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Effects of Sodium Carbonate on *Striga hermonthica* Del. Infestation and Agro-morphological Parameters of *Sorghum bicolor* (L.) Moench in the Sudano-Sahelian Zone of Cameroun

C. Ndouyang[1*], D. R. Braogue[1] and T. J. B. Noubissié[1]

[1]Unit of Genetics and Plant Breeding, Department of Biological Sciences, Faculty of Sciences, University of Ngaoundere, P.O.Box 454, Ngaoundere, Cameroon.

Authors' contributions

This work was carried out in collaboration among all authors. Author CN managed the literature searches, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors and DRB and TJBN participated to field experiments and managed the analyses of the study. Author TJBN designed the study. All authors read and approved the final manuscript.

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ABSTRACT

Sorghum bicolor is the main food widely used to feed millions of people in Central and West Africa. Sorghum production in Sub-Saharan Africa is limited by biotic factors including the parasitic witchweed *Striga hermonthica.* In Northern Cameroon chemical and organic fertilizers, biological methods and cultivation practices were used by farmers to control *Striga hermonthica* in field. Some farmers spread sodium carbonate salt (locally named natron or kilbou) in high rates in fields to reduce parasite infestation but in high rate. This salt plays an important role in soil pH buffering. This study was conducted to evaluate effects of different rates of natron on striga emergence and on agro-morphological parameters of sorghum using a susceptible genotype GD-MP04. Field experiments have been conducted from 2017 to 2018 at Touboro, Mayo-Rey Division in the North Region located between longitude 13°34'; 12°07' East and latitude 7°21'; 15°01'North. The experimental design was a complete randomized bloc with pots (11 m × 11 m) filled with soil

**Corresponding author: E-mail: cndouyang@yahoo.fr;*

naturally infected by striga seeds and different rates of sodium carbonate (0 g, 2 g, 4 g, 6 g, 8 g, 10 g and 12 g per 5 dm^3 of soil) were employed. The numbers of emerged striga and sorghum parameters were evaluated. Results showed that striga-infestation and agro-morphological parameters of sorghum varied significantly ($p < 0.05$) with rates of sodium carbonate. The mean number of emerged striga plants per pot varied from 0.08 in pot of 2 g of salt to 5.4 in the control. The number of sorghum leaves per plant, stem diameter, sorghum height, panicle weight and sorghum kernel yield varied significantly ($p < 0.05$) with natron application rate. The application of 2 g of sodium carbonate per pot was the optimal rate to control *Striga hermonthica* and improve the main agro-morphological parameters of sorghum with 78.27% increase in g of kernel yield and simultaneously inhibited striga infestation by 98.62%. Application of 2 g of sodium carbonate in area naturally infested by striga for improving sorghum yield is required.

Keywords: Sorghum bicolor; Striga hermonthica; sodium carbonate; agro-morphological parameters; Sudano-Sahelian zone.

1. INTRODUCTION

Parasitic plants in the *Striga* genus are major biotic constraints for the production of *sorghum bicolor* (L.) Moench in sub-Saharan Africa [1]. Sorghum is the main source of food in the Sudano-Sahelian zone of Cameroon [2]. This cereal is used for the manufacture of doughnuts, pebbles, porridge, couscous and above all very much in demand for the preparation of local beer (dolo and bil bil) and to feed animals [3,4,5,6]. However, sorghum production in sub-Saharan African countries is slowing due to certain factors, including biotic factors, particularly parasitic weeds and precisely those from the genus *Striga* [7,8]. Depending on the variety and the degree of infestation, the damage can range from a small decrease in yield to a total failure of the crop [1]. Weed control is a major constraint on Crops in Sudanese Savannah [9]. *Striga hermonthica* is a root hemiparasite whose infestation is a major biological constraint to cereal production in general and especially sorghum production [7,8]. It emerges during the early growth of the sorghum and blooms during its maturation. It is associated with low soil fertility conditions [10]. A single Striga plant can produce up to 500 000 seeds that remain viable for long as 20 years and will germinate when exposed to favorable moisture and temperature for several days (preconditioning) and only in the presence of germination stimulant exuded by the hosts [1,10]. Yield damage caused by *S. hermonthica* often varies significantly and is estimated from 10-100% depending on varieties and the level of infestation [1,11]. In northern Cameroon, yield losses were estimated in average from 40% to 100% leading to the abandonment of the field [12]. Several studies have been conducted to find ways and means to fight effectively against striga infestation [13]. Traditional farming practices such as hand-weeding, soil fertility improvement, rotation or intermediate farming were applied and although providing beneficial levels of control, but do not counter effectively striga infestation [14,15]. Chemical control, biological approaches and cultural control methods have met with limited success. Chemical fertilizers and appropriate herbicides are quite effective but not accessible to poor farmers [16]. Some farmers also use the application of sodium carbonate decahydrate ($Na_2CO_310H_2O$) salt locally named 'natron' or 'kilbou' to control *Striga hermonthica* on cereal crops Ndouyang & Noubissié [17]. As part of practicing integrated control, some Burkinabe farmers who use cooking salt to reduce the germination of striga seeds, include the use of resistant or tolerant varieties [18]. Ndouyang & Noubissié [17]. In Touboro, Cameroon, it has been shown that the application of natron increases the yield of sorghum. Natron has improved the growth and yield of sorghum by reducing the number of emerged striga that attach to the host. As this salt increases soil alkalinity and pH, it is important to choose the appropriate rate to reduce saline stress [19].

