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Impact of Plant-Based Pre-Emergence Bio-Herbicide Application on Weed Density, Survival and Growth of *Oryza sativa* L.

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Abstract

Concerns about the negative impacts of chemical weed control for crop production have called for the need for bio-herbicides for sustainable environmental management. This study aimed to assess the pre-emergence bio-herbicide potential of botanicals (*Ageratum conyzoides*, *Bidens pilosa*, *Chromolaena odorata, Euphorbia hirta*, *Aspilia africana* and *Tithonia diversifolia*) on rice at early growth stage. A field of rice was treated with aqueous extracts, ethanolic extracts and air-dried powders of leaves, stems and roots of the botanicals; chemical herbicide (Atrazine); cultural method (hand weeding); and the control. It was a pre-emergence treatment set up in a randomized complete block design with intra- and inter-row spacing of 22.5 × 22.5 cm and replicated 10 times. The botanicals reduced weed density by 60%-80%. All rice plants survived under weed control with bio-herbicides against chemical herbicide with 60% mortality. Aqueous extracts (AE), ethanolic extracts (EE) and plant powders (PP) increased rice height by 55.0%, 54.7% and 57.4%, respectively relative to the control. The number of tillers produced with AE, EE and PP treatments also increased by 67.7%, 72.3% and 65.9%, while leaf area was increased by 24.1%, 9.6% and 14.2%, respectively. The fresh weight of rice was increased from 100 g in the control to 258.9, 266.1 and 166.5 g in AE, EE and PP treatments, respectively. Similarly, the dry weight values were higher under AE (97.45 g), EE (108.18 g) and PP (88.20 g) treatments than the control (32.20 g). Leaf aqueous and ethanolic extracts were most effective in weed suppression (65-85%); at par with chemical herbicide (96%). The bio-herbicides appeared to be highly capable of suppressing weeds and improving rice growth.

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Introduction

Rice (*Oryza sativa* L.) is a cereal, belonging to the family Poaceae (Gramineae) which is a large monocotyledonous family of some 600 genera and around 10,000 species [1]. It is the major food crop grown in Asia, Africa and Latin America. It is the sixth most cultivated food crop after millet, sorghum, cowpea, maize and yam in Nigeria [2]. It is an important staple food crop that serves as the backbone of food security in the country by providing more than 50% of the calories [3]. It is usually planted in the early rainy season (May-July) when rainfall is high; a period associated with heavy weed infestation. The yield potential of rice is quite low in Nigeria due to many environmental stresses and weed infestation in particular. Weed is any plant, native or non-native, that interferes with crops for limited resources in agroecosystems and has the habit of encroaching where it is not wanted [4]. They are plants considered undesirable in a particular situation and plants in the wrong place. They are out-of-place plants, often prolific, persistent and not intentionally propagated. They are naturally strong competitors and those weeds that can best compete always tend to dominate. These interfere with agricultural operations, increase labor costs and reduce crop yields [5].

Weed infestations are recognized as a serious biological constraint to rice production in both lowland and upland ecosystems in Nigeria because they could cause quality and quantity deterioration of rice yields. Scientific records show that losses caused by weeds in rice cultivation areas ranged from 16%-68% and could reach up to 96% depending on the cultivation technique used, either direct seeding methods or transplanting techniques [6]. According to a study [7], the annual rice yield loss due to weed infestation is about 15-21%. The use of agrochemicals over time has caused serious problems to the environment and humans, as well as increasing the development of herbicide-resistant weeds [8]. High volumes of herbicide usage induce numerous changes in plant growth, like inhibition of growth, foliar chlorosis, albinism and necrosis [9]. Moreover, they are more expensive than the biological method of weed control [8-9]. Many herbicides persist in the environment because they are not biodegradable and cause bio-magnifications [4-5, 8]. Also, they can leach into fruits and vegetables consumed by animals and man, resulting in health hazards [6]. There is, therefore, a need to develop biodegradable herbicides.

