Morphological traits and germination of *Loxodera ledermannii* (Pilger) W.D. Clayton ex Launert caryopses in Southern-Benin

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Abstract

Domestication is a tool for biodiversity conservation in grasslands. To that end, morphological traits and germinative capacity were examined with naked caryopses of *Loxodera ledermannii* (Pilger) W.D. Clayton ex Launert, an earlier fodder grass species yielded from Benin sudanian savannahs. Experiments were carried out in laboratory and fields. As results, the caryopses were brown in colour, lengthened 46 mm with thickness of 1.23 mm and weighted 2.4 mg. The germination rate ranged from 20 to 100 % in controlled sites and from 12 to 66 % in the field. Germination process was late and costed 2 times longer than that of other grasses such as *Andropogon gayanus* Kunth *var. bisquamulatus* and *Panicum maximum* C1 in full field; but this process was less early in controlled sites. The substrate texture, structure and humidity influenced the speed of the caryopsis lifting and germination. The depth of sowing and the heating effects were also perceptible. The radicle emerged in 24 hours. *L. ledermannii* showed a notable resistance to water stress where the aridity index was 2.5. Our results showed that *L. ledermannii* caryopses were heavier than those of *A. gayanus* and *Panicum maximum*, however but their fertility and germinative capacities are not that much better.

Key words: Morphological traits, germination, *Loxodera ledermannii*, Benin

Caractéristiques morphologiques et germination des caryopses *de Loxodera ledermannii* (Pilger) W.D. Clayton ex Launert au Sud - Bénin

Résumé

La domestication est un outil pour la conservation de la biodiversité dans les pâturages. A cet effet, des caractéristiques morphologiques et la capacité germinative sont examinées chez des caryopses nus de *Loxodera ledermannii* (Pilger) W.D. Clayton ex Launert, une espèce de graminée fourragère très précoce des savanes soudaniennes du Bénin. Des expérimentations sont menées au laboratoire et au champ. Les résultats ont montré des caryopses bruns rallongés de 46 mm, épais de 1,23 mm avec une masse de 2,4 mg. Le taux de germination a varié de 20 à 100 % au laboratoire et de 12 à 66 % au champ. La germination a été tardive et a duré 2 fois plus longtemps que celle de *Andropogon gayanus var. bisquamulatus* et *Panicum maximum* C1 en plein champ. Toutefois, ce processus n'était pas aussi tardif en milieux contrôlés. La texture, la structure et l'humidité de substrat influençaient la levée et la germination du caryopse. La profondeur de semis et les effets thermiques sont également perçus. La radicule a émergé en 24 heures. *L. ledermannii* montre une résistance notable au stress hydrique où l'indice d'aridité est 2.5. Nos résultats ont prouvé que les caryopses de *L. ledermannii* ont été plus lourds que ceux de *A. gayanus* et de *P. maximum* C1. Toutefois, leur fertilité et capacités germinatives n'en sont pas pour autant meilleures.

Mots clés: Caractéristiques morphologiques, germination, *Loxodera ledermannii*, Bénin

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INTRODUCTION

Perennial pastures are widely used by livestock and mixed farmers to provide high-quality feed on a year-round basis (Lejoly and Sinsin, 1991). *Loxodera ledermannii* (Pilger) WD Clayton ex Launert belongs to species that dominated the northern pastures of Benin (Sinsin *et al.*, 1989). *L. ledermannii* is a tropical perennial fodder grass species, i.e. a monocot Poaceae in Cormophytes group, Spermaphytes from Angiosperms Monocotyledonous class (Brunel *et al*., 1984; Whyte *et al.*, 1959). This species results from the type *Ledermann 3605* known in Cameroon (Holo-B, delet., K, fragm). *L. ledermannii* belongs to the African genus of savannas. *It* is an earlier grass species typical of shrubby and woody savannas dominated by *Acacia spp* and *Vitellaria paradoxa* in the northern Benin where it covers the deep clayed and ferruginous soils (Assan *et al.*, 1994; Oumorou & Lejoly 2003a; Ekué *et al.*, 2004, Oumorou *et al.*, 2004, Gouwakinnou *et al.*, 2009).

