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Weed Management In Maize (Zea Mays L.) Crop Using Allelopathy Of Sunflower (Helianthus Annuus L.) And Johnson Grass (Sorghum Halepense) Aquatic Extracts

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Abstract

The impact of weeds on growth and yield of miaze has tremendously reduced per hectare yield due to their competition with maize for water, nutrients and placement. Usually weeds in maize are controlled by either manual weeding or by herbicide application, even in some areas the farmers let the weeds to grow freely with this crop. Manual weed control is laborious and time consuming whereas, application of herbicide with higher doses not only develops resistance in weeds but also degrades the environment. Therefore, this study was framed with objectives to determine suitable allelochemical plant and its dose as well as form for weed management and increasing maize yield. A series of field experiments were conducted at Student's farm, Department of Agronomy, Sindh Agriculture University Tandojam for weed management by using aquatic extracts as allelopathy of two plants sunflower and Johnson grass. As illustrated in the analysis of variance, the results for maize traits were found statistically significant ($P<0.05$) under various treatments. The treatments were weedy check, sunflower aquatic extract at 20 L and 40 L ha^{-1}, Johnson grass aquatic extract at 20 L and 40 L ha^{-1}, sunflower aquatic extract at 20 L with herbicide 1 L ha^{-1} and Johnson grass aquatic extract at 20 L with herbicide 1 L ha^{-1}, Johnson grass aquatic extract at 20 L ha^{-1} with herbicide 1 L ha^{-1}, herbicide at 2 L ha^{-1} and interculturing twice. The application of sunflower and Johnson grass aquatic extracts resulted for weed traits that minimum weed density (m^2), weed fresh and dry biomass (g m^2) was recorded with Johnson grass aquatic extract at 20 L ha^{-1} with herbicide 1 L ha^{-1} at 1st irrigation. The maximum stem girth (cm), cob length (cm), kernel weight (g cob^{-1}) and biological yield (kg ha^{-1}) recorded with Johnson grass aquatic extract at 20 L ha^{-1} with herbicide 1 L ha^{-1} (1st irrigation). The treatment, Johnson grass aquatic extract at 40 L ha^{-1} (1st irrigation) produced maximum plant height (cm), kernel rows cob^{-1}, kernel cob^{-1}, kernel yield (kg ha^{-1}) and straw yield (kg ha^{-1}). It is concluded from the study that sunflower and Johnson grass application on weed management and yield enhancement had high allelopathic potential in maize crop. Therefore, aquatic extracts of sunflower and Johnson grass with lower dose of herbicide may be applied to control weeds in maize crop for enhancement of growth and yield parameters to overcome the issues of food security for human beings that is based on low input, high production.

Keywords: Allelopathy, sunflower, Johnson grass, maize, weeds

INTRODUCTION

Allelopathy is an environmental friendly science which has emerged rapidly during the last few decades. It has different applications in sustainable agricultural systems. Allelopathy may be the substitute for attaining weed management (Singh et al., 2003; Farooq et al., 2008 and 2011). Allelopathy deals with the partial or complete inhibition of one species by the action of other species after release of certain chemicals. The "Inhibitory" chemicals are released by the allelopathic plants which are further dispersed into the environment where they affect the development and growth of certaion nearby plant species (Ferguson et al., 2013). Allelochemicals or secondary plant metabolites when translocated to the environment, influence the emergence and growth of the seedlings of neighboring weeds (Ezatollah et al., 2012). Plants show their allelopathic capability through production of allelopathic chemicals as well as uses into the atmosphere by either of the ways such as decomposition, leaching and volatilization (Farooq et al., 2008 and 2011). It is also considered that allelopathy is associated with specific plant competition and may determine the process of the direct contact between them. The plant may show inhibition or slight stimulation to the germination and growth of other neighbouring plants. (Jabeen and Ahmed, 2009; Ankitaand Chabbi, 2012; Ghafarbi et al., 2012). The adoptation of plant allelopathy to address the weed problems in the field has been generally accepted as an effective approach since it is an environment friendly and economical method (Li et al., 2020). Allelopathy is one of the substantial mechanism of plant disruption which is facilitated by the accumulation of phytotoxins produced by the plants to the environment and affect neighbouring plants (Ambika, 2012). Also, Cheema et al., (2012) described the key role of allelochemicals for pest management.