Much research on bio-herbicides has centered on the application of microorganisms with weed growth-suppressive traits and applied as concentrated culture preparations in an inundated manner similar to herbicides [10-11]. However, the unpredictable response of microorganism inoculum to unfavorable environmental conditions after spraying, with the need to maintain viability for long to achieve infection following application, has been challenging. Additionally, once on the field, the ability for the application of inoculum to be timed to coincide with the most favorable environmental conditions and susceptible growth stage of the weed remains a problem. Besides, after the weed problem has been removed, the natural constraints to ensure that the pathogen population returns to a low level once again, are almost unachievable [11]. This has diverted more attention to bio-herbicides derived from plants containing phytotoxic allelochemicals [11]. This type of bio-herbicide is clearly defined for target weeds with no side effects on beneficial plants, no risk to the health of animals or humans that consume them, lack of pesticide residue build-up in the environment and effectiveness for control of some herbicide-resistant weed species. This shows that herbicides developed from plants are biodegradable; hence they are more environmentally friendly, cheaper and safer for animal and human health than the chemical weed management method [4-5, 8]. The study therefore, aimed to assess the pre-emergence bio-herbicide potential of botanicals (*Ageratum conyzoides*, *Bidens pilosa*, *Chromolaena odorata, Euphorbia hirta*, *Aspilia africana* and *Tithonia diversifolia*) on rice field at the early growth stage.

Materials and Methods

Study area

The study was conducted in the research field of the Plant Science and Biotechnology Department, Adekunle Ajasin University, Akungba-Akoko, Ondo State, Nigeria, with an average annual temperature of 26.7 ^{o}C and annual rainfall of 2378 mm.

Collection of soil used for planting

Composite soil samples were collected from the research field and analyzed for physico-chemical properties. They were shade-dried, and passed through a 2-mm sieve, before analysis for physical and chemical properties using standard methods of the Association of Official Analytical Chemists.

Table 1 Soil physicochemical properties of the experiment site.

Properties	Value
Sand (%)	56.80
Clay (%)	27.20
Silt (%)	16.00
Soil Textural class	Sandy clay loam
Soil pH	6.20
Electrical Conductivity EC (%)	0.45
Organic Matter (%)	1.32
Available N (mg/kg)	0.12
Available P (mg/kg)	24.42
Available K (cmol/kg)	0.19
Available Na (cmol/kg)	0.23
Available Ca (cmol/kg)	6.00
Available Al (cmol/kg)	18.60
Available Mg (cmol/kg)	2.10

Source of materials

Allelopathic botanicals (*Ageratum conyzoides* L., *Bidens pilosa* L., *Chromolaena odorata* L., *Euphorbia hirta* L., *Aspilia africana* Pers. and *Tithonia diversifolia* Herms) were obtained fresh from the wild at Akungba-Akoko, Ondo State, Nigeria (Latitude 7°37 N and Longitude 5°44 E). The plants were authenticated at the herbarium of the Department of Plant Science and Biotechnology, Adekunle Ajasin University, Akungba-Akoko. Grains of upland rain-fed rice (variety Faro 59) were obtained from Premier Seed Nigeria Limited, Zaria, Kaduna State, Nigeria. A chemical herbicide (Atrazine) was also obtained from an agrochemical shop at Akungba-Akoko, Ondo State.

Seed preparation

Damaged seeds were discarded upon visual examination and viability test by floatation. The viable seeds were surface sterilized in a 0.03% formalin solution for 10 minutes and thereafter rinsed thoroughly with distilled water. They were cleaned, air-dried and stored in darkened airtight containers before use.

Aqueous and ethanolic extract preparation

Five hundred g fresh samples (leaves, stems and roots separately) of each of the botanicals were washed, cut into small pieces and pulverized into a fine paste. About 20 g of the paste was soaked in 200 ml distilled water (for aqueous extract) or absolute ethanol (for ethanolic extract) at 1:10 w/v and left for 48 hours at room temperature. Soaked materials were occasionally stirred and the contents were filtered through Whatman No. 1 filter paper (particle retention of 11 μm). The extract was concentrated using a rotary evaporator, and freeze-dried before use.

Plant powders preparation

Five hundred g of each of the plant samples was air-dried, ground into powder and stored in air-tight polyethylene bags before use.

Experimental setup

The land used was tilled manually and prepared into subplots with beds. Seeds were sown at about 2-3 cm deep with inter- and intra-row spacing of 22.5 cm × 22.5 cm. NPK fertilizer (15:15:15) was applied one week after sowing at 100 kg/ha in line with standard agronomical practices for rice. Seedlings were later thinned to two per space and gap filling of the areas where seeds did not germinate was done 10 days after planting. The plots were adequately irrigated until the commencement of rain. Each treatment was replicated 10 times and the experiment was conducted on medium-low land plots with sandy clay loam soil having adequate soil fertility status for rice (Table 1).

Application of extracts

Plant extracts and powders were prepared at 200 g per liter of water, and sprayed on the plots with a hand-held sprayer while the weedy check (plots without weeding) sprayed with distilled water, was the control. Atrazine applied at the recommended rate of 10 g/L was chemical control, and hand weeding was the cultural control method. Weed control was carried out at fifteen days intervals till 50% flowering of rice.