2. MATERIALS AND METHODS

Field experiments have been conducted from 2017 to 2018 at Touboro, Mayo-Rey Division belongs to North Region located between longitude 13°34' ; 12°07' East and latitude 7°21'; 15°01'North. This part of Cameroon belongs to agro-ecological zone of Sudano-Sahelian pattern of transition between Adamawa region (Sudano-Guinean type) and Far-North region (Sudano-Sahelian type). Touboro is situated at 524 m of altitude between longitude 15°22' East and Latitude 7°46' North at 400 km at south-East to

Benoue Division. The annual pluviometry in average is about 1 280 mm. The climate is the tropical type with two seasons: the rainy season (from june to october) and the dry season (from november to may). The annual average temperature is 26°C [20,21]. Soil composition varied from ferruginous sandstone type, sandy to sandy-clayey and it is poor in organic maters [22].

2.1 Plant Material

A rainfed sorghum cultivar susceptible to striga called *GD-MP04* has been studied in pot. It is a precocious genotype of sorghum with a moderate height. The emergence of parasitic plant *Striga hermonthica* was registered to evaluate the infestation rate and negative effects on sorghum. This accession of sorghum is widely cultivated by farmers of Sudano-Sahelian zone of Cameroon. It is locally called *Konen bi bolé* [17].

2.2 Mineral Material

Natron or sodium carbonate ($Na_2CO_310H_2O$) was used to inhibit the emergence of striga. This mineral is usually employed by some farmers in northern Cameroon to control striga infestation. Natron is a dissolved salt transported by the ground water. It is crystallized either in a solid form by evaporation into interdune depressions when the phreatic water is in direct contact with the atmosphere, or by capillary evaporation in the efflorescence form on the surface of the soil when it is deeper [23]. Natron is used for human and animal feed, as well as for industry [24]. Coming from Chad where deposits are found, it is transported to the market of Touboro (Cameroon) by Peuhl traders. In addition to human, animal feed and the industrial use of natron, this mineral is used by some farmers in Northern Cameroon in the fields to fight against striga infestation. The bicarbonate is a polyvalent product with amazing and various properties; it is used like detergent, powder for washing, deodorant, softening, is biodegradable, without environmental hazard and is cheap [25].

2.3 Pot Experiment

Pots were filled with 5dm^{3}of soil naturally infected by striga. The infected soil was brought from an abandoned cereal field due to striga infestation after a survey near to farmers. The sampling was taken from a plot naturally infested by striga during previous agricultural campaigns. The soil was dug by a hoe on the superficial part at 5cm of depth and then taken.

Seven different rates of natron (0 g, 2 g, 4g, 6 g, 8 g, 10 g and 12 g) have been employed to evaluate their effects on striga infestation and to find an effective rate that can optimize sorghum performance. Totally 84 pots were prepared and implanted following a complete randomized bloc design with three replications. The experimental unit constituted of pots for each of 7 different rates that were treatments. Twelve pots were used for each rate over the 3 replicates. The natron was applied in the pot at a depth of 3cm one week before sowing. Two sorghum seeds were sown in each pot on June (the beginning of the rainy season) and one plant of sorghum has been let in pot immediately after emergence. The delay of sorghum germination was taken for each natron rate. The number of pots with sorghum shoots and the number of dead seedlings of sorghum were inventoried to estimate the rate of sorghum emergence and mortality percentage of seedlings by the following relationship:

$$PM = [(NSP - NSS) / NSP] \times 100$$

Where PM is the percentage of seedling mortality; NSP is the number of total pots with viable plants and NSS is the number of surviving seedlings in pots 40 days after emergence.