Sunflower is known to be a strong allelopathic plant which has significant compounds with identified allelopathic nature for other plants (Zahir and Abdul, 2014). Sunflower contains allelochemicals which are available in the leaves roots and stems (Bhaskar et al., 2018). Sunflower contains allelopathic compounds that can inhibit the growth of weeds that could be applied for effective weed management (Kandhro et al., 2016). Sunflower is said to be the source of bioactive allelochemicals. Several terpenoids and phenolic acids have been reported in sunflower (Spring et al., 1992, Macias et al., 2002, Anjum and Bajwa, 2008). Allelochemicals found in sunflower have potential to be used as natural herbicides (Anjum et al., 2005). With the application of various extracts of sunflower and other plants for the management of rice weeds, grasses and sedges, the root and shoot length, accumulation of biomass and chlorophyll amount was significantly reduced (Khaliq et al., 2013). Certain water soluble allelochemical compounds are available in sunflower plants, which are responsible to reduce the emergence and growth of other plant species. This strategy could be adopted in weed control programme. Sunflower leaf extract bioassays strongly responded in stimulation and inhibition of seed germination and root length of the tested species of the plants. The antioxidant process of the targeted plants may be affected by allelopathy of sunflower which results permeability of cell membrane and also may responsible for cellular injuries, restructing the germination capability of the targeted plants and resulting the steady affect on seed vigor (Oracz et al., 2007).

Johnson grass is considered as highely allelopathic plant due to presence of several phenolic acids and terpenoids. The occurrence of inhibitor substances in all the organs of Johnson grass studied (Ramona et al., 2015). The allelopathic property of this weed species is witnessed by the action of cyanogenic, glycogenic and phenolic acid found in dealing with the inhibititon of growth and develpment of crop plants (Stef et al., 2013). Studies also determined that fresh and dry biomass of some plants was significantly reduced due to autotoxity of Johnson grass water extract (Yazlik et al., 2016). The reduced herbicides dose in combination with allelopathic plant water extracts can be appleied to control weeds that would result as the less hazardous to the environment (Khan et al., 2012). Johnson grass has a strong allelopathic effect that suppresses competing weeds in proportions that vary according to the species of weeds and the concentration of allelochemical compounds (Sakran et al., 2021). Certain plants such as sorghum, sunflower, and parthenium have phytotoxic effect against some maize weeds. The existence of such water soluble allelochemical substances could affect on the germination percent and growth attributes of weeds (Rashid et al., 2020). Johnson grass has capability to cause the inhibitory effect on different plants through its strong allelopathic capabilities (Huang et al., 2015). The occurrence of cyanogenic, phenolic and glycogenic components in Johnson grass is responsible of the suppression of crop plants. (Stef et al., 2013). The existence of highly effective allelopathic compounds in all Johnson grass plant parts studied (Ramona et al., 2015). Johnson grass allelopathy found to reduce diversity of the native species (Rout et al., 2013). The findings have also been justified in the study carried out by using different concentractions of aqueous extracts obtained from different tissues of Johnson grass (Nouri et al., 2012). Later on more allelopathic inhibititon was reported by other researchers up to 64% in maize (Rout and Chrzanowski, 2009). The application of sorghum water extracts along with other crop extracts offers an environment friendly, economical and effective weed management (Mushtaq et al., 2010). When herbicide applied in combination with water extracts, worked effectively and the results could be helpful to minimize herbicide doses (Cheema et al., 2005; Razzaq et al., 2012). Ejaz et al. (2015) reported that extracts of sorghum, sunflower and congress grass leaves can be applied twice with the interval of 30 and 60 days to control weeds and to enhance wheat yield upto 52% and 53%, respectively. Afridi et al. (2013) revealed that aquatic extract concentrations significantly reduced weed population and even more response was observed with the increased aquatic extract concentrations.