Data collection and analysis

Weed density was determined by the number of weed species per unit area with 1 m × 1 m quadrats. Rice survival was calculated as the percentage of plants that survived against the initial planted. Height was measured with the meter rule from the base of the plant to the tip of the spikes. The numbers of leaves and tillers were determined by manual counting. Leaf area was measured as a product of leaf length from the tip of the leaf to the ligule on the stem, and the width at the middle multiplied by 0.75 [12]. Plant biomass was assessed through fresh and dry weight determinations. Data were subjected to one-way analysis of variance (ANOVA) and means separated using Duncan's Multiple Comparison Test at a 5% level of probability with the Statistical Package for Social Science (SPSS) software version 24.0 [13]. This was used as it offered reliable and fast answers; was effective in data management; did not require a lot of effort; and was easy to use for quantitative data analysis.

Results and Discussion

Weed density

The aqueous extracts (AE), ethanolic extracts (EE) and plant powders (PP) of bio-herbicides reduced total weed density (60%-80%) relative to the control (Fig. 1). The maximum weed control (90%) was achieved under Atrazine chemical, followed by the bio-herbicides. Leaf and stem aqueous extracts as well as ethanolic extracts of *C. odorata* and *T. diversifolia* reduced the total density of weeds by 80% each, while the root aqueous extracts, ethanolic extracts and powders of *A. conyzoides, B. pilosa, E. hirta* and *A. africana* reduced total density of weeds by 60% each, relative to the control. The finding conforms with the earlier one [14] that hand weeding gave a maximum reduction of 78% in total weed density, followed by the application of sorgaab (sorghum water extract) which reduced it by 63%. Similarly, it was found that *Bidens pilosa* was an effective allelopathic species to eradicate 80% of weeds in rice fields [15]. In earlier research, ethyl acetate, n-butanol and aqueous extracts of stems, leaves and roots of *Ligularia sagittal* significantly inhibited seed germination and seedling growth of four *Gramineae* forages: *Festuca ovina, Elymus nutans, Agropyron cristatum* and a Legosuminae forage and *Medicago sativa* [16]. In this study, extracts obtained using ethanol solvent (ethanolic extract) were most effective in weed suppression. Weed growth inhibition by aqueous extracts was also to a similar extent to ethanolic extracts and the degree of inhibition in both increased with increasing extract concentration. This is in agreement with earlier findings that ethyl acetate extract had the most significant inhibitory effect on shoot length and fresh weight of weeds including *F. ovina, E. nutans, A. cristatum* and *M. sativa* compared to other solvents [16]. They confirmed that the extracts inhibited the shoot length of *M. sativa* seedlings to the same extent and the degree of inhibition increased with increasing extract concentration. The reduction was attributed to the inherent ability of the allelochemicals in the botanicals to negatively impact cell division, cell growth and germination of weed seeds. They concluded that *L. sagitta* affected the growth and development of the forage seedlings mainly by inhibiting the growth roots. Furthermore, extracts obtained from leaves and stems of the botanicals were more effective in weed control than the root (Fig. 1). This agrees with the finding that leaves of plants with allelopathy have the greatest allelopathic activity, followed by the stem than roots [16]. This also confirms the significant differences in plant allelopathic effects among the extract sources, concentrations and plant species tested. Comparable to previous findings, plant extracts from the above plant parts (leaves and stems) of the botanicals significantly inhibited the growth of weed species even at low concentrations [16-17]. The allelochemicals might have caused root damage to the weeds as the roots of most seedlings are usually more sensitive to external allelopathy than to other indicators [18-19]. The above-ground parts rely on the roots to absorb nutrients to satisfy plant growth needs, therefore, only when the roots are stressed to a certain extent, water and nutrients cannot be supplied normally, and the other parts of the plant show

