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Study of the herbicidal properties of aqueous extracts of *Prosopis juliflora* leaves on different yield parameters and yield

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Abstract

Millet is Alongside rice, maize and sorghum one of the main cereals grown in the Senegal. However, its production is still facing some challenges including weed pressure, lack of nutrients and water in the soil. This study aims to contribute to the improvement of agricultural production in the groundnut basin through sustainable weed management. Specifically, we intend to: 1-determine the effect *Prosopis* juliflora extracts on stem growth and yield, 2- characterize the effect of the application date on the millet cobs and stems, 3- determine the effect of extracts on the yield. The treatments were made using 100 g of *Prosopis juliflora* leaf pounded and infused in 1000 ml of water for 24 hours. From the resulting mixture, two dilutions were made (5% and 10%) and applied to the experimental plots. Each experimental plot received 150 kg/ha of nitrogen fertilizer (urea) in 2 applications. The results shows that the Growth and yield parameters (number of cobs, number and weight of ears) variate depending on the year and treatments. The Yield and its components are inversely proportional to the grass cover. We recommend therefore to increase the concentration of extracts and to carry out a single weeding at the beginning of the cycle in order to reduce weed infestation and promote a better growth and development of millet.

Keywords: Millet; Yield; *Prosopis juliflora* Extracts; Pre-Emergence; Post-Emergence; Concentration

1. Introduction

In Senegal, agricultural production falls far short of the ever-changing population's food need. In addition to pedoclimatic and socio-economic constraints, weed pressure is one the main causes of the declining agricultural yield. Weeds compete with crops for water, light, nutrients and space [9], [20], [27]. In West Africa, weed control occupies 20 to 50% of labour time [21], [33], [27]. However, over the last six decades [18], weed control has relied heavily on the intensive use of herbicides (which generally scores 95% mortality of the target species) [42]. This intnsive use of herbicides has stabilised world food production [22]. In the early 1990s, this production system was widely criticised for its negative effects on health and the environment: contamination of water, soil and air, loss of biodiversity [41], [26], [18]. It is in this context that the study of the effects of Prosopis juliflora leaf extracts was carried out in pre-emergence and post-emergence following a cultivation schedule established by [33] from the data of the real weed flora of the area.

The present work therefore proposes to determine the effects of Prosopis juliflora extracts on millet as well as on weeds. Specifically, we intend to: 1-determine the effect of the extracts on tillering and heading, 2-characterise the effect of the application date on tillering, heading and yield, 3-determine the effect of the extracts on yield.

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2. Material and methods

2.1. Presentation of the study area

The Groundnut Basin covers the administrative regions of Diourbel, Louga, Kaolack, Fatick, Thiès, Kaffrine and Tambacounda (Koumpentoum department) [23]. It occupies 46,387 km2 , solely 25% of the national territory [23]. This Groundnut basin covers 57% of Senegal's arable land and provides an average of 60% of national groundnut production. It contains 65% of the rural population and accounts for 70% of cereal production [14]. The area provides most of the national agricultural production, where groundnuts as the main crop [17]. The area is characterised by soil impoverishment due to chemical, physico-chemical and biological degradation processes [29]. It belongs to the northern Sudanian domain which is swept for 7 to 8 months by the Atlantic monsoon and 4 to 5 months by the harmattan. It records rainfall of between 500 and 1000 mm received from June to October [11]. The main Surface water resources are the Sine and Saloum rivers and the bolongs: the Diombos and the Bandialang, as well as the 60 km long coastline [25]. The groundnut basin has a population of 1,244241 [2] of which 52 % are women. The ethnic groups are Wolofs (62%), Sereres (33%) and Peulhs (4%) [14]. The vegetation in this part of the country has a floristic and physiognomic diversity that varies according to the gradient of rainfall, soil type and human activity [10]. In this area, natural forest formations are regressing due to anthropogenic action and climate change phenomena, often giving way to agroforestry parks [14].

