International Journal of Agriculture Innovations and Research
Volume 8, Issue 1, ISSN (Online) 2319-1473
Manuscript Processing Details (dd/mm/yyyy):
Received: 03/07/2019 | Accepted on: 26/07/2019 | Published: 05/08/2019

Weed Control using Rice, Cymbopogon, Mucuna and Maize Stover Allelopathic Water Extracts

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Abstract – **Allelopathy has high potential in weed control. A field study was carried out during 2016 at Ikulwe Research Station in Uganda to determine the efficacy of water extracts from Mucuna pruriens (Mc), Cymbopogon nardus (C), Zea mays (Mz) and Oryza sativa (R) in weed control. 24 kg of stover of each crop were chopped into 2 cm pieces and soaked in 24 litres of tap water for 48 hours to make 100 percent extract solutions. Solutions were filtered and mixed to make 100 percent combined ten extracts as mixtures of three solutions to get RMcC, MzRC, MzRMc, MzMcC, MzDMc, MzMcD, MzRD, RMcD, RCD and MzCD. Water extracts and Butanil herbicide were applied (PRE) to weed free soil together with a weedy check as control. Treatments were laid out in a randomized complete block design with three replications. Data were collected at 42 and 65 days after application of the extracts. RMcC and MzRC water extracts controlled the weeds more than MzRMc and MzMcC water extracts. Extracts with Desmodium had the lowest weed control efficacy. Terpenoids and phenolic secondary metabolites were associated with the weed growth inhibition which was attributed to allelopathy. Rice/ cymbopogon/ desmodium and maize/ cymbopogon/ desmodium extracts exhibited hormesis. Based on this study, it can be suggested that the use of mixed allelopathic plant water extracts is a potential weed control strategy and rice, cymbopogon, maize and mucuna crops have high potential for bio-herbicides development.**

Keywords – **Hormesis, Water Extracts, Weed Biomass, Weed Density.**

I. Introduction

Weeds are a major constraint to direct seeded rice (Rao *et al.*, 2007). Use of chemical herbicides in weed control is a serious threat to sustainable agricultural production worldwide. The development of resistance in some previously susceptible weed species and environmental pollution in soils are some of the major drawbacks associated with chemical herbicide use (Macias *et al.,* 2007). The potential of plant species to control weeds can be exploited in many ways including utilization of water extracts from plant species. Anwar *et al.,* (2003) recorded 4% reduction in weed biomass with 8% increase in seed cotton with reduced herbicide application and Sorgaab extracts. Cheema *et al.,* (2010) reported suppressed weed dry weight by 86-100% when reduced rates of atrazine were used in combination with sorghum and sunflower water extracts at 10 L ha^{-1}. Sorgaab at 12 L ha^{-1} combined with ethoxy sulfuron at 15 g a.i. ha^{-1} and butachlor at 600 g a.i. ha^{-1} reduced weeds by 77 and 68% respectively, which was to the equivalent to the effects of these herbicides. Elahi *et al.,* (2011) reported reduced weed dry matter and increased grain yield by rice, sorghum and sunflower mixed water extracts with reduced herbicide phenoxaprop-p-ethyl and Isoproturon. Miri and Armin (2013) observed that application of 10L ha-^{1} aqueous extracts with reduced doses of wheat herbicides reduced herbicide application in wheat and increased grain yield by 17.8%. Naeem *et al.,* (2018) reported that increasing water extract doses (12-21L ha-^{1}) reduced total weed density and dry biomass production of weeds with 19.5%, increased grain yield of wheat (87.14%) with higher net benefits and marginal rate of returns. Iqbar *et al.,* (2019) noted that application of sorghum + brassica water extract at 1.5 L ha^{-1} most effectively reduced the dry biomass (40%) of *Trianthema* *portulacastrum* and *Cyperus rotundus* and increased seed cotton yield (12%). Besides their other potential values, the allelopathic bio-active compounds in mucuna, cymbopogon, desmodium, rice and maize may be utilised for weed control as liquid derivatives of naturally occurring compounds.The objective of the study was therefore to determine the allelopathic potential of water extracts from rice, cymbopogon, mucuna and maize in controlling weeds.