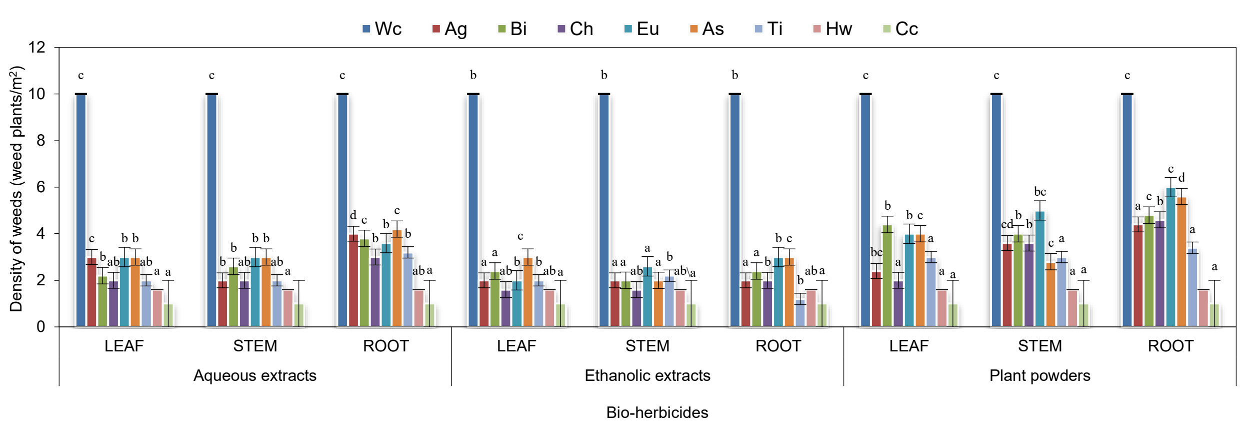

Fig. 1 Density of weeds in rice plant farm using plant extracts and powders of selected allelopathic botanicals as pre-emergence bio-herbicides.

For each parameter, bars with the same letter(s) are not significantly different at $P \geq 0.05$ (DMR test).

Wc = Control, Ag = *Ageratum conyzoides*, Bi = *Bidens pilosa*, Ch = *Chromolaena odorata,* Eu = *Euphorbia hirta,* As = *Aspilia africana,* Ti = *Tithonia diversifolia,* Hw = Hand weeding, Cc = Chemical control

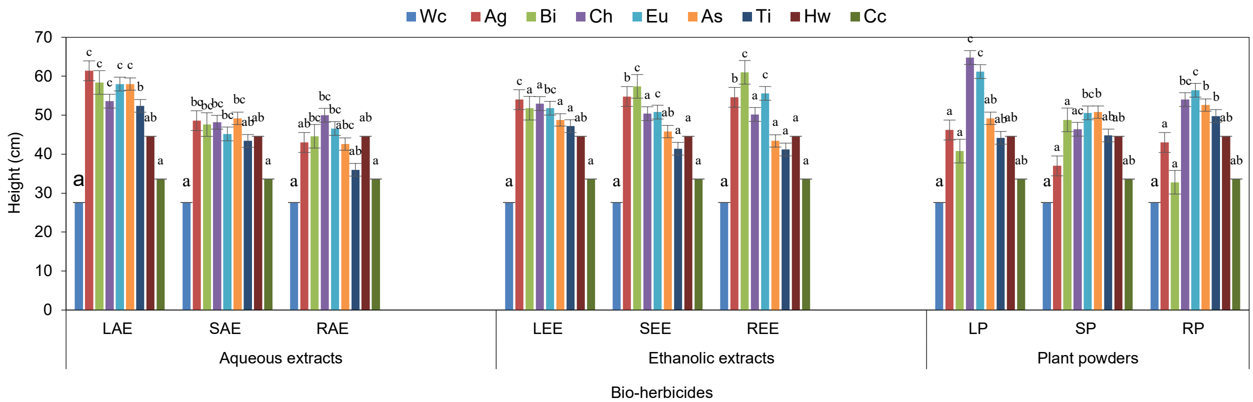

Fig. 2 Height of rice plant at 13 WAT in a farm using plant extracts and powder of selected allelopathic botanicals as pre-emergence bio-herbicides.
For each parameter, bars with the same letter(s) are not significantly different at $P \geq 0.05$ (DMR test).
Wc = Control, Ag = *Ageratum conyzoides*, Bi = *Bidens pilosa*, Ch = *Chromolaena odorata,* Eu = *Euphorbia hirta,* As = *Aspilia africana,* Ti = *Tithonia diversifolia,* Hw = Hand weeding, Cc = Chemical control, LAE = leaf aqueous extract, SAE= stem aqueous extract, RAE = root aqueous extract, LEE = leaf ethanolic extract, SEE = stem ethanolic extract, REE = root ethanolic extract, LP = leaf powder, SP= stem powder, RP = root powder, WAT = weeks after treatment.