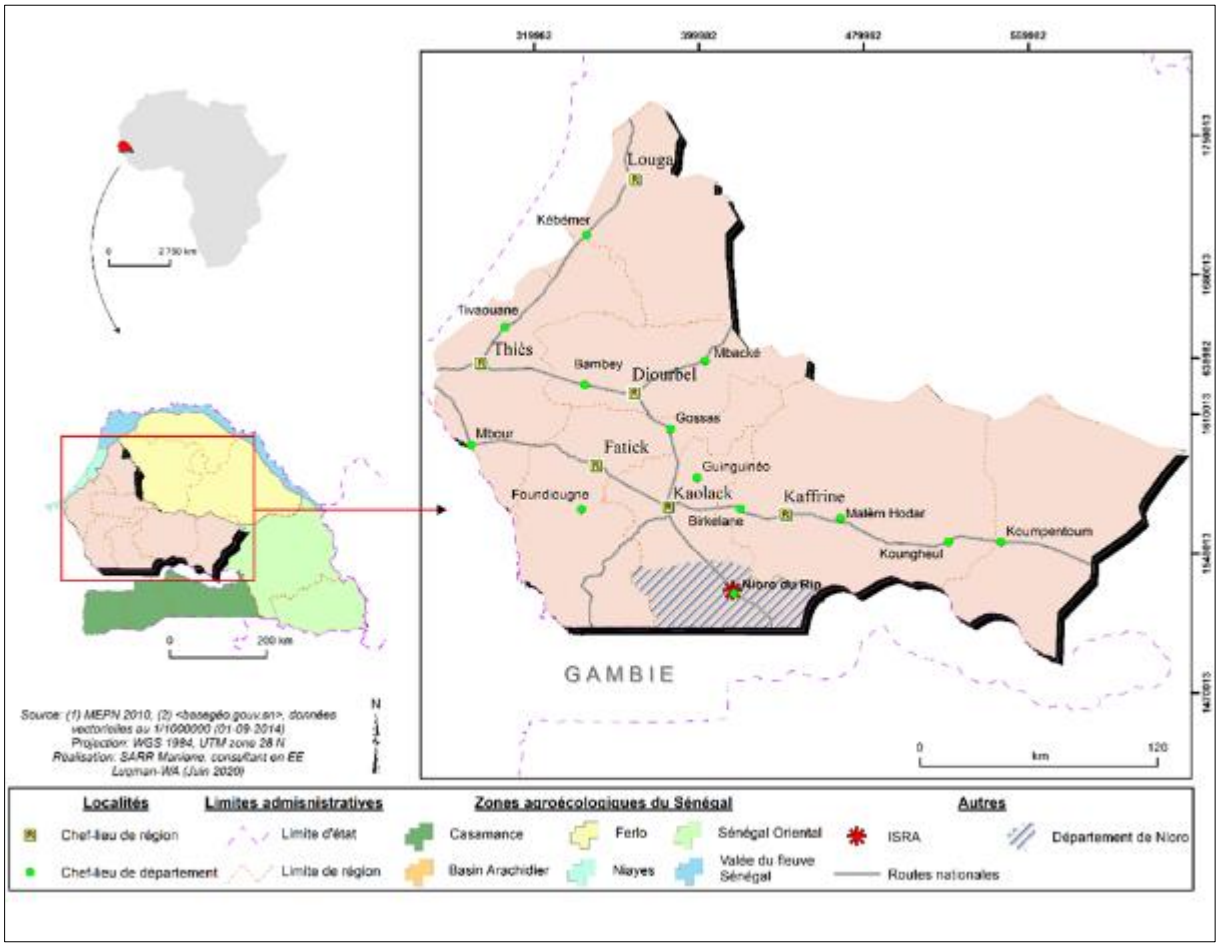


Figure 1 Carte du bassin arachidier

2.2. Plant material

2.2.1. Millet

The studied plant is millet *Pennisetum glaucum [L.] R. Br.),* a cereal plant commonly known as “petit millet” or millet of the variety Souna III, or IRAT P2 (ISRA, 1975; Lambert 1983a and b). The average growth cycle is 85 to 90 days from sowing to harvest. According to some authors, the flowering period can occur at 52 days (Jansen & Gosseye, 1986), and

between 54-57 days [9]. The Souna III has a bushy, drilled habit. The stem is robust, simple, more or less branched. It has a villosity at the nodes and under the inflorescence. Its section is cylindrical, full and can reach 2 to 3 meters in Hight [4], [31], [32], [29]. The seed or caryopsis after threshing is olive-yellow in colour and ovoid in shape. The potential grain yield is 2.4 to 3.5 tonnes/hectare [29].

