Sawadogo/Ilboudo *et al.*
CABI Agriculture and Bioscience (2022) 3:61
https://doi.org/10.1186/s43170-022-00129-z

CABI Agriculture and Bioscience

RESEARCH

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Aqueous extracts from indigenous plant in Burkina Faso with bio-herbicide properties to reduce *Striga hermonthica* (Del.) Benth propagation

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Abstract

Background: The genus *Striga* includes 11 parasitic plants species of food crops in at least 50 African countries. *Striga hermonthica* (Del.) Benth. is a major biotic constraint to the cereal crops production in Africa. It is the most widespread species in fields in Burkina Faso and grows on all types of soil inducing losses estimated at 35–40% on sorghum and millet. The substantial reductions in yield caused by *S. hermonthica* contribute significantly to an insufficient food supply for the populations in the area.

Methods: This study aims to identify local plants with bio-herbicidal properties for the management of *S. hermonthica*. The inhibiting and stimulating effect of aqueous extracts from 13 local plant species on the germination of *S. hermonthica* seeds was assessed in vitro.

Results: The aqueous extracts from the leaves of *Azadirachta indica* A. Juss, *Jatropha curcas* L., *Jatropha gossypiifolia* L., *Lawsonia inermis* L. and those from the leafy stems of *Cassia obtusifolia* L., *Crotalaria retusa* L., *Phyllanthus amarus* L. completely inhibited germination of *Striga*. Five other plant extracts significantly stimulated germination, of which the highest germination rate (60%) was recorded with the extract from *Euphorbia hirta* L. leafy stems.

Conclusions: The plant extracts thus constitute an ecological avenue for *S. hermonthica* control. Further experiments could lead to the formulation of bio-herbicides against the parasitic plant to improve cereal production while limiting environmental pollution.

Keywords: Bio-herbicide, Plant extracts, Striga hermonthica, Cereal crops

Background

Striga hermonthica, an obligate root-parasitic weed, is one of the most economically important parasitic plants among the 42 known *Striga* species. Infestations with *S. hermonthica* has become a major threat to food security, exacerbating hunger, and poverty in many African countries (Khan et al. 2014). *S. hermonthica* causes enormous yield losses with a value ranging from 7 to 10 billion US$ annually affecting the life of more than 300 million people in Africa (Gressel et al. 2004; Rodenburg and Riches 2010).

Finding suitable *S. hermonthica* control strategies is crucial on order to reduce the extent of damage and also to limit further spread into the non-contaminant fields (Berner et al. 1995). A multitude of control methods such

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as chemical or mechanical means, the use of resistant varieties, and cultural measures have been developed and proposed to address the challenge presented by *S. hermonthica* (Teka 2014; Jamil et al. 2021). These approaches have been used in isolation or in integrated ways to improve soil fertility or directly target the pest. In effect, the supply of nutrients to the soil, particularly nitrogen, considerably reduces the production by the host plant of root exudates containing the germination stimulants of *S. hermonthica* seeds (Dembélé and Sidibé 2009). Use of herbicides and synthetic suicidal germination agents to deplete *S. hermonthica* seed bank in infested soils has recently gained a lot of attention (Zwanenburg et al. 2016; Kountche et al. 2019).