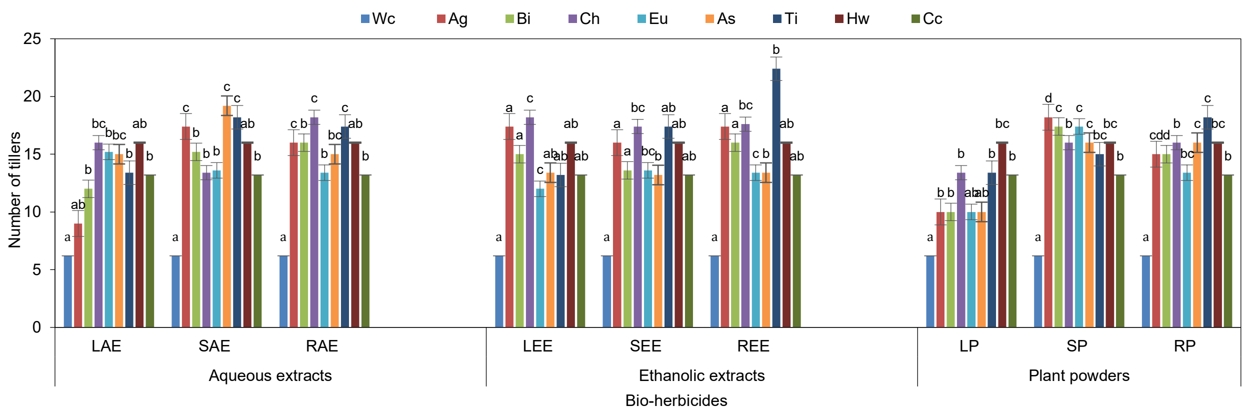

Fig. 3 Number of tillers of rice plant at 13 WAT in a farm using plant extracts and powders of selected allelopathic botanicals as pre-emergence bio-herbicides
For each parameter, bars with the same letter(s) are not significantly different at $P \geq 0.05$ (DMR test).
Wc = Control, Ag = *Ageratum conyzoides*, Bi = *Bidens pilosa*, Ch = *Chromolaena odorata,* Eu = *Euphorbia hirta,* As = *Aspilia africana,* Ti = *Tithonia diversifolia,* Hw = Hand weeding, Cc = Chemical control, LAE = leaf aqueous extract, SAE= stem aqueous extract, RAE = root aqueous extract, LEE = leaf ethanolic extract, SEE = stem ethanolic extract, REE = root ethanolic extract, LP = leaf powder, SP= stem powder, RP = root powder, WAT = weeks after treatment.

symptoms of damage [20-21].

Rice plant survival and growth

The survival percentage of rice plants subjected to bio-herbicides and cultural control treatments was 100%, which was reduced to 40% by chemical treatment as against 80% survival in the control (Table 2). Height was significantly ($P \leq 0.05$) stimulated at 13 weeks after treatment by plant aqueous extract (AE) 61.40 cm, ethanolic extract (EE) 61.00 cm and plant powder (PP) 64.80 cm of all the botanicals as the mean values recorded were higher compared to the control value of 27.60 cm (Fig. 2). Under AE, the leaf aqueous extract (LAE) of *A. conyzoides* led to the highest height for *O. sativa,* whereas root ethanolic extract (REE) of *B. pilosa* gave the highest value under EE. Under PP, however, leaf powder (LP) of *C. odorata* resulted in the maximum height of *O. sativa* while cultural and chemical treatments led to lower heights of 44.60 cm and 33.60 cm respectively. The findings are in line with a previous one [22] which reported that plant height of mungbean was significantly increased by sorgaab (sorghum water extract) treatment. Similarly, it was reported that foliar application of sorgaab extract improved maize growth when used for weed

Table 2 Survival (%) of *Oryza sativa* (rice) in a farm using plant extracts and powder of selected allelopathic botanicals as pre-emergence bio-herbicides