Although it is fact that there are many physical and economical advantages, but herbicide use in field crops have adverse effects on human health and overall environment (Rahman, 2016). Manual weeding is an effective way but time consuming, slow and expensive. In such situation there is need of alternative control measures especially under large scale production. Chemical weed control is of great importance to manage early weed competition (Nurse et al., 2007; Fontem and Chikoye, 2012). Weed management by using allelopathy may practically be applied by either spraying or incorporating aqueous extracts of plants (Farooq et al., 2011). Application of plant extracts in combination with weedicides is more useful for controlling weeds than sole application (Cheema et al., 2012).When sunflower aquatic extract (100%) was applied, wheat production increased upto 7% and weed dry weight reduced upto 51%. The combination of aquatic extracts of leaves of eucalyptus tree, sunflower and sorghum resulted successful weed suppression in comparison their sole application (Haq et al., 2010). The herbicide degrades slowly in natural environment, which lead to its accumulation in the soil and environment (Ustuneret al., 2020). The alternative strategies for weed management are required so that use of synthetic herbicides could be minimized (Farooq et al., 2011). Therefore integrated weed management approach may be adopted for obtaining best results (Fahad et al., 2015). Xiao et al. (2020) explored that soluble and insoluble allelopathic substances in soil provided a deep insight into microflora variation. Microbes may responsible for allelochemicals expulsion in the soil and addition of residues inhibited specific microbial population.

Alsaadawi et al. (2019) concluded that sorghum residues when applied with 50% trifluralin herbicide in cowpea field significantly enhanced seed yield and provided environmental safety by reducing reliance on herbicides. Moreover, allelopathic residues have potential for improving chemical, physical and nutritional status of the soil, and can be recommended for the large scale application. Alsaadawi et al. (2020) reported that the application of herbicides in combination with allelochemicals has great potential in reducing the herbicide quantity in the ecosystem and the chance of development of resistance against herbicides also decreases. The availability of different allelochemical compounds in the decomposing crop residues and water extracts makes the weeds vulnerable to different modes of action and hence prevent the development of herbicide resistance. The studies clearly suggested that plant allelopathic effects through weed extracts may cause less damage to weeds if applied alone, but if commercial herbicides are applied in combination with the extracts, considerable economic benefits can be achieved for the growers and the environment. In view of the above facts and findings, the present research was conducted to reveal the potential of sunflower and Johnson grass aquatic extracts application, interculturing and sole herbicide application for weed control and maximize yield of maize (Zea mays L.).

MATERIALS AND METHODS

The current field experiment was conducted in a three replicated randomized complete block design (RCBD) at Students' experimental farm, Department of Agronomy, Sindh Agriculture University Tandojam, Pakistan. The experiment was comprised of treatments such as weedy check, sunflower aquatic extract at 20 L and 40 L ha^{-1}, Johnson grass aquatic extract at 20 L and 40 L ha^{-1}, sunflower aquatic extract at 20 L with herbicide Primextra Gold 720 SC 1 L ha^{-1} and Johnson grass aquatic extract at 20 L with herbicide Primextra Gold 720 SC 1 L ha^{-1}, Johnson grass aquatic extract at 20 L ha^{-1} with herbicide Primextra Gold 720 SC 1 L ha^{-1}, herbicide Primextra Gold 720 SC at 2 L ha^{-1} and interculturing twice.

Soil status of experimental field

Physical and chemical properties of soil (0-30 cm depth) was tested, and experimental soil state was found as silty clay loam in texture, moderately saline (pH 8.4-8.1), organic matter (OM) was 0.46-0.40%, deficient in nitrogen (0.02-0.01%), low in phosphorus (4.0-2.8 mg kg^{-1}) and potassium (366-274 mg kg^{-1}).