However, the excessive use of synthetic pesticides in agriculture poses risks of environmental contamination and health issues (Anjarwalla et al. 2016). Thus, chemical pesticides are a global human rights concern (UN 2017). In some countries, deaths from pesticide poisoning even exceed deaths from infectious diseases (Eddleston 2002). Issues with synthetic pesticides have led to more targeted research and development of botanical pesticides (Anjarwalla et al. 2016). The use of plant pesticides has the advantage of respecting the environment while being effective in controlling pests (Stevenson et al. 2014; Mkenda et al. 2015). Their effect on non-target species has been shown to be negligible compared to synthetic pesticides (Charleston et al. 2006; Amoabeng et al. 2013; Mkenda et al. 2015). Usage of local pesticides originated from local plants offers considerable potential for smallholder farmers but remains underexploited (Isman 2006, 2008). Some foods and drugs contain compounds with pesticidal properties and can be used in this area (Anjarwalla et al. 2016). In this respect, water extracts from sixteen local species of which *Azadirachta indica, Jatropha. Curcas*, *Jatropha gossypiifolia*, *Eucalyptus camaldulensis*, were screened by Yonli et al. (2010) in bio-assays to test their ability to induce or inhibit the germination of *S. hermonthica* seeds. The efficacy of the 10% extract from *E. camaldulensis* to inhibit the germination was 84.33%. Likewise, seed and leaf powders of neem and fruit and fruit peel powders of parkia trees were evaluated under screenhouse and field conditions by Marley et al. (2004) in the Nigerian savannah to control *S. hermonthica* in sorghum. Neem seed powder was the most effective, with only 16.5% of *S. hermonthica* emergence. Irrigation of a maize field sown on soil infested by *S. hermonthica*, with an aqueous extract of *Desmodium uncinatum* plants resulted in a highly significant reduction in infestation (Qasem 2006). The aqueous extract of the seeds of *Trigonella foenum-graecum* L., a medicinal plant of the Fabaceae family, has also been observed to significantly inhibit the germination of *S. hermonthica* seeds (Hassan et al. 2013). The ethnopharmacology and pharmacology of *Euphorbia hirta* (Feiyangcao) of which its anti-malarial, anthelmintic and larvicidal activity were reported by Kumar et al. (2010) and Huang et al. (2012). Umeh and Ndana (2010) have shown the effectiveness of *Jatropha curcas* and *Jatropha gossypiifolia* plant extracts in the control of the soil nematode Meloidogyne incognita on Abelmoschus esculentus. *Phyllanthus amarus* is also known for its traditional and medicinal uses as well as its many virtues (Patel et al. 2011). The present study aims to identify Burkina Faso's local plants whose aqueous extracts have bio-herbicide properties for *S. hermonthica* control. The specific objectives were: to identify aqueous plant extracts effective for the inhibition of *S. hermonthica* seed germination, and to identify the ones that are effective in *S. hermonthica* suicidal germination.

Table 1 List of local plant species on which aqueous extractions have been performed

Plant species	Plant families	Plant material used
Acacia nilotica var. adansonii (L.) Willd. ex Delile	Fabaceae-Mimosoideae	Bark (B)
Azadirachta indica A. Juss.	Meliaceae	Bark and leaves (B + L)
Balanites aegyptiaca (L.) Delile	Balanitaceae	Bark (B)
Cassia obtusifolia L.	Fabaceae-Caesalpinioideae	Stem and leaves (St + L)
Crotalaria retusa L.	Fabaceae-Faboideae	Stem and leaves (St + L)
Eucalyptus camaldulensis Dehnh.	Myrtaceae	Leaves (L)
Euphorbia hirta L.	Euphorbiaceae	Stem and leaves (St + L)
Jatropha curcas L.	Euphorbiaceae	Leaves (L)
Jatropha gossypiifolia L.	Euphorbiaceae	Leaves (L)
Khaya senegalensis (Desr.) A. Juss.	Meliaceae	Leaves (L)
Lawsonia inermis L.	Lythraceae	Leaves (L)
Moringa oleifera Lam.	Moringaceae	Leaves (L)
Phyllanthus amarus L.	Phyllanthaceae	Leaves (L)

Table 2 Germination rates at the end of the three inhibition tests

Treatments	Test 1 (%)	Test 2 (%)	Test 3 (%)
H_2O	92.8a	82.7a	84.8a
Euphorbia hirta (L + St)	77.8b	51.5c	48.7bc
Eucalyptus camaldulensis (L)	57.2c	49.0c	54.7b
Azadirachta indica (B)	53.6c	38.9d	39.7c
Khaya senegalensis (B)	43.2d	74.1b	42.5c
Moringa oleifera (L)	33.8e	29.0e	39.6c
Acassia nilotica (B)	0.4f	0.0f	0.0d
Azadirachta indica(L)	0.0f	0.0f	0.0d
Balanites aegyptiaca (B)	0.0f	0.0f	0.0d
Cassia obtusifolia (L + St)	0.0f	0.0f	0.0d
Crotalaria rotusa (L + St)	0.0f	0.0f	0.0d
Jatropha curcas (L)	0.0f	0.0f	0.0d
Jatropha gossypiifolia (L)	0.0f	0.0f	0.0d
Lawsonia inermis (L)	0.0f	0.0f	0.0d
Phyllanthus amarus (L + St)	0.0f	0.0f	0.0d
Mean	23.9	21.7	20.6
LSD (5%)	9.402	8.687	8.733
cv%	48.7	49.7	52.4
F pr	< 0.001	< 0.001	< 0.001