Weed control method	Survival (%)								
	LAE	SAE	RAE	LEE	SEE	REE	LP	SP	RP
Control	80.00 ±2.20[a]	80.00 ±2.20[a]	80.00 ±2.20[a]	80.00 ±2.20[b]	80.00 ±2.20[b]	80.00 ±2.20[b]	80.00 ±2.20[b]	80.00 ±2.20[b]	80.00 ±2.20[b]
Ageratum conyzoides	100.00 ±0.00[a]	100.00 ±0.00[a]	100.00 ±0.00[a]	100.00 ±0.00[a]	100.00 ±0.00[a]	100.00 ±0.00[a]	80.00 ±6.60[b]	100.00 ±0.00[a]	60.00 ±6.60[c]
Bidens pilosa	100.00 ±0.00[a]	100.00 ±0.00[a]	100.00 ±0.00[a]	100.00 ±0.00[a]	100.00 ±0.00[a]	100.00 ±0.00[a]	100.00 ±0.00[a]	80.00 ±6.60[a]	100.00 ±0.00[a]
Chromolaena odorata	100.00 ±0.00[a]	100.00 ±0.00[a]	100.00 ±0.00[a]	100.00 ±0.00[a]	100.00 ±0.00[a]	100.00 ±0.00[a]	100.00 ±0.00[a]	100.00 ±0.00[a]	100.00 ±0.00[a]
Euphorbia hirta	100.00 ±0.00[a]	100.00 ±0.00[a]	100.00 ±0.00[a]	100.00 ±0.00[a]	100.00 ±0.00[a]	80.00 ±6.60[c]	80.00 ±2.20[b]	100.00 ±0.00[c]	100.00 ±0.00[c]
Aspilia africana	100.00 ±0.00[a]	100.00 ±0.00[a]	100.00 ±0.00[a]	100.00 ±0.00[a]	100.00 ±0.00[a]	80.00 ±2.20[b]	80.00 ±2.20[b]	100.00 ±0.00[a]	100.00 ±0.00[a]
Tithonia diversifolia	100.00 ±0.00[a]	100.00 ±0.00[a]	100.00 ±0.00[a]	100.00 ±0.00[a]	100.00 ±0.00[a]	60.00 ±6.60[b]	100.00 ±0.00[a]	80.00 ±2.20[c]	100.00 ±0.00[a]
Hand weeding	100.00 ±0.00[a]	100.00 ±0.00[a]	100.00 ±0.00[a]	100.00 ±0.00[a]	100.00 ±0.00[a]	100.00 ±0.00[a]	100.00 ±0.00[a]	100.00 ±2.20[a]	100.00 ±0.00[a]
Chemical control	40.00 ±6.60[c]	40.00 ±6.60[c]	40.00 ±6.60[c]	40.00 ±6.60[c]	40.00 ±6.60[c]	40.00 ±6.60[c]	40.00 ±6.60[c]	40.00 ±6.60[c]	40.00 ±6.60[c]

For each parameter, values are mean ± SE. Values with the same letter(s) are not significantly different at $P \geq 0.05$ (DMR test). LAE= leaf aqueous extract, SAE = stem aqueous extract, RAE = root aqueous extract, LEE = leaf ethanolic extract, SEE = stem ethanolic extract, REE = root ethanolic extract, LP = leaf powder, SP = stem powder, RP = root powder

control [23]. Likewise, sorghum allelopathy for weed control was deployed in cotton fields with a similar result [24] and attributed to better weed control than other treatments. The number of rice tillers was significantly ($P \leq 0.05$) improved by AE (19.20), EE (22.40) and PP (18.20) of all plant parts of the selected botanicals (Figure 3). The mean values recorded were higher than that of the control (6.20). Under AE treatments, the stem extract of *A. africana* resulted in the highest number of tillers of *O. sativa*. Under EE treatments, however, the root extract of *T. diversifolia* led to the maximum number of tillers while under PP, the stem powder of *A. conyzoides* and root powder of *T. diversifolia* resulted in the highest values. The number of tillers produced at hand weeding (16.00) and chemical herbicides (13.20) were also higher than the control (6.20). This finding concurs with a previous one [25] that reported *T. diversifolia* to increase rice tillers. In agreement also, it was found that allelopathic extracts of sunflower and sorghum combined with lower rates of herbicides, raised the number of tillers in *Triticum*

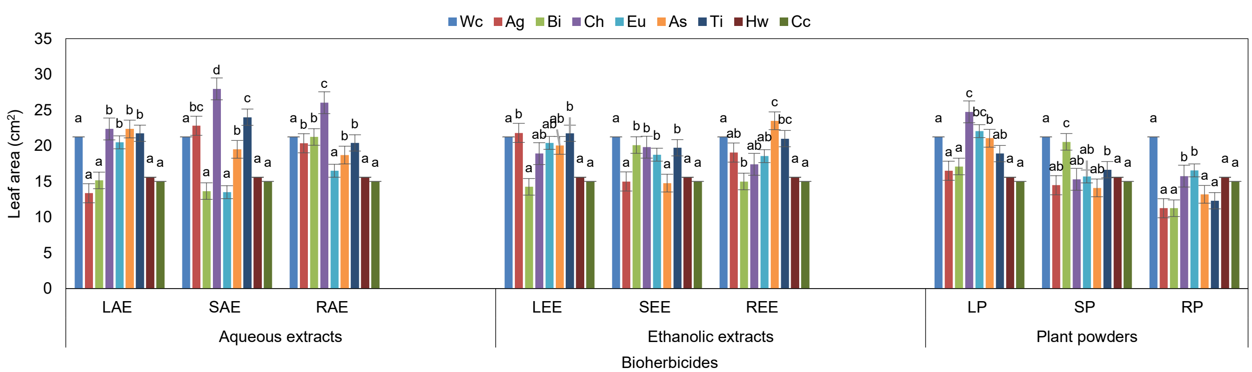

Fig. 4 Leaf area of rice plant on a farm using plant extracts and powders of selected allelopathic botanicals as pre-emergence bio-herbicides

For each parameter, bars with the same letter(s) are not significantly different at $P \geq 0.05$ (DMR test).