2.3. Experimental protocol

2.3.1. Preparation of leaf extracts

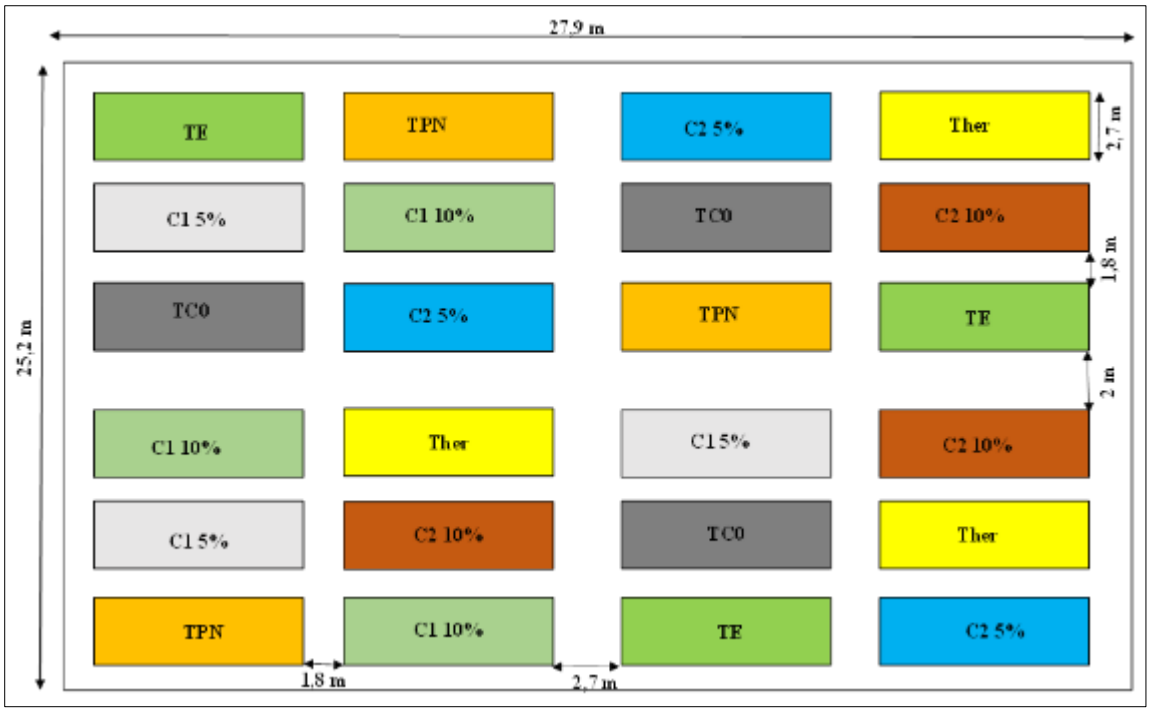
A quantity of 100 g of leaf powder is macerated in 1000 ml of water for 24 hours. The resulting mixture is filtered. The dry residue was discarded and the filtrate collected. From the filtrate, two other concentrations were prepared (2.5%, 5%).

2.4. Determination of the effectiveness of *Prosopis juliflora* extracts on the control of millet weeds on station

In this activity, millet (Souna III variety) is used. Nitrogen fertilisation is applied at the rate recommended by ISRA for millet (granulated urea at a rate of 150 kg/ha in 2 applications, during hoeing and weeding and then on the 40th day. The treatments are as follows

- A pre-emergence treatment
- A post-emergence treatment at 5% concentration
- A post-emergence treatment at a concentration of 10%.
- A clean, manually weeded control (Noba protocol control)
- A control with a herbicide treatment (HERBEXTRA 720 SL " 2,4-D amine salt 720g/l ") of post-emergence acting by systemic action on a large number of dicotyledonous weeds.
- A grassed control
- A control sprayed with water

2.5. Experimental design



TE= Grassed control; TPN: Noba protocol control; Ther: Herbicide control; TC0: Watered control; C1: Pre-emergence treatment; C2: Post-emergence treatment; 5% and 10%: Concentration of extracts

Figure 2 Field Experimental design

The Fisher experimental design with 3 fully randomised replicates. The design consists of 18 elementary plots in total. The sowing was carried out at end of June with the variety SOUNA III. Biocidal treatments were carried out in two conditions: pre-emergence with a single application and post-emergence with three applications. Finally, four controls

were installed: a clean control manually weeded, a herbicide control, a grass control and finally a control watered with water.