As the ruminant production is constrained by the natural availability of forage (Peters and Lascano, 2003; Carr *et al.*, 2005), *L. ledermannii* can offer an useful fodder option, as it grows well in the dry seasons, flowers early and produces good-quality fodder (Whyte *et al.*, 1959; Hepper, 1972; Brunel *et al.* 1984; Sinsin, 1993; Sinsin, 1994). *L. ledermannii* has spread naturally on the sudanian and sudano-sahelian savanna in the following countries: Nigeria, Uganda, Cameroon and Niger (Hutchinson and Dalziel, 1972; Skerman and Riveros, 1990; Van Der Zon, 1992; Sinsin, 1993). Typical from the southern to the northern sudanian Benin (Sinsin, 1993, 1994), the species also occurs in the Central Benin between guineo-sudanian and sudano-guinean zone, e.g. Dassa (Agbani *et al.*, 2000 unpublished, Oumorou and Lejoly, 2003b). Apart from studies of its spread area, no published information exists either on the caryopses, morphological characteristics or the species establishment. The domestication of this species will increase its availability, the biodiversity in pasture and to provide a better understanding of its morphological characteristics and germination. Appropriate experimental conditions for germination clearly should reflect the environmental conditions of the microhabitat in the field. Tropical perennial grasses seed germination was found very low (depending on percentage seed set), whereas germination in caryopses was much higher (up to 92 %) (Parihar and Pathak's, 2006). The main objectives were: (i) to assess morphological characteristics of naked caryopses *of L. ledermanni* and (ii) to determine some germination abilities of these naked caryopses.

STUDY AREA

This work was carried out at the experimental field of the Faculty of Agronomic Sciences at the University of Abomey-Calavi in Benin, firstly from May to October 1995; and after from March to June 1996 at the laboratory in Cotonou. Therefore the whole experiment was repeated during the year 2003 in the same conditions. The both perimeter belongs to the subequatorial zone. The climate is characterized by a bimodal pluviometric mode with two marked dry seasons: mid-July in mid-September, and mid-November in mid-March (Adam and Boko, 1983). The annual rain during the year 1994 was 1,300 mm including 915.8 mm for the great season of rain (figure 2). Annual average temperatures ranged from 25.8 to 28.6 ℃ (Table 1). The irradiance annually averaged 2300 hours and relative humidity, annually ranged from 30 to 90 %. The ETP of Penman averaged 1650 mm (ASECNA, 1994-1995). Herbaceous savannah dominated by *Panicum maximum* C1 had occurred on ferralitic soils. Soils are "terre de barre", i.e. a sandy-clayed of dark red colour on surface and red from the horizon B, defective in P_2O_5 and K_2O and poor in biogenic salts (Karimou 1988; CENAP, 1995).

Table 1. Monthly average temperatures (°C) of Abomey-Calavi (1993 -1995)

Year	Months											
	J	F	M	A	M	J	J	A	S	O	N	D
1993	25.5	27.3	31.9	27.9	26.7	25.4	24.5	25.1	25.4	25.8	26.4	26.2
1994	25.6	27.9	28.1	28	27.1	25.9	25.5	25.6	26	26.1	26,1	26.2
1995	27.1	28.4	28.2	28.6	28	26.6	25.8	25.8	27.5*	27.8	28.5	28.1
Average	26.1	27.9	29.4	28.2	27.3	26	25.3	25.5	26.3	26.5	26.1	27.1

Source: ASECNA, 1995

METHODS

Experimental site history and installation of the tests

The Faculty of Agronomic Sciences experimental field covers 6 ha. It had previously received two years successive tests cropping including *Imperata cylindrica* and *Cymbopogon citratus*. Sands were taken up for the Laboratory tests in pots and vats. A collection plot established with 3 to 5 cm of depth

July 18th, 1995, was firstly sprinkled after 9 days with 1.5 litres per seed hole before undergoing a periodic watering at the frequency of 2 contributions of water per week during August. The vats and pots were installed respectively 16th and 19th July 1995 and were sprinkled periodically at one litre of water per day during 30 days, one litre of water every 2 days during 15 days and one litre of water every three days during 18 days. The analysis of the first 80 cm of the soil was shown in table 2. The ratio of C/N was 10.6 in the first 30 cm explored by grasses roots. Cotonou soil is sandy. The whole experiment was repeated in the year 2003 in the same conditions and changes were not significant.