Cultural practices

The land was thoroughly prepared by two dry plowings, after that heavy soaking dose was applied. When soil became in workable condition, it was leveled. Two cross-wise plows were applied with cultivator and planking with Patio to manage fine seedbed. Nitrogen application was done @ 160 kg ha^{-1} in the form of Urea, while phosphorus was supplied @ 60 kg ha^{-1} as DAP which was done early at sowing time as per recommendation by Paksitan Agricultural Research Council (PARC, 2021). Thining was done after the 15 days of emergence. The overall five irrigations were applied. The plant protection measures were carried out by applying integrated pest management method. However, no major pest attack was observed. The crop was harvested when moisture content of the grains was about 20-25% and cob sheath was dried completely.

Preparation of sunflower and Johnson grass aquatic extracts

Sunflower and Johnson grass plants from field were harvested, dried and drenched in water at the ratio of 1:10 w/v for 24 hours. Then the extracts were filtered through muslin cloth and concentrated to 20 times by boiling at 100^{o}C on gas burner to reduce the volume of extract (Hussain et al., 2016). The Johnson grass and sunflower water extract as well as herbicide were sprayed treatment wise by hand sprayer (Cheema et al., 2002; Awan et al., 2009).

Statistical analysis

The data recorded from each plot was subjected to statistical analysis by applying Statistix 8.1 software (Statistix, 2006). Least significant difference (LSD) test was used to compare treatments superiority where it was necessary.

RESULTS

Allelopathic effect of aquatic extract on maize weeds

The results of the study revealed that sunflower and Johnson grass aquatic extracts in different amounts, herbicide treatment, aquatic extracts application in combination with herbicide and interculturing treatments showed highly significant effect on maize weeds (Table-1 and Figure 1&2). The results revealed that minimum weed density (15.06 m^{2}) was recorded with Johnson grass aquatic extract at 20 L ha^{-1} with herbicide 1 L ha^{-1} (1st irrigation) followed by (19.76 m^{2}) with treatment sunflower aquatic extract at 20 L ha^{-1} with herbicide 1.0 L ha^{-1} (1st irrigation), similarly, minimum weed fresh and dry biomass (298 g m^{2}) and (122.63 g m^{2}) was recorded with treatment Johnson grass aquatic extract at 20 L ha^{-1} with herbicide 1.0 L ha^{-1} (1st irrigation) followed by (309 g m^{2}) and (131 gm^{2}) with treatment sunflower aquatic extract at 20 L ha^{-1} with herbicide 1 L ha^{-1} (1stirrigation) respectively. However, maximum weed mortality (69.43 %) was recorded in treatment Johnson grass aquatic extract at 20 L ha^{-1} with herbicide 1 L ha^{-1} (1st irrigation) followed by (64.61%) in treatment sunflower aquatic extract at 20 L ha^{-1} herbicide 1 L ha^{-1} (1stirrigation). The results indicated that maximum weed density (57.46 m^{2}), weed fresh biomass (936 g m^{2}) and weed dry biomass (392 g m^{2}) were recorded from weedy check (no weeding) treatment. Similarly (0.00 %) weed mortality was also determined from treatment weedy check (no weeding).

Table-1. Allelopathic influence of sunflower and Johnson grass aquatic extract and herbicide on weed fresh and dry biomass of maize weeds

Treatments	Weed fresh biomass (g m^2)	Weed dry biomass (g m^2)
Weedy check (no weeding)	936 a	391.80 a
Sunflower aquatic extract at 20 L ha^{-1}	444 bc	183.50 bc
Sunflower aquatic extract at 40 L ha^{-1}	349 de	141.77 def
Johnson grass aquatic extract at 20 L ha^{-1}	410 cd	168 cd
Johnson grass aquatic extract at 40 L ha^{-1}	373 cde	141.33 def
Sunflower aquatic extract at 20 L ha^{-1}+ Herbicide 1.0 L ha^{-1}	309 e	131.13 ef
Johnson grass aquatic extract at 20 L ha^{-1}+ Herbicide1.0 L ha^{-1}	298 e	122.63 f
Herbicide at 2.0 L ha^{-1}	399 cd	164.50 cde
Inter culturing twice	494 b	206.13 b
S.E ±	39.751	15.829
LSD	84.269	33.556