Each elementary plot is a rectangle 5.4m long and 2.7m wide, i.e. a surface area of 14.58m2 containing 4 lines with 7 plants per line, with a density of 0.90 x 0.90m. The distance between plants is 90 cm and between lines 90 cm, i.e. 36 plants per elementary plot. The plots are separated by 1.8m aisles. The two blocks are 3m apart.

2.6. Observations and measures

Data was collected on 5 millet plants in each experimental plot. The following observations and measurements were taken into consideration: number of tillers, number of ears and production (yield).

NB. In the absence of being able to speak of yield, which is the product of the number of grains per m^2 and the weight of a thousand grains (Casagrande, 2008), this work reports the production of millet per unit area

3. Results

3.1. Post-emergence

In 2016, the statistical analysis of the number of tillers and ears using the Fisher test with a degree of confidence of 95%, shows a high significant effect of treatments (< 0.0001). These results are organized in three distinct groups with the same number of treatments for the number of tillers and ears, with a mean around 1 (tillers, ears). The first group is represented by treatments T0, T1 and T2, with an average density of 1 ear/m2 and 1 tillers/m2. Group 2 is composed of treatments T3 and T4, with a number of tillers varying around 2 tillers/m2 and with an average spike slightly higher than 1 spike/m2. The treatment T5 belongs to group3, with 8 tillers m2 and slightly more than 4 spikes/m2.

Table 1 Effect of post-emergence treatments on the number of tillers and spikes

Biocides	number of tillers	Number of ears
Pro_10%	2.25 c	1.25 b
Pro_5%	2.25 bc	1.33 b
TC0	1.083 a	1.083 a
Tenh	1.58 ab	0.83 a
Therb	0.83 ab	0.5 a
TPNoba	8.167 d	4.42 c
p-value	< 0.0001	< 0.0001

T0: TC0; T1: TEnh; T2: Therb; T3: Pro5%C2; T4: Pro10%C2; T5: TPN

3.2. Pre-emergence (2016)

Table 2 Effect of pre-emergence treatments on the number of tillers and spikes

Biocides	number of tillers	Number of ears
Pro_10%	4.5 b	2 b
Pro_5%	2.17 a	1.17 a
TC0	1.08 a	1.08 a
p-value	< 0.0001	< 0.0001

T0: TC0; T1: Pro5%C2;T2: Pro10%.

The statistical analysis of the number of tillers and ears using Fisher's test (at of 95% confidence degree), shows a high significant effect of the applied treatments (< 0.0001). From the Fischer's test we identify 2 distinct groups. Group 1 composed of T0 and T1 with 1 to 2 tillers/m2 respectively. Group 2 registering 4 tillers/m2 is reprented by T2. For the number of ears, similar results were observed with 2 groups: group 1 characterized by treatments T0 and T1 with an

average of 1.17 and 1.08 ears/m2 respectively and group 2 represented by treatment T2, with an average of 2 ears/m2. It is also clear that the average number of tillers and spikes increases as the concentration of extracts increases and vice versa.

3.3. Post-emergence (2017)

The statistical analysis of the number of tillers and ears, shows a very high significant effect of treatments (< 0.0001). It allowed us to identify 3 groups for the average number of tillers and 2 groups for the number of ears.

Group 1 is made up of T0, T1 treatment in which we find the lowest average number of tillers, around 1 tillers/m2. Group 2 englobes the treatments T3 and T4, with a number of tillers around 3 tillers/m2; group 3 include treatment T5, with an average of 7 tillers/m2.