Table 2. Characteristics of the soil of experimentation site of the Faculty of Agronomic Sciences

Granulometry (%)	0 - 2 µm 2 - 20 µm 20 - 50 µm 50 - 200 µm 200 - 2000 µm	10.4 2.7 1.9 19.7 65.2
pH (H_2O)		6.4
pH (KCl)		5.4
Ca^{++} ech.meq/100g		2.58
Mg^{++} ech.meq/100g		1.32
K^{+} ech.meq/100g		0.47
Na^{+} ech.meq/100g		0.10
CEC meq/100g		6.23
P_2O_5 p.p.m		6.89
N (%)		0.077
Organic matter (%)		1.40
C (%)		0.81
C/N		10.60

Source: Centre National d'Agro-Pédologie (CENAP, 1996).

Plant material and parameters

Diaspores of *L. ledermannii* collected in full sudanian fields in the northern Benin, and stored in the laboratory under 15 to 25 °C at 40 to 90 % of relative humidity were measured using materials such as: small mortars, tool for dissection, graph paper, balances with sensitivity 1/1000000th. The experimental design consists in a collection plot of 15 m² (5 m x 3 m) used for Fischer block tests. Three seeds per hole in density of 30 cm x 20 cm. In the laboratory, pots are circular cones with 175 cm^3 (height = 6.3 cm; small diameter D = 5 cm; Large diameter D = 6.8 cm). The vacs sized 2,669 cm^3 (Diameter D = 20 cm; Height H = 8.5 cm) were used. The length, thickness and weight of the caryopses were measured on a 100 sampled caryopses. Data analyses were performed using a one-way ANOVA and a multiple regression with STATITCF 5.1. Sowing and lifting dates, the number of seedlings per seed hole, pots and vacs were counted. Sheets length and inflorescences were raised during the vegetative growth with scales rulers and graph paper.

Parameters calculation

The germination rate was estimated as followed:

$$TG = (NCF/QSU) \times 100\ \%, \text{ with:}$$

TG = Rate of germination fertile; NCF = a number of caryopses; QSU = quantity of seeds used.

The aridity index of the site is calculated based on the index of Martonne and Aufrère (1928):

$$I = P/(T + 10), \text{ with:}$$

P = annual average pluviometry; T = annual average temperature.

The speed of germination was calculated based on the following expression:

$$V = dLi/dt\ (a), \text{ with:}$$

V = speed of germination in mm per hour; Li = Length of stem in mm between the time intervals t_0 and t_1. This speed is roughly estimated as follows:

$$V = \sum_{i=1}^{n} (L_1 - L_0)/n\ (t_1 - t_0)\ \text{(b), with:}$$

L_1 = the length of the stem at time T_1; L_0 = the length of the stem at time T_0; T_1 = the time T of length L_1 measurement; T_0 = the time T of length L_0 measurement; n = number of stems sampled.

RESULTS AND DISCUSSION

Morphological characterization

The caryopses brown in colour, measured 46 mm ± 0.5 mm in length, 1.23 mm ± 0.25 mm in thickness and weighted 2.4 ± 0.3 mg (Table 3). Allometric relations exist between the length, thickness and weight of the caryopses. The multiple linear regressions established for the caryopses arise in the following form (table 4). Thickness and weight significantly explain the length (Y_L) of naked caryopsis; but regressions were not strong ($r^2 < 50$ %; $p < 0.05$). Increasing the weight involves a maximum reduction of the length. The low level of correlation ($r < 0.50$) might depend on the harvest and conservation conditions of diaspores. The weight of 100 caryopses was estimated to 5.1 g. Otherwise the correlation was strong and highly significant between the length and the thickness ($p < 0.05$).