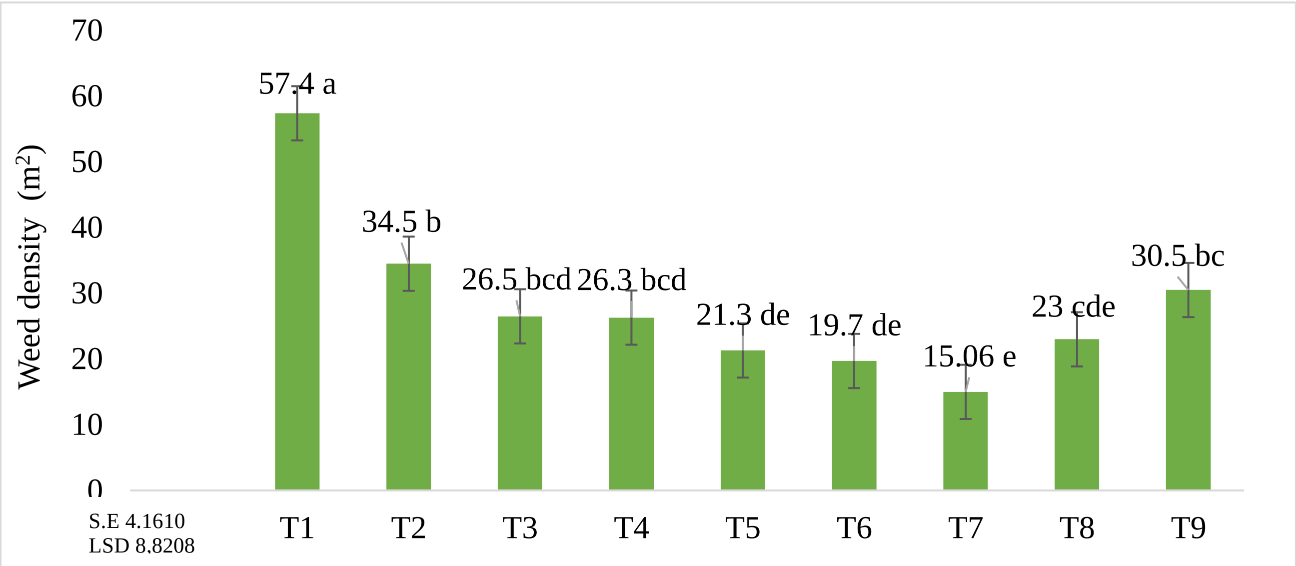

Figure 1.Effect of aquatic extracts and herbicide on weed density (m^2)