The inhibition rate of striga by the natron was calculated by the following formula:

$$IRx = [(NStrCO - NStrx) / NStrCO] \times 100$$

Where IRx is the inhibition rate for one application rate; NStrCO is the total number of striga emerged from control pot and NStrx is the number of emerged striga from an application rate.

The number of sorghum leaves at maturity and the number of emerged striga plants in different pots were counted. The weight of the panicle after drying and the kernel yield were noted.

2.4 Statistical Analysis

Data collected were treated and analysed. All data were subjected to descriptive statistical analysis via Excel 2007. For all quantitative characters of the agro-morphological parameters studied, a comparison of means by analysis of variance (ANOVA) was made, using Duncan's test with the STAT GRAPHICS PLUS software.

Table 1. Physical and chemical composition of Touboro soil

Pedological parameters		Mean values
Average P^H	Horizons H1	6.11
Average P^H	Horizons H2	5.78
Phosphorus content (mg/kg of soil)	Horizons H1	9.5
Phosphorus content (mg/kg of soil)	Horizons H2	4.1
Organic matter content (%)		1.33
Nitrogen content (%)		0.48
Ratio C/N		15.59
Calcium content (méq./100 g)		3.29
Magnesium content (méq./100 g)		0.74
Potassium content (méq./100 g)		0.26
Sum of exchangeable bases (méq./100 g)		4.26
Cationic exchange Capability (CEC) (méq./100 g)		5.77

3. RESULTS

3.1 Interaction Between Natron Rates and Striga Infestation on Agro-Morphological Parameters of Sorghum

Analysis of variances of data collected (Table 2) shows that the number of leaves, stem diameter, sorghum height; panicle weight and the kernel yield were strongly influenced by the different rates of sodium carbonate and by the striga infestation and their interaction ($P < 0.05$).

3.2 Natron Rates Effects on Striga Emergence and on Agro-Morphological Parameters of Sorghum

Table 3 shows that different rates of natron have an impact on the emergence of striga and on the agro-morphological parameters of pre-emergence sorghum.

The first striga plant appeared 43 DAS (day after sowing) in the control, 62; 65; 68 DAS respectively within rates of 2 g, 4 g and 10 g. Within rate of 12 g, 8 g and 6 g, a complete inhibition (100%) of the striga emergence was recorded. while in the control, an average of 5.4 striga. The overall emergence in average was 0.82 striga plants.

The overall sorghum emergence rate was 83.63% with a maximum of 100% in the rate of 02 g and a minimum of 66.66% in rates of 8 g and 12 g. The delay of sorghum shoot appearance varied in average from 3.66 DAS in the control to 6 DAS in the rate of 12 g with an average of 4.7 DAS. These results show that striga has no inhibitor effect on the time of sorghum germination or on the sorghum emergence.

The mortality percentage of sorghum seedlings ranges from an average of 0.0% within rate of 2 g to 45.45% within rate of 12 g with an overall average of 21.78%.

In all, ignoring different rates applied and the level of striga infestation, the average number of sorghum leaves was 12.42 leaves per plant. This number varied significantly ($p < 0.05$) between rates and depending of the striga infestation, from 8.6 in the control to 14.2 in rates of 2g and 4 g. This variable was correlated with the stem diameter of sorghum which varied between 2.62 cm (rate 12 g) and 3.95 cm (rate 2 g) with an overall average of 3.42 cm. As far as sorghum height, it was significantly influenced by the various rates of natron and striga infestation and ranged from 1.08 m (rate12 g) to 1.98 m (rate 2 g) with an overall average of 1.61 m (Table 4).

The panicle weight varied on average from 31.68 g in the rate of 12 g to 59.58 g in the rate of 2 g with an overall average of 47.71 g. However, the kernel yield varied from 16.77 g (rate 12 g) to 39.13 g (rate 2 g) and the overall average was 29.54 g.

4. DISCUSSION

Agro-morphological parameters of Sorghum namely germination delay, emergence rates, sorghum mortality, the number of emerged striga, the number of sorghum leaves at maturity, the stem diameter, sorghum height, panicle weight and the kernel yield of sorghum were highly influenced by sodium carbonate rates application, striga infestation and their interaction. A similarity of interaction genotypes x salinity was demonstrated by Ndouyang & Noubissié [17] on 24 sorghum accessions. An interaction between sorghum accessions and organic fertilization has been studied by Haussmann and their collaborators [26], in agreement with the results obtained by Sinebo & Drennan [27] and Showemimo et al. [28] on the interaction of nitrogen x sorghum genotypes and by Noubissié et al. [15].