In a column, means followed by the same alphabet letter are not significantly different

LSD (5%), Least significant differences of means (5% level); cv, coefficient of variation, F Pr, Fisher probability; L, leaves; St, stems; B, bark

Material and methods

Materials

Striga hermonthica seeds were harvested in 2015 from a sorghum field in the Kouaré village, in the Burkina Faso's eastern region located between 11°95′03″ North and, 0°30′58″ East.

To obtain the plant extracts, 13 local plant species (Table 1) were harvested in 2016 in the vicinity of Ouagadougou, in Burkina Faso's Center region. The choice of these species was made on the basis of their virtues and properties shown in the background section, their availability or even abundance in Burkina Faso.

Methods

Aqueous extraction

The extractions and tests were carried out in 2017 in vitro at the CREAF (Environmental, Agricultural and Training Research Center) in Kamboinsé, Burkina Faso, Africa in the Laboratory of Phytopathology and Weeds. The harvested plant samples were dried in the shade at ambient laboratory temperature (25–30 °C) for at least 30 days and then ground to powder. Aqueous extracts were prepared by introducing 10 g of the powder from each sample into an Erlenmeyer flask containing 100 ml of sterile distilled water. The mixture was placed on a stirrer and stirred for 24 h. The extracts thus obtained were filtered and the filtrates, which are aqueous extracts concentrated at 10%, were used for the *S. hermonthica* seeds germination tests. Two samples of *Azadirachta indica* were used for the extractions: the first one on the leaves and the second one on the bark. This gives a total of 14 aqueous extracts used for the evaluation of inhibiting or stimulating properties on the germination.

Evaluation of the plant extracts inhibitory effect on the germination

Striga hermonthica seeds were disinfected and placed on 6 mm diameter Wattman GF/A filter paper discs with 20–30 seeds per disc. Seed disinfection was done by soaking them in 70° ethanol and 1% sodium hypochlorite (NaOCl) for 3 min and 5 min respectively. Four discs were placed equidistantly in a Petri disc (9 cm in diameter) and 3 ml of extract was added."

They were 15 treatments in comparison: (1) *S. hermonthica* seeds conditioned with sterile distilled water (control); and (2) *S. hermonthica* seeds conditioned with each of the 14 plant extracts.

Petri dishes were sealed and wrapped with aluminum foil and then incubated at 28 °C for 14 days. At the end of 14 days, 25 µl of the GR24 (0.0001%), synthetic germination stimulant was applied to each disc to check if the plant extracts inhibited the seed's germination. The 0.0001% GR24 solution was prepared by first dissolving 0.05 µg powder of GR24 in 1 ml of pure acetone and then mixed with 49 ml of sterile water. The dishes were sealed and rewrapped for a 72 h incubation after which they were opened to observe the germinated seeds under a binocular microscope. Germination rates were calculated to determine the effectiveness of each treatment in inhibiting seed germination. Each treatment was replicated three times and the experiment was repeated three times.

Evaluation of the plant extracts stimulatory effect on the germination

Striga hermonthica seeds were disinfected and placed on 6 mm diameter Wattman GF/A filter paper discs with 20–30 seeds per disc. Four discs were placed equidistantly in a Petri disc (9 cm in diameter) with sterile distilled water. Dishes were sealed, wrapped with aluminum foil, and incubated at 28 °C for 14 days to break the seeds dormancy. Then, 25 µl of extract (10%) or the control GR24 (0.0001%) was applied to the seeds of each disc to verify their ability to stimulate germination. The dishes were further sealed and wrapped for another 72 h of incubation after which they were observed under a binocular microscope to calculate the induced germination