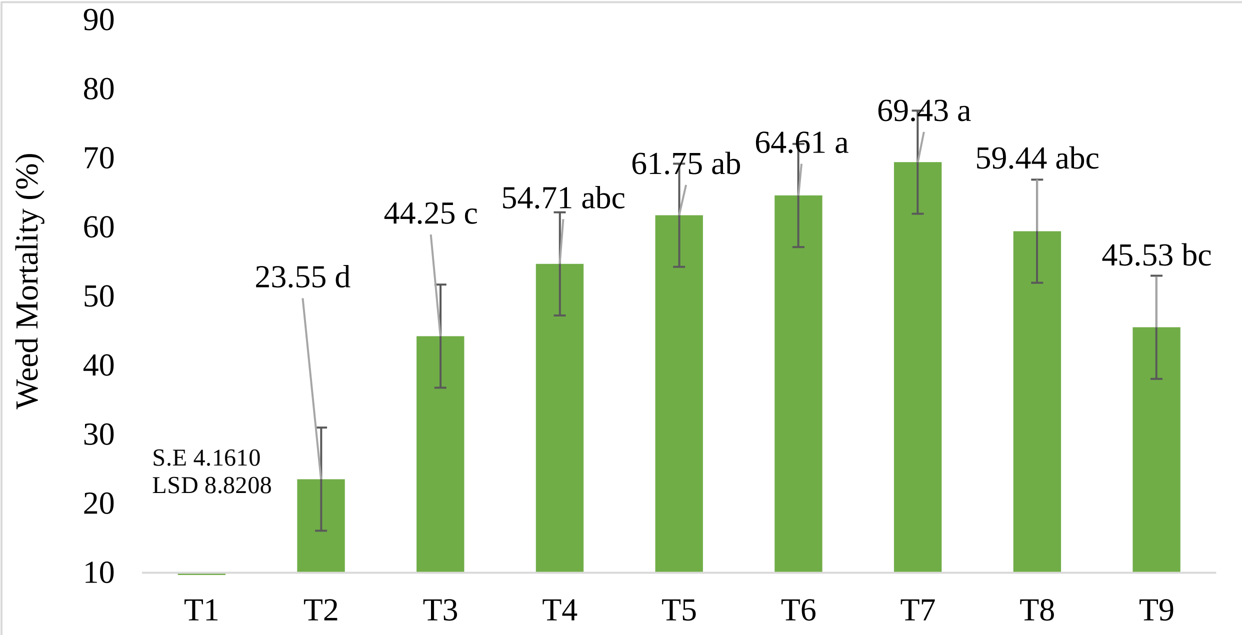

Figure 2. Effect of aquatic extract and herbicide on weed mortality %

T_1 = Weedy check (no weeding)
T_2 = Sunflower aquatic extract at 20 L ha^{-1}
T_3 = Sunflower aquatic extract at 40 L ha^{-1}
T_4 = Johnson grass aquatic extract at 20 L ha^{-1}
T_5 = Johnson grass aquatic extract at 40 L ha^{-1}
T_6 = Sunflower aquatic extract at 20 L ha^{-1} 1.0 L ha^{-1}
T_7 = Johnson grass aquatic extract at 20 L ha^{-1} 1.0 L ha^{-1}
T_8 = Herbicide at 2.0 L ha^{-1}
T_9 = Inter culturing twice

Allelopathic effect on agronomic traits of maize

The sunflower and Johnson grass aquatic extract application, aquatic extract in combination with herbicide and interculturing showed highly significant effect on agronomic traits of maize whereas, non-significant effect was recorded on kernel rows (Table 2). The results indicated that Johnson grass aquatic extract at 40 L ha^{-1} (1^{st} irrigation) produced maximum plant height (224 cm) followed by (211 cm) produced in treatment sunflower aquatic extract at 20 Lha^{-1} with herbicide 1 L ha^{-1} (1^{st} irrigation). However, maximum stem girth (6.51cm) and cob length (24.68 cm) was determined from Johnson grass aquatic extract at 20 L ha^{-1} with herbicide 1 L ha^{-1} (1^{st} irrigation) followed by (6.16 cm) stem girth from treatment sunflower aquatic extract at 20 L ha^{-1} with herbicide 1 L ha^{-1} (1^{st} irrigation) and (23.33 cm) cob length from treatment Johnson grass aquatic extract at 40 L ha^{-1} (1^{st} irrigation). The minimum values of plant height (143.33 cm), stem girth (4.70 cm) and cob length (18.07 cm) were recorded in weedy check (no weeding) treatment. The maximum kernel rows cob^{-1} (15.33) were observed in Johnson grass aquatic extract at 40 L ha^{-1} (1st irrigation) followed by (15.06) in sunflower aquatic extract at 40 L ha^{-1} (1st irrigation). Sunflower aquatic extract at 20 L ha^{-1} with herbicide 1 L ha^{-1} (1st irrigation) resulted maximum (421) kernel cob^{-1} followed by (404) with Johnson grass aquatic extract at 40 L ha^{-1} (1st irrigation).