Table 3. Morphological traits of naked caryopses of *Loxodera ledermannii* (N = 100 caryopses)

Parameters	Minimum value	Maximum value	Average value	Coefficient of variation (%)	Standard deviation of sample
Length (mm)	3	6	4.55 ± 0.05	11.29	0.52
Stickiness (mm)	1	1.5	1.23 ± 0.025	20.26	0.25
Weight (g)	0.0196	0.03	0.024 ± 0.0003	12.27	0.003

Table 4. Morphological traits and Allometric relationships (N = 100 caryopses)

	Allometric relations	Legend
(a)	$Y_E = 0.769 + 0.095\ X_L + 1.102\ X_P$	Y_E = caryopses thickness (mm); X_L = length (mm); X_P = caryopses mass ; $r^2 = 0.038$; R = 0.178; P = 0.152; e = 0.248
(b)	$Y_L = 5.403 - 34.759\ X_P$	Y_L = caryopses length (L) in mm; X_P = caryopsis mass (P) in mg; $r^2 = 0.042$: R = 0.204; P = 0.045; e = 0.51
(c)	$Y_L = \text{Expo}\ (1.39 + 0.096\ X)$ or $Y_L = E^{(1.39 + 0.096\ X)}$	Y_L = caryopses length (L) in mm; X = caryopses thickness (E) in mm p = 0.043

Speed of germination

The figure 1 showed that the speeds of germination estimated for naked caryopses, were higher in the laboratory than in the field conditions.

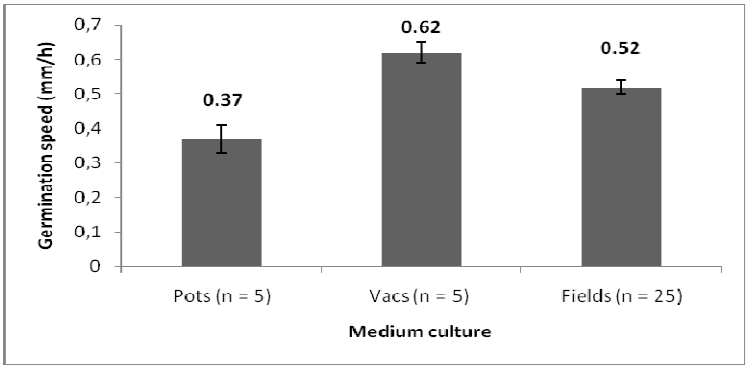

Figure 1. Germination speed of naked caryopses of *L. ledermannii* in subequatorial Benin

Significant differences were found by the one-way ANOVA among medium of culture à 5 %. Values were the highest in vats while average in pots ($p < 0.001$), and the lowest in fields ($p < 0.01$). The difference was also significant between vacs and fields ($p < 0.05$). This trait is depending on sowing depth, which value is lower than one cm in vat. Plants grow rapidly in field. Growth speed was higher in field and lower in the pots (Figure 2).

