesium (MgO) : 0.17 % ; Calcium (CaO) : 1.15 % and pH : 7. Clumps of *L. ledermannii* originated from the W National park (Sudanian climate) were first acclimated in the Botanical and Zoological Garden of University of Abomey-Calavi (Subequatorial climate) where they were taken from. A pure crop of *L. ledermannii* was sown in plots sized 3 m² on 16 August 2013. The compost was applied on 30 september 2013. Three treatments were studied (Compost: 5 t/ha i.e. 60 g/plant ; 10 t/ha i.e. 120 g/plant and 0 t/ha : absolute control). A complete random block of 3 treatments (0 t/ha, 5 t/ha and 10 t/ha of compost) in 3 replicates was designed. Globally, 9 plots and 24 tussocks per plots were installed. Biological traits (height, diameter and number of tillers, leaf area, Specific Leaf Area, Leaf specific dry mass) and agronomic traits (regrowth and recovery rates, fresh and dry biomass) were collected and submitted to a one-way ANOVA and Pearson Correlation analyses under STATISTICA 9.0. The effects of compost were concluded at 5 %.

The whole trial was repeated from july 2014 to february 2015 ; but as the data collected were not significantly different from a period to another, only one year trial data matrix was considered in this report.

RESULTS

Loxodera ledermannii tussocks morphological and biometric responses to the compost application

Tussock height ranges from 58.9 to 67.7 cm depending on treatments (Table 1). *L. ledermannii* tuft showed significant differences in height. The controls had much lower values (< 63 cm) compared to the compost treatments generally having higher values (> 65 cm) ranking first or second in all treatments (Table 1). The comparison of both compost treatments with the controls showed significant increase in the height with respective magnitudes of 12 % and 15 %. The number of tillers ranges from 147.4 to 179.9 depending on treatments (Table 1). Highly significant difference also occurs in this trait.

Table 1. Effects of compost on *Loxodera ledermannii* tussocks morphology* : $P < 0.05$; ** : $P < 0.01$; ns : non-significant ; a, b : homogenous groups at 5 %.

Treatments		Tussock height (cm)	Tussock diameter (cm)	Number of tillers (NT)
TC_{120}		67.67 ± 1.86b	97.33 ± 11.80a	157.70 ± 6.30a
TC_{60}		66.00 ± 5.50ab	97.33 ± 1.22a	179.90 ± 7.30b
T_0		58.90 ± 4.50a	92.80 ± 3.86a	147.35 ± 11.05a
ANOVA	$F_{(2,6)}$	3.62	0.40	11.57
	P	*	ns	**
	R^2	0.40	0.12	0.72

The dose of 60 g/plant offers the highest number of tillers (>170 tillers). Globally, the compost induced increasing number of tillers with significant magnitude of 22 %. These results suggest that the dose of 60 g/plant favors a greater tuft development. The tussock diameter was constant or increased in the compost treatments. But this was not significant.

Loxodera ledermannii functional responses to the compost application

The Specific Leaf Area (SLA) ranges from 166 to 209 $cm^2.g^{-1}$ depending on treatments (Table 2). SLA differs significantly from a treatment to another ($F_{SLA(2, 6)} = 12.05$; $R^2 > 0.5$; $p < 0.01$; Table 2). The much lower values belongs to the controls (166.19 ± 12.86 $cm^2.g^{-1}$) while the compost treatments showed the highest values (>208 $cm^2.g^{-1}$). Comparative analysis indicates significant increase in SLA due to compost adjunction in magnitude of 25 % for both compost doses (60 g and 120 g/tussock). Similarly, the compost adjunction significantly affects Leaf Water Content ($F_{LWC(2, 6)} = 13.53$; $R^2 > 0.5$; $p > 0.01$; Table 2). Pearson correlation analysis indicates a strong positive relationship between SLA and Leaf Dry Mass Ratio LDMR ($r = 0.88$; $p < 0.01$; Table 3). The trend differs from a treatment to another (Figure 1a,b,c). SLA negatively correlated to Leaf Water Content LWC ($r = -0.89$; $P < 0.01$; Table 3). Leaf Dry Mass Rate increased with compost doses in respective magnitudes of 90 % and 113 % from doses of 60 g per tussock and 120 g per tussock. At the reverse, the compost adjunction reduces the LWC in respective magnitudes of 16 % and 20 %. Otherwise, the foliar lengths and density were constant or decreased or increased with compost adjunction while the widths consistently decreased in treatments compared to controls. But the results were not significant.