Wc = Control, Ag = *Ageratum conyzoides*, Bi = *Bidens pilosa*, Ch = *Chromolaena odorata,* Eu = *Euphorbia hirta,* A s= *Aspilia africana,* Ti = *Tithonia diversifolia,* Hw = Hand weeding, Cc = Chemical control, LAE = leaf aqueous extract, SAE = stem aqueous extract, RAE = root aqueous extract, LEE = leaf ethanolic extract, SEE = stem ethanolic extract, REE = root ethanolic extract, LP = leaf powder, SP = stem powder, RP = root powder

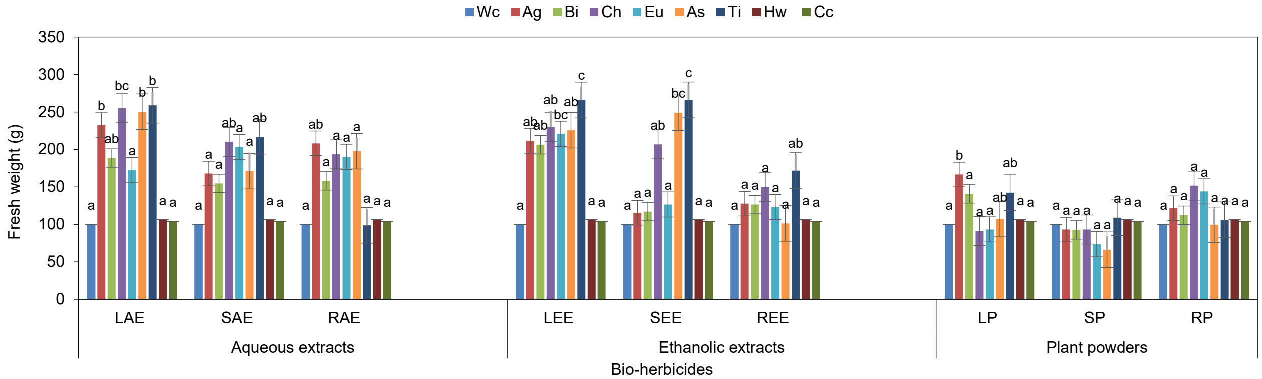

Fig. 5 Fresh weight of vegetative parts of rice plant in a farm using plant extracts and powder of selected allelopathic botanicals as pre-emergence bio-herbicides

For each parameter, bars with the same letter(s) are not significantly different at P≥ 0.05 (DMR test).

Wc = Control, Ag = *Ageratum conyzoides*, Bi = *Bidens pilosa*, Ch = *Chromolaena odorata,* Eu = *Euphorbia hirta,* As = *Aspilia africana,* Ti = *Tithonia diversifolia,* Hw = Hand weeding, Cc = Chemical control, LAE = leaf aqueous extract, SAE = stem aqueous extract, RAE = root aqueous extract, LEE = leaf ethanolic extract, SEE = stem ethanolic extract, REE = root ethanolic extract, LP = leaf powder, SP = stem powder, RP = root powder