II. Materials and Methods

2.1 *Experimental Design and Treatments*

A field study was carried out at Ikulwe station during 2016. Water extracts were prepared from mature leaves, stems and roots of 90 days old fresh plant stover of cymbopogon, desmodium, mucuna, rice and maize. Twenty four kilograms of the stover were chopped into 2 cm pieces with a livestock feed chopper and soaked in 24 litres of tap water for 48 hours to make 100% extract solutions. The solutions were filtered and mixed in equal combinations of three water extracts from test plants that exhibited the best weed control in both the screen house (Kaiira *et al.,* 2019a) and mulch experiments (Kaiira *et al.,* 2019b). The ten mixed water extracts were namely rice/ mucuna/ cymbopogon, maize/ rice/ cymbopogon, maize/ mucuna/ cymbopogon, maize/ rice/ desmodium, maize/ desmodium/ mucuna, rice/ mucuna/ desmodium, rice/ cymbopogon/ desmodium, maize/ rice/ mucuna, maize/ cymbopogon/ desmodium and maize/ mucuna/ desmodium. The 100% water extracts were applied to weed free soil at a rate of 2 liters per plot in thirty plots each 20 m^2 laid out in a randomised complete block design with three replications. For comparison, a weedy check control and the recommended rate of Butanil (Butachlor + Propanil) at 1.8 kg a.i. ha^{-1} was applied as a standard synthetic pre-emergence herbicide treatment.

2.2 *Data Collection and Analysis*

Data were recorded at 42 and 65 days after application (DAA) of extracts, on the number of weeds and weed dry biomass per square metre using a 1 x 1 m quadrate. Data collected were subjected to analysis of variance (ANOVA) using Genstat statistical package 13th edition, 2013. Fischer's least significant difference (LSD) test at P = .05 was used to compare the treatment means.

III. Results

3.1 *Weed Density and Biomass under different Allelopathic Water Extracts*

Generally higher weed densities and biomass per unit area were observed at 65 days after application of water extracts (DAA) for all the treatments relative to the observations at 42 DAA (Table 1). Weed density increased (216 & 201 weeds/ m^2) at 42 DAA by 7% & 4% under rice/ cymbopogon/ desmodium and maize/ cymbopogon/ desmodium extracts relative to the control. Weed density under ice/ cymbopogon/ desmodium and maize/ cymbopogon/ desmodium however reduced at 65 DAA by 33 % and 20 % respectively at 42 DAA, contrary to weed densities under other treatments that increased with time. Maize/ rice/ cymbopogon, rice/ mucuna/ cymbopogon, maize/ rice/ mucuna and maize/ mucuna/ cymbopogon extracts did not influence the biomass per weed (0.1 g) at 42 DAA but the biomass increased under all desmodium water extracts to 0.2g.. Desmodium water extracts namely rice/ cymbopogon/ desmodium, maize/ cymbopogon/ desmodium, rice/ mucuna/ desmodium, maize/ rice/ desmodium and maize/ mucuna/ desmodium increased weed biomass per unit area