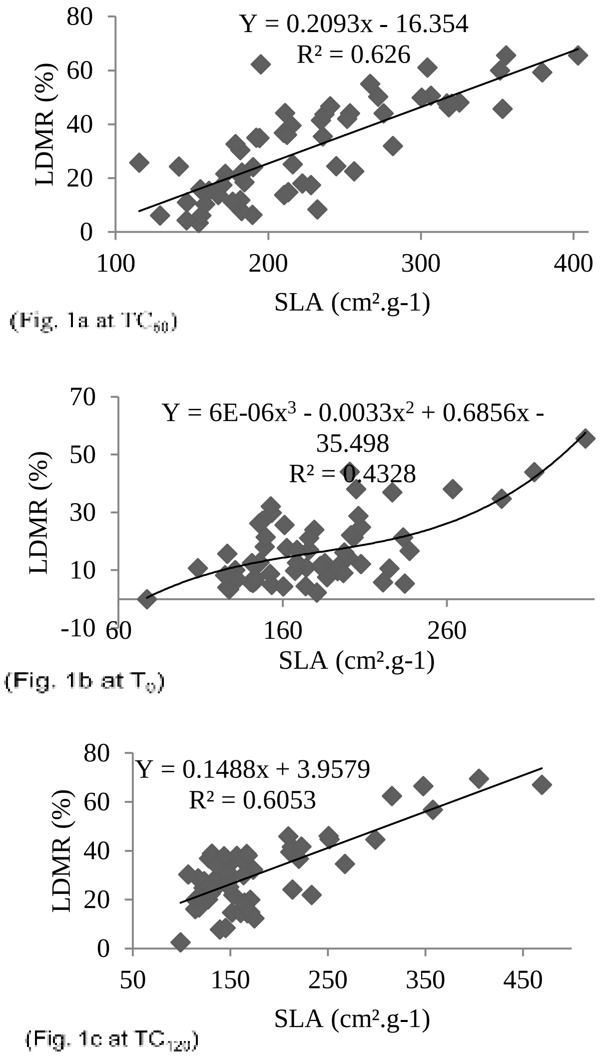

Figure 1. Covariations of SLA with LDMR (N = 180 leaves ; $r = 0.88$; $p < 0.01$).

The positive trend was due to the controls that are showed lower values for both traits while the others expressed the highest values.

Table 2. Effects of compost doses on functional traits of *Loxodera ledermannii*. $F_{(2, 6)}$: F-value ; P : probability of significance ; R^2 : Coefficient of determination ; Treatments T_0 : controls ; TC_{60} : dose of 60 g per tussock; TC_{120}: dose of 120g per tussock. * : P < 0.05 ; ** : P < 0.01 ; ns : non-significant ; a, b : homogenous groups at 5 %.

Treatments		Foliar Length (FL in cm)	Foliar Width (FW in cm)	Leaf Area (LA in cm^2)	Specific Leaf Area (SLA in $cm^2.g^{-1}$)	Leaf Density (LD in $g.cm^{-2}$)	Leaf Water Content (LWC in %DM)	Leaf Dry Mass Rate (LDMR)
TC_{120}		45.10 ± 3.53a	0.65 ± 0.03a	29.57 ± 3.20a	208.13 ± 10.81b	7.64 ± 0.85a	67.73 ± 0.99a	32.06 ± 0.18b
TC_{60}		47.41 ± 2.04a	0.64 ± 0.03a	30.39 ± 1.92a	209.61 ± 13.10b	6.97 ± 0.38a	70.71 ± 6.55a	28.50 ± 7.20b
T_0		47.78 ± 3.73a	0.66 ± 0.05a	31.58 ± 4.74a	166.19 ± 12.86a	7.29 ± 0.45a	84.41 ± 2.95b	15.03 ± 2.46a
	$F_{(2,6)}$	0.62	0.19	0.25	12.05	0.95	13.53	12.56
ANOVA	P	ns	ns	ns	**	ns	**	**
	R^2	0.17	0.06	0.08	0.73	0.24	0.76	0.74

Table 3. Pearson 's Coefficients of variation from covariations of the foliar morphological and ecophysiological traits of *Loxodera ledermannii*. ** : P < 0.01 ; *** : p < 0.001 ; ns : non-significant. FL : Fresh length ; FW : Fresh Weight ; LA : Leaf Area, SLA : Specific Leaf Area, LD : Leaf Density ; LDMR : Leaf Dry Mass Ratio

	FL	FW	LA	SLA	LD	LWC	LDMR
FL	-						
FW	0.55ns	-					
LA	*0.90****	*0.86***	-				
SLA	0.04ns	0.19ns	0.11ns	-			
LD	-0.65ns	-0.34ns	-0.58ns	-0.28ns	-		
LWC	0.07ns	-0.13ns	0.002ns	*-0.89***	-0.11ns	-	
LDMR	-0.10ns	0.15ns	-0.01ns	*0.88***	0.14ns	*-1.00****	-

Agronomic responses of Loxodera ledermannii to the compost application

The leaf biomass accumulation ranges from 5.83 to 10.33 $tDM.ha^{-1}$ depending on treatments and the difference was highly significant from a treatment to another ($p < 0.01$; Table 4). While the lowest values are shown with composted treatments, the highest biomass production appeared with the controls reaching 1.87 fold that of the others.