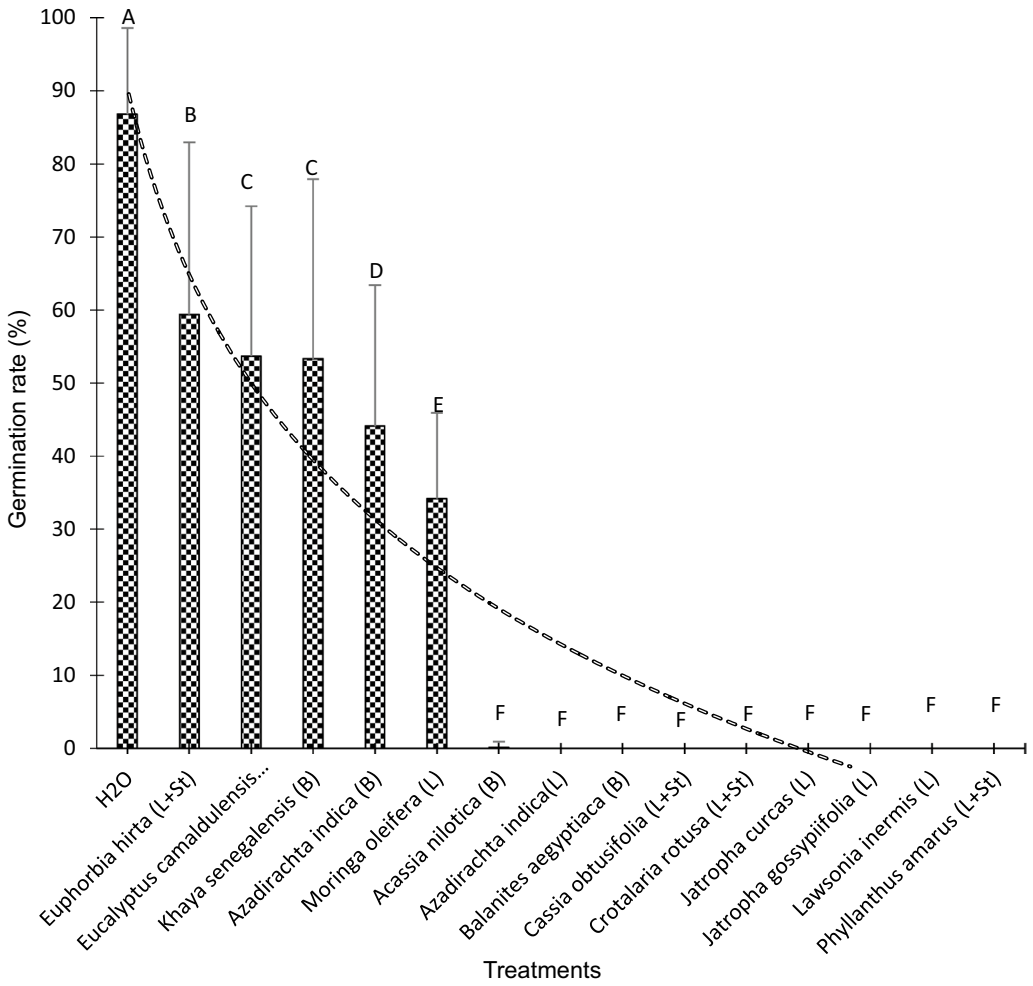

Fig. 1 Inhibition effect of aqueous plant extracts on the *S. hermonthica* seeds germination. L, leaves; St, stems; B, bark. The means followed by the same alphabet letter are not statistically different at the 5% level according to the Newman Keuls Student test

rates. 3 dishes were used per extract or per control treatment (GR24). The test was repeated 3 times and the efficacy of the extracts to stimulate the *S. hermonthica* seeds germination was evaluated.

Data statistical analysis

The data collected were subjected to one-way analysis of variance (ANOVA) through GenStat Release 12.1. software (PC/Windows Vista), VSN International Ltd. A comparison of germination rates averages was performed by the Newman Keuls Student test at the 5% level.

Results

Germination inhibition by the plant aqueous extracts

Inside every experiment, significant differences ($P < 0.001$) were observed among treatments for inhibition of germination after treatment with the plant extracts (Table 2). There are also significant differences between the three runs of the experiments. In each of the experiments, the extract from *E. hirta* followed by those from *E. camaldulensis*, *A. indica*, *K. senegalensis*, *M. oleifera* are those which inhibited germination less. The other nine extracts completely inhibited germination.