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(54.3-74.3 g m^{-2}) and per weed (0.3-0.5 g) at 65 DAA. Maize/ rice/ mucuna, maize/ mucuna/ cymbopogon, rice/ mucuna/ cymbopogon and maize/ rice/ cymbopogon water extracts produced lower weed biomass per unit area (0.9-3.2 g m^{-2}) relative to all extracts with desmodium (3.3-38.5 g m^{-2}) at 42 DAA. Rice/ mucuna/ cymbopogon and maize/ rice/ cymbopogon water extracts produced lower weed density (7-17 weeds/m^2) and biomass per unit area (0.9-1.3 g m^{-2}) than maize/ rice/ mucuna, maize/ mucuna/ cymbopogon (16-29 weeds/m^2 & 1.5-1.6 g m^{-2}) water extracts at 42 DAA. Weed density (478-605 weeds m^{-2}) and biomass per unit area (24.3-49.3 gm^{-2}) increased under maize/ rice/ cymbopogon, rice/ mucuna/ cymbopogon, maize/ rice/ mucuna and maize/ mucuna at 65 DAA relative to observations at 42 DAA (7-29 weeds m^{-2} & 0.9-1.6 gm^{-2}). Application of Butanil produced the lowest weed density and biomass per unit area and the control recorded higher weed density at 42DAA,

Table 1. Weed Density and Biomass as Influenced by Water Extracts Under Field Conditions.

	42 DAA			65DAA		
Treatment	**Density (weeds m^{-2})**	**Biomass/area (g m^{-2})**	**Biomass/weed (g)**	**Density (weeds m^{-2})**	**Biomass/area (g m^{-2})**	**Biomass/weed (g)**
Control	201.0c	12.8c	0.2a	232.0g	72.7a	0.4b
Rice/cymbopogon/desmodium water extract	216.0a	29.7b	0.2a	155.0i	74.3a	0.5a
Maize/cymbopogon/desmodium water extract	209.0b	38.5a	0.2a	185.0h	58.5b	0.5a
Rice/mucuna/desmodium water extract	79.0d	11.7d	0.2a	241.0g	60.6b	0.3c
Maize/rice/desmodium water extract	16.0f	3.3e	0.2a	405.0e	54.3c	0.3c
Maize/mucuna/desmodium water extract	28.0e	3.2e	0.2a	291.0f	57.7b	0.1e
Maize/mucuna/cymbopogon water extract	29.0e	1.6f	0.1b	478.0d	37.3d	0.1e
Maize/rice/mucuna bio-extract	16.0f	1.5f	0.1b	605.0a	49.3c	0.1e
Rice/mucuna/cymbopogon water extract	7.0g	1.3g	0.1b	578.0b	29.3e	0.1e
Maize/rice/cymbopogon water extract	17.0f	0.9g	0.1b	521.0c	24.3f	0.1e
Butanil 70 (PRE) herbicide	4.0g	0.6h	0.2a	85.0j	13.0g	0.2d
P-value	<0.001	<0.001	<0. 01	<0.001	<0.001	<0.001
LSD (*P*=.005)	5.76	0.55	0.05	15.56	3.46	0.01
CV (%)	4.0	3.4	3.5	12.4	6.4	2.3

Values with different letters in a column are significantly different at P=.05, DAA = Days after application of water extracts,

IV. Discussion

4.1 *Effects of Water Extracts on Weed Growth and Development*

The observed higher weed densities and biomass per unit area recorded at 65 days after application of the water extracts (DAA) relative to observations at 42 DAA may be attributed to development of the weeds following uptake of nutrients and deposition of assimilates into the weeds. It may also be associated with reduced efficacy of the allelopathic water extracts following the declines in concentrations of the metabolites. The higher weed density under rice/ cymbopogon/ desmodium and maize/ cymbopogon/ desmodium treatments at 42 DAA relative to the control and observations at 56 DAA could be attributed to stimulation at sub-optimal allelochemical doses (hormesis) by metabolites in the stover of the combined mulches. Kaiira *et al.,* (2019c) identified several compounds including 2 terpenoids namely 2, 2'-Diethylbiphenyl and 1-Ethyl-2-(1-phenylethyl)benzene in the stover of both rice and desmodium and an ester named called Hexadecanoic acid was found in the rice stover alone. A phenol called Falcarinol and a terpenoid named Ionene were also identified in the maize stover alone. The metabolites could have by antagonism interacted with compounds profiled in cymbopogon stover namely Citronellyl butyrate ester and the ten terpenoids called Citronellal, β-Citral, cis-Geraniol, trans-Carane, Eugenol, Geraniol acetate, β-Elemen, Caryophyllene, α-Gurjunene, γ-Cadinene, causing the observed reduced weed control. Hormesis is the stimulation of growth at sub-optimal levels of allelochemicals common in auxin herbicides which mimic the growth hormone auxin but which are lethal at higher doses (Allender 1997). Hormesis was also reported by Cedergreen and Olen (2010) when Glyphosate at 10% of the rate for field conditions promoted crop growth. Investigations by Abbas *et al.* (2015) in a related study observed that Glyphosate hormesis at low doses (18-72 g a.i. ha^{-1}) caused maximum growth and yield parameters of chick pea (*Cicer arietinum* L).