For the average number of spikes, group 1 include treatments T0, T1, T2, T3 and T4 with an average of 1 spike/m2; group 2 is represented by T5 with an average of 4 spikes/m2. It is also clear that the average number of tillers and spikes increases as the concentration of extracts increases and vice versa. However, the lowest numbers of tillers and ears were recorded with treatments T2 and T3, which represent the C0 control and the grassed control respectively. On the other hand, the highest number of ears and tillers was recorded in treatment T5. However, the number of tillers and spikes in the other treatments increased as the concentration of *Prosopis juliflora* leaf extracts increased and vice versa.

Table 3 Effect of post-emergence treatments on the number of tillers and spikes

Biocides	number of tillers	Number of ears
Pro_10%	367 b	1.33 b
Pro_5%	3.08 b	1.08 ab
TC0	1.58 a	1.08 ab
Tenh	1.33 a	0.75 a
Therb	3.58 b	1.17 ab
TPNoba	7.08 c	3.92 c
p-value	< 0.0001	< 0.0001

T0 : TC0 ; T1 : TEnh ; T2 : Therb ; T3 : Pro5%C2 ;T4 : Pro10%C2 ; T5 : TPN

3.4. Harvest (2017)

The statistical analysis using Fisher's test (at 95% confidence level) shows that the treatments have high significant effect on the number of tillers and ears of the millet (p-value< 0.0001). These results allowed to distinguish 2 distinct groups. Group 1 is characterized by an average of 1.58 tillers/m2 is composed of T0. Group 2 include treatments T1 and T2, with an average of 5.18 and 3.38 tillers/m2 respectively. For the number of ears, similar results were observed with 2 groups: group 1 composed of T0 and T1 with an average of 1.67 and 1.08 ears/m2 respectively and group 2 represented by treatment T2, with an average of 2.5 ears/m2. It is also clear that the average number of tillers and spikes increases as the concentration of extracts increases and vice versa.

Table 4 Effect of pre-emergence treatments on the number of tillers and spikes

Biocides	number of tillers	Number of ears
Pro_10%	5.16 b	2.5 b
Pro_5%	3.58 b	1.67 a
TC0	1.58 a	1.08 a
p-value	< 0.0001	< 0.002

T0 : TC0 ; T1 : Pro10% ; T2 :Pro5%

the relationship between the number of tillers and the number of ears during the two years of experimentation was assessed using the Pearson correlation coefficient. The correlation between these two quantitative variables was stronger in 2016 with a coefficient of 0.802, compared to the one of 2017 which was 0.711.

3.5. Correlation matrix (Pearson)

3.5.1. 2016

Table 5 Relationship between the number of tillers and the number of ears

Variables	number of tillers	Number of ears
number of tillers	1	< 0.802
Number of ears	< 0.802	1

Values in bold are different from 0 at significance level alpha=0.05

3.5.2. 2017

Table 6 Relationship between the number of tillers and the number of ears

Variables	number of tillers	Number of ears
number of tillers	1	0.711
Number of ears	< 0.711	1

Values in bold are different from 0 at significance level alpha=0.05

The analysis of the number of tillers in pre- and post-emergence show high significant results (< 0.0001) in Pro 10%. The analysis of the number of ears did not give significant results. According to the results obtained, the number of tillers is higher in pre-emergence than in post-emergence in Pro 10% with an average of 4.5 and 2.25 tillers/m2 respectively and lower in Pro5% with an average of 2.25 in post-emergence and 2.17 in pre-emergence. Regarding the number of spikes, the same observation as before was registered: in Pro10% we obtained 2 spikes/m2 and in post-emergence 1.25 spikes/m2. In Pro 5% the number of ears is higher in post-emergence than in pre-emergence, with an average of 1.33 and 1.17 ears/m2 respectively.