Results of the three runs of the experiments on the inhibition are shown in one figure, despite the fact that there were differences among the repetitions. The comparison of the means showed that the germination rate (GR) of the control is significantly higher than those of all the plant extracts (Fig. 1). Five (5) extracts reduced the germination of *S. hermonthica* seeds with inhibition rates ranging from 31.6% (leafy stems of *E. hirta*) to 60.6% (leaves of *M. oleifera*) compared to the control. Among these five extracts, two are not significantly different (those of *E. camaldulensis* leaves and *K. senegalensis*

Table 3 Germination rates at the end of the three stimulation tests

Treatments	Test 1 (%)	Test 2 (%)	Test 3 (%)
GR24	69.3a	96.7a	97.9a
Euphorbia hirta (L + St)	66.7a	56.1b	57.3b
Azadirachta indica (B)	29.6b	25.1c	28.1c
Khaya senegalensis (B)	8.3c	7.1d	2.0e
Moringa oleifera (L)	3.6cd	3.1e	7.6d
Eucalyptus camaldulensis (L)	3.4 d	3.2e	2.6e
Acassia nilotica (B)	0.0d	0.0f	0.0e
Azadirachta indica(L)	0.0d	0.0eg	0.0e
Balanites aegyptiaca (B)	0.0d	0.0eg	0.0e
Cassia obtusifolia (L + St)	0.0d	0.0eg	0.0e
Crotalaria rotusa (L + St)	0.0d	0.0eg	0.0e
Jatropha curcas (L)	0.0d	0.0eg	0.0e
Jatropha gossypiifolia (L)	0.0d	0.0eg	0.0e
Lawsonia inermis (L)	0.0d	0.0eg	0.0e
Phyllanthus amarus (L + St)	0.0d	0.0eg	0.0e
Mean	12.8	12.7	13.0
LSD (5%)	5.537	2.652	3.908
cv%	56.9	25.8	37.1
F pr	< 0.001	< 0.001	< 0.001

In a column, means followed by the same alphabet letter are not significantly different

LSD (5%), Least significant differences of means (5% level); cv, coefficient of variation, F Pr, Fisher probability; L, leaves; St, stems; B, bark

bark) while the other three extracts are significantly different. The GR of *S. hermonthica* seeds conditioned with eight (8) extracts (those from the leaves of *A. indica*, *J. curcas*, *J. gossypiifolia*, *L. inermis*, leafy stems of *C. obtusifolia*, *C. retusa*, *P. amarus*) were nil. The GR average obtained with the *A. nilotica* bark extract is not significantly different from that of the eight extracts which each generated a zero GR (Fig. 1).

Germination stimulation by the plant aqueous extracts

Inside every experiment, significant differences ($P < 0.001$) were also observed among treatments for germination rate after treatment with the plant extracts (Table 3). There are also significant differences between the three runs of the stimulation experiments. Control GR24 stimulated germination more than plant extracts. In test 1, extract from *E. hirta* was statistically identical to control GR 24 in terms of its ability to stimulate germination. In tests 2 and 3, the extract from *E. hirta* is the one that still stimulated the most germination among the 14 extracts but with rates significantly lower than that of the control.

Results of the three runs of the experiments on the stimulation are shown in one figure, despite the fact that there were differences among the repetitions. ANOVA showed significant differences ($P < 0.001$) between the germination percentages caused by the 14 plant extracts and the control on the *S. hermonthica* seeds (Fig. 2). Comparison of means showed that GR24 (positive control) induced the highest *S. hermonthica* seeds germination rate. It is followed in descending order by those obtained with extracts from leafy stems of *E. hirta*, leaves of *M. oleifera E. camaldulensis*, *A. indica* bark and *K. senegalensis*. The average germination rates of the last three extracts are not significantly different. However, those induced by the extracts of *E. hirta* and *M. oleifera* are different and superior to those obtained with the other extracts. As for the extracts from the leafy stems of *C. obtusifolia*, *C. retusa*, from *P. amarus*, from the leaves of *A. indica*, *J. curcas*, *J. gossypiifolia*, *L. inermis* and from the bark of *A. nilotica*, *B. aegyptiaca*, they were statistically identical with a zero rate.