The biomass per weed was not influenced by maize/ rice/ cymbopogon, rice/ mucuna/ cymbopogon, maize/ rice/ mucuna and maize/ mucuna/ cymbopogon at 42 DAA probably due to the similar additive influences of 6 compounds namely three terpenoids identified as 1,4- Eicosadiene, Butylated Hydroxytoluene, 3,4- Diethyl-1,1'- biphenyl and three phenols namely 2, 5- di-tert-butyl-Phenol, 3, 7, 11, 15- Tetramethyl- 2- hexadecen- 1-ol, and (9Z)- 9- Icosen-1-ol that were identified as common in maize, mucuna and rice stover by Kaiira *et al*., (2019c). Increased biomass per weed was recorded under rice/ cymbopogon/ desmodium and maize/ cymbopogon/ desmodium water extract. The increase in biomass may be attributed to reduced inhibition on processes that enhance plant growth, resulting from possible antagonism between two terpenoids called 2, 2'-Diethylbiphenyl and 1- Ethyl- 2- (1- phenylethyl) benzene only identified in desmodium and rice and other metabolites in maize and cymbopogon water extracts.

Rice/ cymbopogon/ mucuna and maize/ mucuna/ rice extracts exhibited higher efficacies in controlling weed density and biomass per unit area at 42 DAA but the weed control efficacy significantly reduced when the desmodium water extract was introduced into the mixtures. The reduced weed densities and biomass per unit area observed with rice/ maize/ mucuna extracts may be attributed to increased additive inhibitory effects of similar metabolites in the stover of the crops on weed germination, nutrient uptake, growth and development, manifesting into increased weed control. Kaiira *et al.,* (2019c) identified 2 terpenoids namely Butylated Hydroxytoluene, 3 and 4 - Diethyl -1,1'-biphenyl and 3 phenols called 2, 5-Di-tert-butylphenol, 3, 7, 11, 15-Tetraethyl- 2- hexadecen-1 -ol and (9Z)- 9- Icosen- 1- ol as common metabolites in the stover of rice, maize and mucuna. Reduced weed control with application of desmodium extracts was probably due to antagonism between 2'-Diethylbiphenyl, 1-Ethyl-2-(1-phenylethyl) benzene metabolites identified only in desmodium stover and the five common compounds identified in rice, maize and mucuna stover.

The results are further supported by Kaiira *et al*., (2019a) who observed that increasing the leaf, stem and root (LSR) mixed powder concentrations (15-45 % w/w) of rice, maize, mucuna cymbopogon and desmodium significantly reduced the number of sown *Bidens pilosa*, volunteer weeds and weed weight at 30 DAA of the powders. LSR powders of rice/ maize/ cymbopogon and rice/ mucuna/ cymbopogon most effectively reduced the weed density and biomass. Cymbopogon/ desmodium based mixed powders mixed with rice, maize or mucuna expressed the lowest inhibitory effects on weed seed germination and growth and the observations were associated with allelopathy. Kaiira *et al.,* (2019b) similarly reported that application of mixed mulches of maize, rice mucuna with cymbopogon as rice/ mucuna/ cymbopogon, maize/ mucuna/ cymbopogon, maize/ rice/ cymbopogon produced higher weed density (50-99 weeds m^{-2}) and biomass (136-213 weeds m^{-2}) than the maize/ rice/ mucuna mulches. The effect was attributed to additive or synergistic effects by similar molecules in maize/ rice/ mucuna relative to possible antagonism between molecules in cymbopogon and maize/ rice/ mucuna mulches