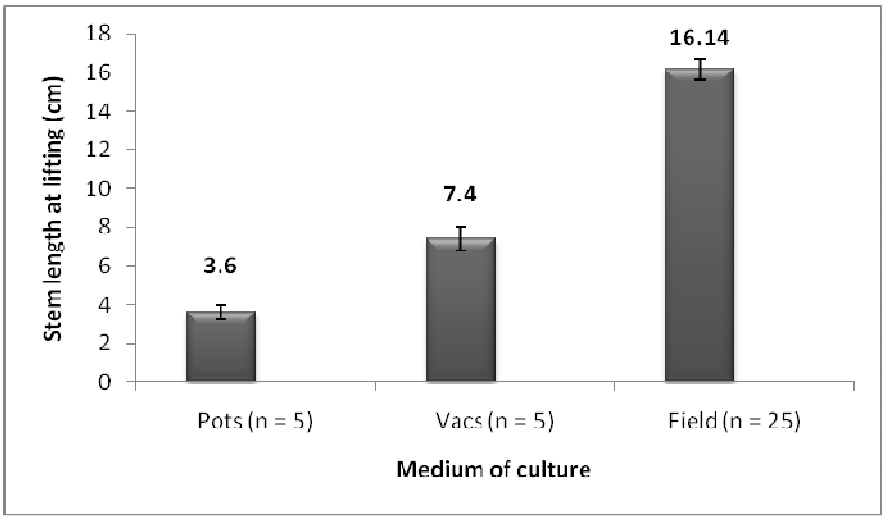

Figure 2. Length of seedlings from *L. ledermannii* naked caryopses

Germination percentage of the naked caryopses

As the test was performed in 96 days, seed started germination since 4th and 5th days. Our results showed: (i) in the full field, 13 days after sowing following a ten days water provision, 75 % holes having 1 seedling while 25 % showed 2 seedlings; (ii) In the laboratory, 5 days after sowing within a diet water provision per day, 40 % of the vacs show each one, 1 seedling weakly grown; (iii) 4 days after sowing, each of 60 % of pots showed 2 seedlings which are vigorous with a progressive tiller appearance; (iv) Appearance of inflorescences between 5th and 6th weeks in the tests in pots. We recorded the best rates in the laboratory with the values ranging from 20 to 50 % in vats and 60 to 100 % in pots. In the full field, values ranged from 12 to 66 % (Figure 3).

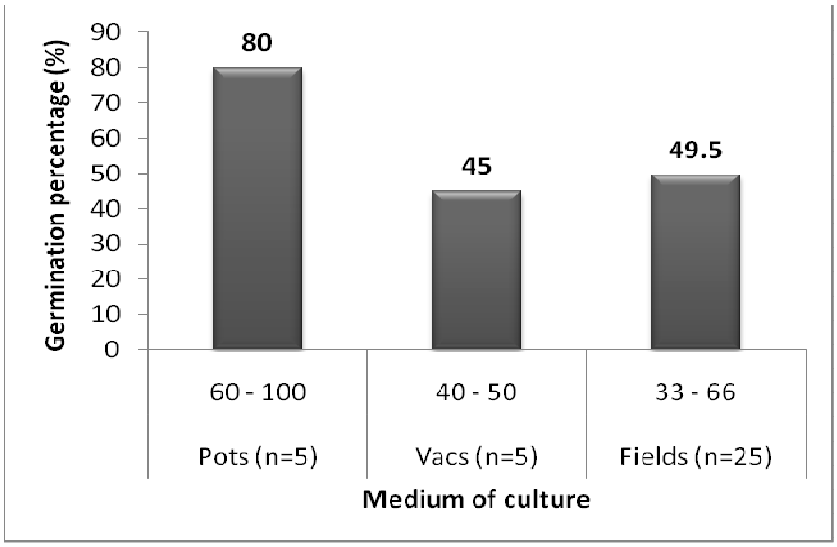

Figure 3. Germination rate of naked caryopses of L. ledermannii is subequatorial Benin

While the duration of germination process might not exceed 7 days in humid field (Bulgen *et al.,* 1991), however, this was longer in the case of *L. ledermannii*. The species germination is hypogeal as it is usual with Poaceae, but it is 2 times longer with *L ledermannii* caryopses in the full field, compared to 2 weeks earlier in pots and vacs. *L. ledermannii* radicles emerged in 24 hours, as for *A. gayanus var. bisquamulatus* (Dieng *et al.,* 1991). Differences in germination between the two species partly depend on the intrinsic physiological properties such as seed purity and dormancy.

Variability in seeds fertility and germination capacity might depend on the conservation conditions. This was proved by *A. gayanus var. bisquamulatus* where the amounts of manure and diaspores

harvest mode have partly induced a higher germination capacity i.e. 76 to 92 % (Dieng *et al.*, 1991). They conclude that a woeful germination raise from caryopses which germination capacity averaged 35 %, grown from 4 to 5 kg/ha and sown at 0.60 m in-line; these caryopses might be purified, diluted in attapulgite and sown at 1cm-depth on a fine substrate. In our experiment, *L ledermannii* germination rate in the full field ranged over 35 % of *A. gayanus var. bisquamulatus*, i.e. 12-66 %. These results help in predicting better agronomic performances for a temporary fodder cropping of *L ledermannii* in subequatorial zone of Benin.