Discussion

The aqueous extracts of the 8 plants which completely inhibited germination, despite the application of the stimulant GR24, would probably contain molecules with allelochemical properties on the germ of the Striga seed. These were *A. indica, J. curcas, J. gossypiifolia, L. inermis, C. obtusifolia, C. retusa, P. amarus* and *B. aegyptiaca*.. The germination inhibition rate of the aqueous extract of *E. camaldulensis* leaves obtained in this study (38.16%) is lower than that recorded by Yonli et al. (2010) with the same extract had already been showed (Yonli et al. 2010). However, the inhibiting of leaf extracts from *A. indica, J. curcas and J. gossypiifolia*, concentrated at 10% reported by this author was not total as is the case in the present study. l. 194: "…family, has also been observed to significantly inhibit the germination…".

The results recorded with the extracts of *C. obtusifolia, C. retusa* and *P. amarus* have particular advantages due to the fact that these plants are wild herbaceous and often weeds of crops that can invade plots. A large-scale application of these results would also make it possible to control these weeds because they would be weeded to use their extracts as bio-herbicides, that would help to valorize them. The inhibitory activity of aqueous and ethanolic extracts from *P. amarus* on the in vitro growth of seven strains of *Mycobacterium ulcerans*, responsible for ulcers, has been reported in Côte d'Ivoire (Coulibaly et al. 2011).

The stimulatory effect of five (5) aqueous plant extracts (*E. hirta, A. indica, K. senegalensis, M. oleifera, E. camaldulensis*) concentrated at 10% revealed in this study, show their potential for contributions to management of *S. hermonthica*. Indeed, the induction

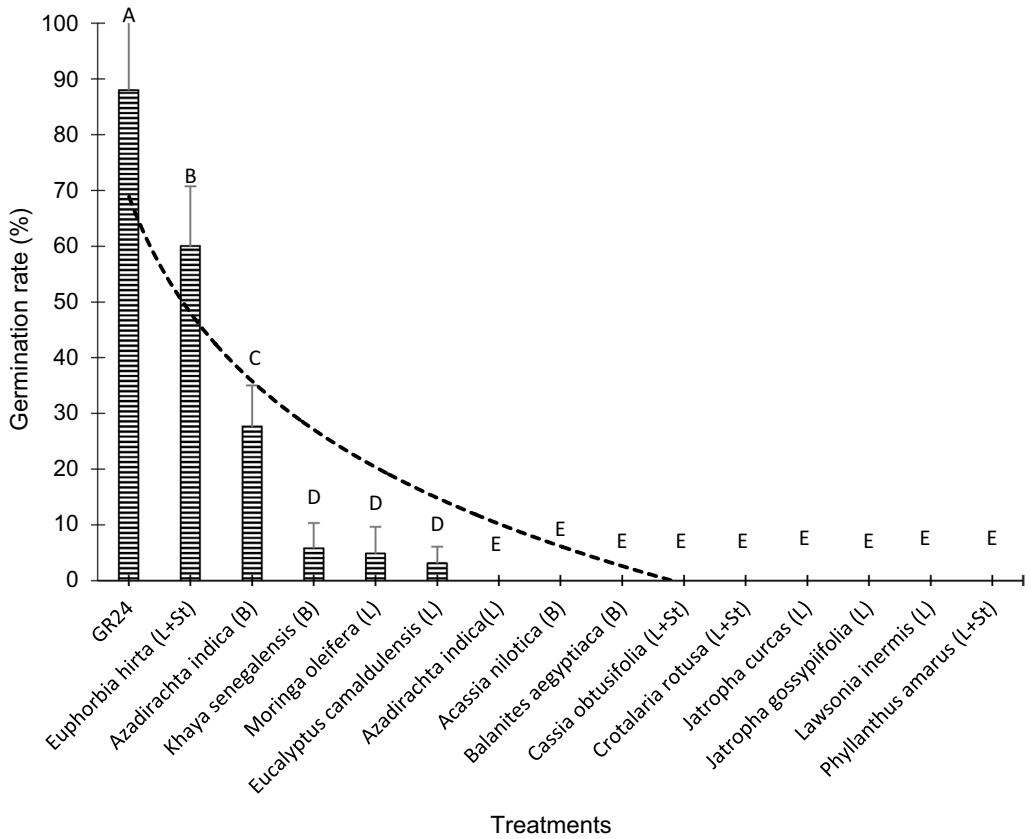

Fig. 2 Stimulation effect of aqueous plant extracts on the *S. hermonthica* seeds germination. L, leaves; St, stems; B, bark. The means followed by the same alphabet letter are not statistically different at the 5% level according to the Newman Keuls Student test