3.5.3. 2016

Table 7 Comparison of pre- and post-emergence biocidal treatments in 2016

Traitements	Mean of Tillers Number			Mean of Ears Number		
	Pro_10%	Pro_5%	TC0	Pro_10%	Pro_5%	TC0
Post-emergence	2.25 b	2.25	1.08	1.25	1.33	1.08
Pré-emergence	4.5 a	2.17	1.08	2.00	1.17	1.08
P-value	<**0,00049**	<0.95	<1.00	<**0.02**	<0.59	<1.00

The statistical analysis of the average number of tillers in pre- and post-emergence showed highly significant results (< 0.0001) in Pro 10%. The statistical analysis of the number of ears did not give significant results. According to the results obtained, the number of tillers is higher in pre-emergence than in post-emergence for Pro 10% with an average of 4.5 and 2.25 tillers/m2 respectively and lower in Pro5% with an average of 2.25 in post-emergence and 2.17 in pre-emergence. Regarding the number of spikes, the same observation as below was made: in Pro10% we obtained 2 spikes/m2 and in post-emergence 1.25 spikes/m2. In Pro 5% the number of ears is higher in post-emergence than in pre-emergence, with an average of 1.33 and 1.17 ears/m2 respectively.

3.5.4. 2017

The statistical analysis shows that the treatments do not have a significant effect on the millet production for pre-emergence treated plots (p<0.066). the comparison of mean of the different treatment allowed us to highlight 2 distinctif groups. Group 1 is composed of treatments T0 and T2, with an average production of 0.28 t/ha and group 2 include treatment T1, with a production of 0.64 t/ha.

Table 8 Comparison of pre- and post-emergence biocidal treatments in 2017

Treatments	**Tillers Number Mean**			**Cobs Number Mean**		
	Pro_10%	Pro_5%	TC0	Pro_10%	Pro_5%	TC0
Post-emergence	3.67 b	3.08	1.58	1.3 b	1.08	1.08
Pré-emergence	5.17 a	3.58	1.58	2.5 a	1.17	1.08
P-value	<**0.0420**	<0.99	<1.00	<**0.0002**	<0.59	<1.00

3.5.5. 2016

Table 9 Effect of pre-emergence treatments on millet production (t/ha)

Treatments	**Production (t/ha)**
Eau	0.28 a
Prosopis_10%	0.64b
Prosopis_5%	0.28 a
p-value	<0.066

T0 : TC0 ; T1 : Pro10% ; T2 :Pro5%

The statistical analysis of millet production in post-emergence treated plot shows a non-significant effect of the different treatments (0.038). however, we can distinguish 3 groups. Group 1, with treatment T2 (0.08 t/ha); and group 2 represented by the intermediate production treatments observed in T0, T1, T3 and T4 with a respective yield of 0.28 0.29 0.27 0.22 t/ha; and lastly group 3 represented by treatment T5, with an average production of 1.46 t/ha.

Table 10 Effect of post-emergence treatments on millet production (t/ha)

Treatments	**Production (t/ha)**
Eau	0.28 ab
Herbicide	0.29 ab
Prosopis_10%	0.27 ab
Prosopis_5%	0.22 ab
Tenherb	0.08 a
TNoba	1.46 b
p-value	<0.038

T0 : TC0 ; T1 : TEnh ; T2 : Therb ; T3 : Pro5%C2 ;T4 : Pro10%C2 ; T5 : TPN

The statistical analysis of the millet production in pre-emergence treated plots, shows that treatment have non-significant effect (0.066). It allowed us to highlight 2 distinct groups. Group 1 characterized by treatments T0 and T2, with an average production of 0.28 t/ha; and group 2 composed of treatment T1, with a production of 0.64 t/ha.

3.5.6. (2017)

The analysis of the data concerning the millet production in post-emergence shows that treatments have non-significant effect (0.038). however, it allowed us to identify 3 groups. Group 1 include treatment T2 with a yield of 0.08 t/ha; group 2 represented by the intermediate production treatments observed in T0, T1, T3 and T4 with a respective yield of 0.28 0.29 0.27 0.22 t/ha; and group 3 is made of treatment T5, with an average production of 1.46 t/ha.