Otherwise, the weight of 100 caryopses of *L ledermannii* ranged from 1.9 and 3 g. Whether *A. gayanus* caryopses weighted 30 to 40 % of diaspores (Dieng *et al.*, 1991), the weight of 1,000 diaspores ranged from 37 to 63 g i.e. 19 g to 30 g for the 1000 caryopses. Additionally, the weight of 1000 seeds of *P. maximum* C1 ranged from 1.77 g in pure stand to 12.13 g in mixture with *Stylosanthes hamata* (Dwivedi *et al.*, 1991). These results show that the caryopses of *L. ledermannii* are heavier than that of *P. maximum* C1 and *A. gayanus* var. bisquamulatus (0.71g - 0.99 g) (Dieng *et al.*, 1991; Buldgen *et al.*, 1991). However, L *ledermannii* caryopses fertility and germinative capacity are not better than those of *A. gayanus* (respectively 60 % vs. 85 %; 60 % vs. 95 %).

Influence of environmental factors on germination

The higher values of germination percentage in pots depend on the substrate and climatic ambiance. Indeed, the experimental substrate used in these pots in laboratory belongs to the bar offshore rich in exchanged bases and organic matter (Mey, 1991); as it offers aeration for a woeful lifting with a favourable structure for the major minerals lift to the seeds. At the reverse, the field soil is fine and poor in minerals in the higher horizons; the seed (also in vacs) difficultly reach essential minerals i.e. phosphorus, potassium and silicon, for a good germination.

The soil moisture also influenced germination rate. The higher values obtained in laboratory is related to the substrate residual moisture. This was maintained by a periodic water provision because of inadequate climatic data for a good germination: 227.5 mm of precipitations, average temperature of 25.8 ℃ and average relative moisture of 87.9 % (AS ECNA, 1995). In fact, the climatic data analysis indicated a rainier period of 1992 to 1994, in particular in the 2nd half; this September precipitations disturbance influences the plant phenology. This also explains the periodic water provision to the test in full field.

Caryopses that have not germinated suggest either a physiological or agronomical influence (Kindomihou *et al.*, 1998). In fact, the caryopses maturity or viability is questionable. In addition, the germination of small sized caryopses of *L. ledermannii* requests a weak depth (< 5cm) whereas the standards range from 5 cm to 10 cm. Buldgen *et al.* (1991) had recommended a sowing depth lower than 1 cm or the seed deposit on the floor with a light covering and wheel tamping. The weak rates of germination in full field (75 % of not germinated surface) suggest thermal influence of the ground.

Moreover, the seed that germinate in pots received water during 3 weeks and marked by fading progress. The zone index of aridity of 2.5 indicates that *L. ledermannii* resist to the dry conditions. This result is in accordance with the arid ecological occurrence of the species. However, its domestication still requires adequate conditions.

CONCLUSION

Morphological traits of naked caryopses of *Loxodera ledermannii* (Pilger) fluctuate. Each caryopsis averaged 4.5 mm length, 1.23 mm thickness and weights 4.9 mg. *L ledermannii* has a germinative capacity that increase in controlled cropping conditions. Germination percentage ranges from 50% in natural conditions to 100% in controlled environments. The species germination requires low sowing depth, between 1 and 5 cm on a humid substrate. Further studies are needed for the species domestication in subequatorial. These imply detailed knowledge on the biology of *Loxodera Ledermannii* including: (i) a comparative analysis of the growth parameters on the sheets and plant of *Loxodera ledermannii* grown caryopses and clumps; (ii) agronomic performances of *Loxodera ledermannii*: Juvenile growth, covering rate and biomass production; (iii) a phenological evaluation of *Loxodera ledermannii* in Benin.

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