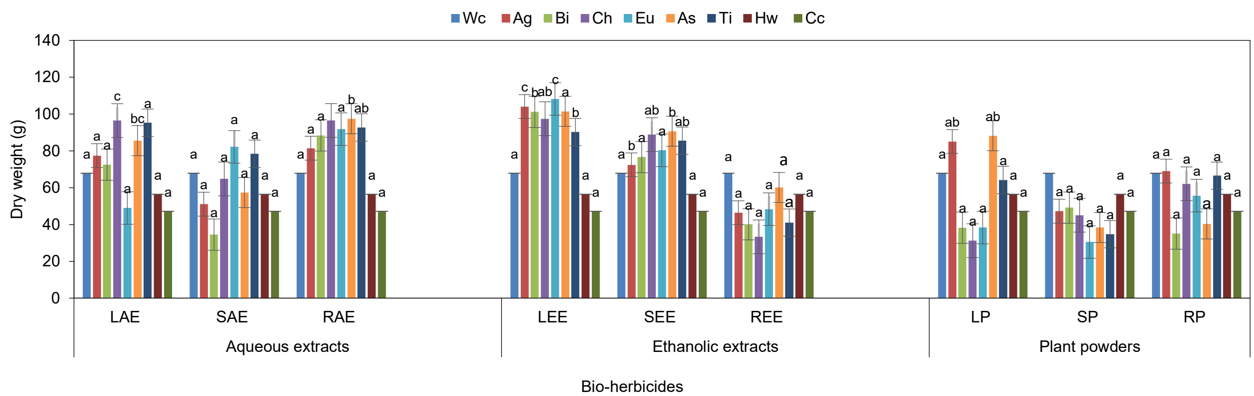

Fig. 6 Dry weight of vegetative parts of rice plant in a farm using plant extracts and powder of selected allelopathic botanicals as pre-emergence bio-herbicides

For each parameter, bars with the same letter(s) are not significantly different at P≥ 0.05 (DMR test).

Wc = Control, Ag = *Ageratum conyzoides*, Bi = *Bidens pilosa*, Ch = *Chromolaena odorata,* Eu = *Euphorbia hirta,* As = *Aspilia africana,* Ti = *Tithonia diversifolia,* Hw = Hand weeding, Cc = Chemical control, LAE = leaf aqueous extract, SAE = stem aqueous extract, RAE = root aqueous extract, LEE = leaf ethanolic extract, SEE = stem ethanolic extract, REE = root ethanolic extract, LP= leaf powder, SP = stem powder, RP = root powder

aestivum [26]. Leaf area was increased by the extracts and powders of the botanicals over that of the control (Fig. 4). Under AE treatments, the stem aqueous extract of *C. odorata* gave the highest value of 27.97 cm^2. Under EE treatments, however, the root of *A. africana* led to the highest value of 23.50 cm^2 while under PP treatments, the leaf powder of *C. odorata* resulted in the highest value of 24.75 cm^2. Meanwhile, hand weeding and chemical treatments gave 15.60 and 15.00 cm^2 respectively. In the same way, a significant positive influence was recorded on the leaf area of mungbean exposed to sorghum water extract treatment followed by that of chemical herbicide [12]. Also, *T. diversifolia* extract increased the leaf area of rice [25] while fresh leaf extract of *Bidens pilosa* reportedly exerted a significant increase on the leaf area of *Amaranthus dubius* [27].

Fresh and dry weights of vegetative parts of *O. sativa*

The fresh and dry weights of vegetative parts of *O. sativa* were significantly increased (P≥0.05) by pre-emergence application of bio-herbicide extracts and powders (Fig. 5 and Fig. 6). The highest values of fresh weights of 258.98, 266.14 and 166.51 g were recorded under AE, EE and PP, respectively against 100 g achieved under the control. The mean values recorded under hand weeding and chemical treatments were 106 g and 104 g, respectively. Under AE treatments, the highest value of fresh weight was achieved under the leaf extract of *T. diversifolia*. However, under EE treatments, the highest value was obtained when stem extract of *T. diversifolia* was used while under PP treatments, the leaf powder of *A. conyzoides* gave the highest value of 166.51 g. The highest mean value of fresh weight of *O. sativa* (266.14 g) was recorded under the stem ethanolic extract of *T. diversifolia,* among all the botanicals. Higher mean values of the dry weight of *O. sativa* were recorded under hand-weeding and chemical treatments (56.40 g and 47.12 g, respectively) than 32.20 g under the control. Under AE treatments, the highest dry weight (97.45 g) was achieved when root extract of *A. Africana* was applied. Under EE treatments, the highest value (108.18 g) was recorded upon application of leaf extract of *E. hirta* while under PP treatments; the leaf powder of *A. africana* gave the highest value of 88.20 g. In an earlier research, aqueous extract of fresh shoots of *T. diversifolia* significantly enhanced shoot and root fresh, and dry weight of *Zea mays* [28]. *T. diversifolia* had been reported too to increase rice biomass production [25]. It was also reported that fresh leaf extract of *Bidens pilosa* significantly increased fresh and dry weights of *Amaranthus dubius* [27]. This was attributed to effective weed suppression by the allelopathic characteristics of the botanicals.

Conclusion

Pre-emergence application of aqueous extracts, ethanolic extracts and dry powders of plant parts of *Ageratum conyzoides*, *Bidens pilosa, Chromolaena odorata, Euphorbia hirta, Aspilia africana* and *Tithonia diversifolia* decreased weed density and improved growth of rice. The botanicals have bio-herbicidal potentials for rice production; there is however, a need for further research on different application rates of the bio-herbicides and crop yield.

Conflict of interest

The authors claim no conflicts of interest.

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