of the germination of *S. hermonthica* seeds whose dormancy had been previously lifted, is of great agronomic interest. Extracts from the leafy stems of *E. hirta* and from the bark of *A. indica* were the most effective in stimulation, resulting in germination rates of 60.0% and 27.6%, respectively. It is speculated that these extracts contain compounds similar to strigolactones and their analogues. A future perspective could be the specification of the optimal concentration for each plant extract, which might be higher or lower than the 10% used in this study. The germination stimulating property would be even more beneficial than that of inhibition for an ecological management. It could be exploited to reduce or even eliminate the stocks of seeds of the parasitic plant and to clean up crop plots by causing suicidal germinations. The practical implementation of these results will consist of using the extracts before sowing the crops. Indeed, applying these plant extracts could cause the suicidal germination of *S. hermonthica* and the crop would develop without being infested. Furthermore, Van Mourik (2007) reported that the germination of *S. hermonthica* seeds is the main factor in the reduction of the seed -bank in the soil.

A previous study has shown that the ethyl acetate and butanol fractions of *E. hirta* exhibited antifungal activity against *P. sorghina*, a parasite of sorghum through inhibition of mycelial growth (Karanga et al. 2017). The use of *E. hirta* would therefore be promising because it will make it possible to control both the fungal pathogen *P. sorghina* and *S. hermonthica* without risk of environmental pollution. The results on the leaf extracts of *A. indica, J. curcas, J. gossypiifolia* perfectly corroborate those of Yonli et al. (2010) where no stimulation was obtained with these extracts…. In addition, the application of the powder of the pods of *P. biglobosa* in peasant fields in the center of Burkina Faso, allowed a reduction in the emergence of *S. hermonthica* and an increase in the contents of macro elements of the soil, with a surplus of maize yield (Kambou et al. 2000). Endogenous plants whose effect of stimulating or inhibiting the germination of *S. hermonthica* seeds has been revealed can thus be evaluated under natural conditions with a

view to transferring green technology. The significant differences between the three repetitions of the experiments shown that botanical products are more variable in their effect than chemical pesticides. It would therefore be necessary to recommend formulations with the extracts for the application of the results in the field conditions.

Conclusion

The results of this study reveal the effectiveness of products derived from some Burkina Faso's local plants for the management of *S. hermonthica*. Aqueous extracts of *E. hirta*, through stimulation of germination and of *A. indica*, *C. obtusifolia*, *C. retusa*, *J. curcas*, *J. gossypiifolia*, through inhibition, are potential bio-herbicides against *S. hermonthica*. Metabolites from these local plants can be used in the control of *S. hermonthica* and improve the yield of the cereal crops host. This experiment carried out in vitro presents a first step in the search for bio-herbicide products to control *S. hermonthica*. Additional tests will determine the optimal concentration of each extract for effective action. This would lead to an application of the results in natural conditions to improve food security.

Abbreviations

GR: Germination Rate; GR24: 3[2,5-Dihydro-3-methyl-2oxo-5-furanyl] oxymethylene-3,3a, 4,8b-tetrahydroindeno-[I,2-b] furan-Z-one; H_2O: Dihydrogen monoxide; UN: United Nations.

Acknowledgements

We thank the director of INERA (Institut de l'Environnement et de Recherches Agricoles) in Burkina Faso for the laboratory pieces of equipment that we benefited from during the assays in the Laboratory of Phytopathology and Weed science in Kamboinsé.

Author contributions

DY, PZ, HT, JIB conceived and designed the project. TCSI applied the project for funding. TCSI and SS performed the laboratory assays. DY and TCSI conducted the data analysis. TCSI prepared the manuscript with substantial input and review from DY, HT, JIB. All authors read and approved the final manuscript.

Funding

We received financial support from the West Africa Agricultural Productivity Program (WAAPP/PPAAO) under Grant: 2016 for this work.

Data availability

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Received: 19 May 2022 Accepted: 5 September 2022
Published online: 15 September 2022

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