Blouin (2004) indicated that herbicides applied in mixtures exhibited synergy compared with single herbicides under low infestation by weeds. Related studies on weed control through allelopathy by foliar sprays of allelopathic plant extracts have been conducted by several researchers. Cheema *et al.,* (2004) and Iqbar and Cheema (2008) indicated that Sorgaab foliar spray controlled weeds relative to hand weeding, chemical herbicides and sorghum mulch. Hegazy and Farrag (2007) found that water, methanol and oil extracts of *Chenopodium ambrosioides* contained flavonoids, alkaloids, terpenoids and volatile oils that were inhibitory to the germination of weeds. Ali *et al.,* (2015) reported significant reductions in both germination and seedling growth of grass weeds at 2.5-10 percent concentration of aqueous leaf extracts of *Pinus eldarica.* The results in the current study are supported by Namkeleja *et al.* (2013) who observed reduced seed germination and growth of *B. dictyoneura* and *C. ternatea* weeds by leaf and seed extracts of *Argemone mexicana*. Inhibition of *Brassica tourney weed* germination and seedling growth due to water extracts applied at a concentration of 10 g L^{-1} has been reported by El-Gawad (2014). It is inferred from the study that maize, rice, cymbopogon and mucuna have the potential to produce bio-herbicides for weed control.

Increases in weed densities and biomasses per unit area at 65 DAA under maize/ rice/ cymbopogon, rice/ mucuna/ cymbopogon, maize/ rice/ mucuna and maize/ mucuna relative to 42 DAA may be attributed to reduced efficacy of the extracts due to declines in concentrations of the bio-compounds within two months of being released into the soil. Barto and Cipollini (2009) reported that the half-life of allelochemicals varies from a few hours to a few months. Kong *et al.* (2008) reported that allelochemical degradation varied with allelochemical concentration, soil type, soil enzymes, soil microbial population and community structure. The lowest weed density and biomass per unit area under Butanil at 42 DAA may be associated with probable higher efficacy of the synthetic Butanil chemical in the control of germination and growth of weeds. The SLR powders and bio-extracts from rice, cymbopogon, maize and mucuna should be further investigated for potential production of triketone bio-herbicides. The bio-herbicides have high potential to control weeds since there are no reports of naturally occurring herbicide resistance to triketone herbicides (Heap (2007) and yet they are reported to have high efficacy (Danijela 2014). It is inferred from the study that allelopathic compounds at lethal doses from rice, mucuna, desmodium, cymbopogon and maize, if appropriately combined, could be utilized to control weeds and the weed control could be attributed to allelopathic effects of the compounds identified by Kaiira et al., (2019c).

V. Conclusion

Mixed water extracts of rice, cymbopogon, maize and mucuna were the most effective in reducing weed density and biomass. This was associated with possible additive and synergistic influences of allelochemicals a-

-nd attributed to secondary metabolites profiled from the stover of the study crops. Desmodium based water extracts expressed the lowest inhibitory effects on weed seed germination and growth due to possible metabolite antagonism. Application of cymbopogon and desmodium liquid extracts increased weed density, biomass and weight per weed at 42 DAA but the density and biomass reduced at 65 DAA. This was attributed to hormesis. Butanil (PRE) herbicide most effectively reduced the weed count and weight per unit area both at 42 DAA and 65 DAA.

Acknowledgements

Support for this research was made possible through a capacity building grant by World Bank under the Agricultural Technologies and Agribusiness Advisory services (ATAAS) project to the Uganda government through the National Agricultural Research Organisation.

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