The number of emerged striga plants varied significantly according to sodium carbonate rate application. The increase in the rate of natron had a significant effect on the emergence of striga. Al-Khateeb et al. [29] and Osman et al. [30] have discovered that sodium chloride (NaCl) applied at a concentration of 3.3 to 6.3 μM and in the presence of a synthetic germination stimulant (GR_{24}) of striga reduced the germination rate of this parasite from 78 to 85% and increase the sorghum kernel yield. Ndouyang & Noubissié [17] in the Sudano-Sahelian zone of Cameroon showed that application of sodium carbonate salt inhibited significantly Striga emergence on sorghum by 48.66 to 92.69% and reduced the host plant damage. On maize, Tarfa et al. [31] noted that calcium and magnesium applications on soils suppressed *Striga hermonthica* emergence by inhibiting the development of the haustorium. When the concentration of natron in pots is high, the number of emerged striga is low and the medium of growth become more saline. Similarly, Hassan et al. [32] showed that applying NaCl at a concentration of 150 mM reduced haustorium formation by 65-66%. Noubissié Tchiagam et al. [33] have revealed that the mean number of emerged *S. gesnerioides* plants 63 DAS was from 1.8 to 2.4 per cowpea plant on susceptible varieties of cowpea in Northern Cameroon whereas in this test, the number of *S. hermonthica* plants varied from 0.08 to 5.4.

On the other hand, the increasing of natron rate retarded the sorghum germination time and decreased the rate of sorghum emergence. Sorghum mortality before striga emergence is only due to higher concentration of sodium carbonate whereas this sorghum mortality after striga emergence is not only associated with a higher concentration of sodium carbonate but is enhanced by striga infestation. Fortunately young seedlings of sorghum were tolerant to sodium carbonate at the rate of 2 g because no sorghum mortality was seen. It may be justified by the fact that at the time of host germination, seeds of the parasite are still sleeping. The germination of the parasite is conditioned by the chemical signal from the host root. So germination of sorghum seeds could not be affected by the effect of striga. These results corroborate those of Kante [34] on sorghum. In the same way, Djilé et al. [35] in the Far North Cameroon also showed that *Striga gesneriodes* had no effect on the germination of *Vigna unguiculata.* While Ahmad et al. [19] discovered that the tolerance of mulberry plants to $NaHCO_3$ was associated with enhanced accumulation/synthesis of the key osmoprotectants, proline and glycine betaine, as well as upregulation of antioxidant enzymes.

Seedlings mortality of sorghum is explained by the high salinity of the natron which also makes the growing medium very basic and by causing dehydration of the plant. On the other hand, striga infestation in the control alone caused 8.33% mortality of sorghum plants. This latter mortality is due to interspecific parasitism between striga and sorghum plants for nutrients, mineral salts and water that are deviated by striga via its haustorium to the detriment of sorghum. Haustorium not only collected host substances but also keeps them and transforms them before their utilization [36]. Similar results were obtained by Dzomeku-Amegbor [37] in Ghana and Kosma et al. [38] in Cameroon, who showed that host growth parameters decreased according to striga infestation. It could be explained by the fact that *S. hermonthica* via its haustorium diviates water, mineral salts and organic matter necessary for the development of the host.

Table 2. F-values of analysis of variances from agro-morphological parameters of sorghum based on natron rates and striga infestation

Source of variation	Df	Number of leaves	Stem diameter	Sorghum height	Panicle weight	Kernel yield
Rates (R)	6	13.06**	3.52**	1.65**	49.01**	30.81**
Striga (S) infestation	1	8.6**	2.82**	1.36**	39.93**	21.95**
R × S interaction	6	12.42**	3.42**	1.61**	47.71**	29.54**
Repetition	2	1.12^{ns}	0.88^{ns}	0.35^{ns}	6.40^{ns}	4.13^{ns}

***: Significant at p < 0.05; ns: not significant; df: degree of freedom*

Table 3. Natron rates effects on striga infestation and on pre-emergence agro-morphological parameters of sorghum

Striga emergence and agro-morphological parameters of sorghum				
Natron Rates (g)	**Emerged Striga**	**Time of germination (DAS)**	**Emergence rates (%)**	**Sorghum mortality (%)**
0	5.4^{a}	3.66^{d}	95.83^{a}	8.33^{bc}
02	0.08^{b}	4.0^{d}	100^{a}	0.0^{c}
04	0.16^{b}	4.3^{cd}	95.83^{a}	8.33^{bc}
06	0.0^{b}	4.3^{cd}	91.66^{a}	10.0^{b}
08	0.0^{b}	5.0^{bc}	66.66^{b}	42.86^{a}
10	0.16^{b}	5.66^{ab}	70.83^{b}	37.5^{a}
12	0.0^{b}	6.0^{a}	66.66^{b}	45.45^{a}
Mean	0.82	4.70	83.63	21.78
PPDS 5%	0.66	0.93	9.52	9.90