Table-2. Allelopathic effect of sunflowerand Johnson grass aquatic extract and herbicide on agronomic traits maize

Treatments	Plant height (cm)	Stem girth (cm)	Cob length (cm)	Kernel rows cob^{-1}	Kernel cob^{-1}
Weedy check (no weeding)	143.33 d	4.70 d	18.07 c	13.60	275 e
Sunflower aquatic extract at 20 L ha^{-1}	150.67 cd	5.05 cd	18.69 c	14.83	353 cd
Sunflower aquatic extract at 40 L ha^{-1}	161.33 c	5.19 bc	22.97 ab	15.06	358 bc
Johnson grass aquatic extract at 20 L ha^{-1}	193.33 b	5.41 bc	21.27 abc	14.13	350 cd
Johnson grass aquatic extract at 40 L ha^{-1}	224.00 a	6.03 ab	23.33 ab	15.33	404 a
Sunflower aquatic extract at 20 L ha^{-1}+ Herbicide 1 L ha^{-1}	211 a	6.16 a	19.31 c	14.83	421 a
Johnson grass aquatic extract at 20 L ha^{-1} + Herbicide 1 L ha^{-1}	209.67a	6.51 a	24.68 a	14.36	397 ab
Herbicide at 2 L ha^{-1}	190.67 b	5.48 bc	21.16 bc	14.20	317 d
Inter culturing twice	184.33 b	5.34 cd	18.93 c	14.50	314 de
S.E ±	6.9781	0.3176	1.6462	0.4888	19.051
LSD	14.793	0.6734	3.4897	-	40.387

Allelopathic effect of sunflower and Johnson grass aquatic extract on kernel features and biological yield of maize

The kernel features and biological yield of maize as influenced by allelopathic effect of sunflower, johson grass aquatic extract, herbicide in combination with aquatic extract, herbicide treatment and interculturing are described (Table 3). The study depicted that various levels of sunflower and Johnson grass aquatic extracts application significantly effected kernel features of maize. The Johnson grass aquatic extract at 20 L ha^{-1} with herbicide 20 SC 1 L ha^{-1} (1st irrigation) resulted maximum kernel weight (207 g cob^{-1}) followed by (205 g cob^{-1}) from sunflower aquatic extract at 20 L ha^{-1} with herbicide 1 L ha^{-1} (1st irrigation). The results indicated that application of herbicide at 2 L ha^{-1} (1st irrigation) produced maximum (16551 kg ha^{-1}) biological yield followed by (16204 kg ha^{-1}) with sunflower aquatic extract at 20 L ha^{-1} with herbicide 1 L ha^{-1} (1st irrigation).The maximum kernel yield (5964 kg ha^{-1}), straw yield (6911 kg ha^{-1}) was recorded with Johnson grass aquatic extract at 20 L ha^{-1} with herbicide 1 L ha^{-1} (1st irrigation), followed by kernel yield (5930 kg ha^{-1}), straw yield (6840 kg ha^{-1}) was recorded with sunflower aquatic extract at 20 L ha^{-1} with herbicide 1 L ha^{-1} (1st irrigation) respectively. The lowest biological yield (14005 kg ha^{-1}) was obtained from sunflower aquatic extract at 20 L ha^{-1} (1st irrigation) whereas, lowest kernel yield (3459 kg ha^{-1}) and straw yield (5502 kg ha^{-1}) was obtained with treatment weedy check (no weeding).