Table 11 Effect of pre-emergence treatments on millet production (t/ha)

Treatments	Production en t/ha
Water	0.87 a
Prosopis_10%	2.06 b
Prosopis_5%	1.46 ab
p-value	<0.049

T0 : TC0 ; T1 : Pro10% ; T2 :Pro5%

Table 12 Effect of post-emergence treatments on millet production (t/ha)

Treatments	Production (t/ha)
water	0.87 ab
Herbicide	1.48 bc
Prosopis_10%	1.19 abc
Prosopis_5%	1.3 bc
Tenherb	0.81 a
TNoba	3.24 c
p-value	<0.012

T0 : TC0 ; T1 : TEnh ; T2 : Therb ; T3 : Pro5%C2 ;T4 : Pro10%C2 ; T5 : TPN

3. Discussion

The obtained results during the two years of experimentations showed that the number of tillers is an agromorphological character that is linked on one hand to the effects of the year [3] and on the other hand to the intrinsic characteristics of millet [27]. This interannual variability in tillering could also be related to climatic conditions (rainfall, temperature, light, etc.) and to the quantitative and qualitative differences in pests, pathogens and weeds [1]. When facing multiple biotic and abiotic constraints, millet plants can react immediately with phenotypic plasticity [19], [36] and consequently with a decrease in the number of tillers. These results corroborate those [7], [30] which indicate that temperature, light, etc., are important for millet productivity. Furthermore, weeds constitute one of the major constraints for millet cultivation, due to their competitiveness for water, minerals, light and space. They have direct negative effects on the growth and development of millet [30], [42], [5]. Comparison of the results of the pre- and post-emergence treatments showed that the number of tillers and ears was higher in the pre-emergence treatments independently of the year. These results corroborate those of [28], [37] on the effect of *Glyricidia sepium* extracts on millet weeds. This could be explained by the fact that the extracts were not able to stop or reduce weed competition for essential resources (water, mineral elements, light and space) and therefore tillers production is below normal. However, the application of the weed control itinerary adopted by [33] as well as the use of herbicide decreased weed competition and consequently increased the number of tillers. The Pearson correlation matrix showed a strong relationship between the number of tillers and the number of ears, independently of the year. These results are in line with the work of [33], [27] and [3] on millet and maize weeds in the southern groundnut basin (Nioro du rip). As far as yield is concerned, the comparison of the results obtained with Prosopis juliflora leaf extracts showed relatively low results. However, a slight increase in yield was observed in treatments T1 and T2 in pre-emergence, corresponding to Pro10% and Pro5% respectively. The observed yield losses in millet were due to the ineffectiveness of the extracts on the main weeds (*Digitaria ciliaris, Cyperus amabilis* and *Cyperus tenuispica*) [37]. Yields also varied from year to year. This is due to the soil condition and climatic parameters (soil fertility, rainfall variation). Weed competition was a determining factor since the crop was never weeded or hoed. Thus, despite nitrogen fertilization, yields were low. This is due to the strong competition of weeds with millet plants for essential nutrients and water that influenced millet production and yield [40]. These results corroborate those of [32], [39], [43]. The dominant weeds of the crop and the millet belong to the same botanical family, therefore, would use the same types of resources and at the same time as the crop. This shows that the crop must be weeded at least once in order to reduce weed competitiveness or increase the concentration of extracts to a threshold value that can cause negative effects on the weed's development and,

consequently, increase the vegetative growth and fair production of the crop. In this case, it is important to consider the nature of the weeds, their degree of competitiveness with the crop in the field in order to reduce yield losses [6].

4. Conclusion

This study allowed us to understand that growth and yield parameters (number of tillers, number of ears and yield) are variable depending on the year, fertilization and weed presence. The number of tillers as well as the number of ears were relatively more important in pre-emerged treated plots than in post-emerged treated plots independently of the year. The number of ears appeared to be strongly related to the number of plants. Furthermore, the Growth and yield were inversely related to the degree of weed infestation, i.e., low growth and yields were obtained in plots with high presence of weed. According to our findings, it is necessary to increase the concentration of extracts and to practice a single weeding at the beginning of the cycle in order to reduce weed infestation and development and favor a good growth and development of millet. The exclusive use of biocidal extracts of Prosopis juliflora may not be a adequate solution to weed management. Its action depends on several environmental factors that are difficult to control. However, an integrated weed management plan where natural and synthetic herbicides are combined with other cultural practices could reduce the risks and impacts of pesticide use on human and animal health, the environment and biodiversity, and consequently increase yields.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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