Values followed by the same letter in a column are not significantly different at p<.0.05; ***DAS:*** *day after sowing*

Table 4. Natron rates effects and striga infestation impact on post-emergence agro-morphological parameters of sorghum

Post-emergence agro-morphological parameters of sorghum						
Natron Rates (g)	**Emerged Striga**	**Number of leaves**	**Stem diameter**	**Sorghum height**	**Panicule weight**	**Kernel yield**
0	5.4^{a}	8.6^{d}	2.82^{b}	1.36^{bc}	39.93^{b}	21.95^{d}
02	0.08^{b}	14.2^{a}	3.95^{a}	1.98^{a}	59.58^{a}	39.13^{a}
04	0.16^{b}	14.2^{a}	3.86^{a}	1.92^{a}	53.58^{a}	37.45^{ab}
06	0.0^{b}	13.6^{ab}	3.72^{a}	1.88^{a}	53.77^{a}	33.08^{c}
08	0.0^{b}	12.5^{bc}	3.82^{a}	1.68^{ab}	54.17^{a}	34.23^{bc}
10	0.16^{b}	12.3^{c}	3.16^{ab}	1.42^{bc}	41.30^{b}	24.18^{d}
12	0.0^{b}	11.7^{c}	2.62^{b}	1.08^{c}	31.68^{c}	16.77^{e}
Mean	082	12.42	3.42	1.61	47.71	29.54
PPDS 5%	0.66	1.12	0.88	0.35	6.40	4.13

Values followed by the same letter in a column are not significantly different at p<.0.05;

Striga infestation and higher natron application rates negatively affect the number of leaves, the stem diameter and the sorghum height. On the other hand, the increasing of natron rate inhibits the emergence of this parasite at a certain level compatible with the development of sorghum. High rates of natron also inhibit the emergence of striga but at the detriment to sorghum because the medium becomes salty and does not promote the development of the cereal. Lakhanisky [39] showed that the hazard of sodium carbonate for the environment is mainly caused by the pH effect of the carbonate ion and the effect of sodium carbonate on the organisms depends on the buffer capacity of the aquatic or terrestrial ecosystem. In general, mortality of the test organisms was found at concentrations higher than 100 mg/l [39]. Results obtained showed that striga infestation and salinity of the medium due to natron significantly reduced sorghum height. These results corroborate those obtained by Yagoub et al. [40] who revealed that sorghum height is significantly reduced by striga infestation. In contrast, these searchers found that this infestation had no effect on the number of sorghum leaves.

Under striga infestation, sorghum yield components were differentially affected by the application of sodium carbonate rates and the striga infestation. *Striga hermonthica* significantly decreases sorghum crop yield. The reduction in kernel yield resulted from a reduced number of kernels per panicle and a reduction of panicle and kernel weight [41]. Low sodium carbonate rates improved the growth and yield of sorghum under infestation by reducing the number of emerged parasites attached to the host. These results showed that striga and natron rates significantly influence the performance of sorghum evaluated on the panicle weight and on the kernel yield. Showemimo [42] in Nigeria found similar results as striga infestation reduced the panicle weight and the kernel yield by 37% and 45% respectively. Mokashi et al. [43] in India have shown that sodium bicarbonate has very significant effects on *Chlorella vulgaris* by increasing the production of essential fatty acids, biomass and photosynthesis pigments.

The development of high-yielding sorghum cultivars combined with appropriate rates of sodium carbonate application can play an important function in Striga control [17]. In this study, the application of sodium carbonate rate at 2 g resulted in the best agro-morphological parameters of sorghum with a maximum reduction of parasite infestation. Application of 2 g of sodium carbonate in area naturally infested by striga for improving sorghum yield is required.

CONCLUSION

The application of sodium carbonate at various rates inhibits the emergence of striga gradually or even total (rate 12 g), on the other hand reduces the time of sorghum germination (6 days instead of 3.66 days) and inhibits in high rate (rate 12 g) the rate of sorghum emergence (33.34%) and causes the death of sorghum seedling plants (45.45%). For an effective cumulative action (natron and striga) that can optimize the best yields of sorghum, the 2g rate of natron is optimal because it allowed the sorghum to record the best agronomic parameters (kernel yield 78.27%) and by reducing the development of striga (98.26%) with a rate of sorghum emergence from 100% and a 4 DAS of time of sorghum germination. Application of 2 g of sodium carbonate in area naturally infested by striga for improving sorghum yield is required.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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