Table 4. Effects of compost on *Loxodera ledermannii* agronomic traits * : $P < 0.05$; **: $P < 0.01$; ns : non-significant ; a, b : homogenous groups at 5 %.

Treatments		Regrowth Rate (RegR in %)	Fresh Biomass (FB in $t.ha^{-1}$)	Dry Biomass (DB in $tDM.ha^{-1}$)	Recovery Rate (RecR %)
TC_{120}		43.06 ± 6.36a	11.25 ± 1.25a	5.83 ± 0.29 a	0.25 ± 0.05a
TC_{60}		36.11 ± 4.81a	13.63 ± 2.60a	5.83 ± 1.21a	0.33 ± 0.05a
T_0		45.83 ± 8.33a	20.95 ± 4.95b	10.33 ± 1.11b	0.35 ± 0.05a
Résultats ANOVA	$F_{(2,6)}$	1.70	7.00	21.73	3.23
	p	ns	*	**	ns
	R^2	0.15	0.60	0.83	0.36

This trend is the same with the Fresh Biomass production ($F_{FB(2,6)} = 7$; $p < 0.05$; $F_{DB(2,6)} = 21.73$; $p < 0.01$; $R^2 > 0.5$; Table 4). Comparative results showed that the compost reduced the biomass accumulation in leaves in magnitude of 46 %.

DISCUSSION

Effect of the compost application on the forage plant morphological traits

L. ledermannii in station shows a range of heights from 58.90 ± 4.50 cm to 67.67 ± 1.86 cm, lower than 100 cm observed in the natural vegetation of Kalalé, Bembèrèkè, Karimama, Park W and Ségbana in Northern Benin (Akoegninou *et al.,* 2006). The height is a morphological trait that discriminates plants species in their ability to accumulate biomass. This trait has an interest in the operation modes for which a high biomass production premium on the quality of harvested grass (reports on foot, late hays for stocks). It is also a trait that can be connected to a certain competitive ability (Westoby, 1998); because the larger species can exert strong competition for light during the long growth cycles (late cuttings). It appears that in the culture medium, the *L. ledermannii* competitive ability decreases while it forage quality would be better in natural environment. Alassane (2009) observed how the potential values of plants heights are genetic in the origin. Recently, these potentials were also proved phenotypic (Kindomihou *et al.,* 2013). Our results show that the potential height can also be linked to the soil environment.

Compared to the controls, the *L. ledermannii* plants grown under the doses of compost show the highest values for SLA, i.e. 208.10 to 209.61 $cm^2.g^{-1}$ versus 166.19 $cm^2.g^{-1}$. According to Garnier (1992), the SLA is a good descriptor of the relative growth rate of a plant species. High values of SLA indicate high plant water content and low carbon rate, things that characterizes leaves of low biomass accumulation per area unit and a short-lifespan (Poorter & Bergkotte, 1992 ; Elberse & Berendse, 1993 ; Garnier & Laurent, 1994; Van Arendonck & Poorter, 1994 ; Van Arendonck *et al.,* 1997). A higher SLA offers the strategies associated with a rapid leaves turnover to re-grow. It appears that the organic fertilization negatively affects the fodder quality of *L. ledermannii*. But the fertilization had induced a renewal foliar regrowth.

Effect of the compost application on the forage plant agronomical traits

The *L. ledermannii* biomasses produced under the doses of compost are lower compared to the controls. These results indicate that the compost application decreases the dry biomass accumulation and by 46 % of magnitude. Generally, it follows that there is a close relationship between nitrogen and crop yield, a relationship well summarized by the law as stated by Mitscherlich (1834). In the case of increasing soil inputs of nutrients, the increases in yields obtained become smaller and smaller as the quantities increase and the harvest is close to its maximum (Knoden *et al.,* 2007). It is observed that the maximum, once exceeded, an additional intake not only causes a depression but is not necessarily economic. Consequently, the compost doses that were applied in this experiment are unfavorable for *L. ledermannii* cropping. Given that a crop performance is set by the level of the most limiting element according to the law of the Minimum, therefore, the decreased yield as a response to the compost use might be explained by a strong soil deficiency in phosphorus (P) and organic matter (OM). Indeed, soil characteristics before the trial starts indicate 2.54 ppm of P and 1.66 % DM for OM (Kindomihou *et al.,* 2009). The compost application therefore induces a mineral imbalance that probably prevents other minerals absorption by the law of the balances. Moreover, the commercial compost used indicates a C : N ratio of 15.85 which confirms to some extent these observations. However, subsequent substrates mineral analyses of the various treatments after the trial as well as those of the foliar organs harvested will better clarify these findings.

CONCLUSION

Loxodera ledermannii originates from the savanna where the impact of agricultural activities is invisible. Our results showed that the organic fertilization has disrupted its development. Subsequent studies involving the doses lower than those used in this trial will help to better appreciate *L. ledermannii* abilities under various fertilization levels.

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