Table-3. Allelopathic effect of sunflower and Johnson grass aquatic extract and herbicide on yield features of maize

Treatments	Kernel weight (g cob^{-1})	Biological yield (kg ha^{-1})	Kernel yield (kg ha^{-1})	Straw yield (kg ha^{-1})
Weedy check (no weeding)	127 e	14037 bc	3459 d	5502 b
Sunflower aquatic extract at 20 L ha^{-1}	166 bcd	14005 bc	3830 cd	6187 ab
Sunflower aquaticextract at 40 L ha^{-1}	169 abc	15393 ab	4038 cd	6557 ab
Johnson grass aquatic extract at 20 L ha^{-1}	190 ab	13773 c	3832 cd	6197 ab
Johnson grass aquaticextract at 40 L ha^{-1}	189 ab	15162 abc	4955 b	6714 a
Sunflower aquatic extract at 20 L ha^{-1} + Herbicide 1 L ha^{-1}	205 ab	16204 a	5930 a	6840 a
Johnson grass aquatic extract at 20 L ha^{-1} + Herbicide 1 L ha^{-1}	207 a	15625 a	5964 a	6911 a
Herbicide at 2.0 L ha^{-1}	147 cde	16551 a	5000 b	6654 a
Inter culturing twice	120 e	14120 bc	4272 bc	6174 ab
S.E ±	18.428	701.85	364.61	389.82
LSD	39.067	1487.9	772.94	826.37

DISCUSSION

The allelochemicals could be manipulated and applied for weed management and turned towards an environment friendly and sustainable agricultural production system (Farooq et al., 2020). Dahiya et al. (2017) depicted that allelopathic substances, if available in crop genotypes, may reduce the required practices for weed management, particularly application of herbicide. Allelochemicals act through direct interference with physiological functions of 'receiver' such as seed germination, root growth, shoot growth and stem growth. The application of sunflower and Johnson grass aquatic extract resulted for weed traits that minimum weed density (m^2), weed fresh biomass (g m^2) and dry biomass (g m^2) recorded with Johnson grass aquatic extract at 20 L ha^{-1} with herbicide 1 L ha^{-1} (1st irrigation). Application of plant extracts in combination with weedicides is more useful for controlling weeds than sole application (Cheema et al., 2012). The results are also confirmed with the findings of Yar et al. (2020) who found significant effect of sorghum extracts on jungle rice. The smallest fresh biomass (g seedling^{-1}) was recorded in sunflower residue. The results are also corroborate with Rashid et al. (2020) revealed that plants species like sorghum have phytotoxic effect against some weeds of maize. These allelochemicals could inhibit the germination % and growth parameters of weeds.

However, maximum agronomic traits such as stem girth (cm), cob length (cm) and kernel weight (g cob^{-1}) obtained with Johnson grass aquatic extract at 20 L ha^{-1} with herbicide 1 L ha^{-1} (1^{st} irrigation). Similar results were also reported by Rashid et al. (2020) that the aquatic extract of allelopathic plants when applied in combination, exhibited extra inhibitory effect than their sole application on seed germination and dry biomass of the tested species.The findings of the present research are further confirmed by many past researchers. Hussain et al. (1987) who also found suppression of maize seed germination with higher concentration of Trianthema water extract. Kadioglue et al. (2005) and Tanveer et al. (2008 and 2010) reported the inhibition in the germination rate of different crops with different plant part extracts. Rashid et al. (2020) further suggested that weed seeds sensitivity and maize seeds tolerance against allelopathic plants is a good sign that may be explored for the commercial usage of the selective weed management strategy.

The treatment, Johnson grass aquatic extract at 40 L ha^{-1} (1^{st} irrigation) produced maximum plant height (cm), kernel rows cob^{-1}, kernel cob^{-1}, kernel yield (kg ha^{-1}) and straw yield (kg ha^{-1}). Khan et al. (2012) also reported that Johnson grass has strong allelopathc potential against the dry biomass of maize cultivars. These results corroborated with Huang et al. (2015) reported that Johnson grass is well known for its negative impacts on the growth and development of neighboring plants through its strong competitive abilities and allelopathic potential. Therefore, Rashid et al. (2020) depicted that the aquatic extract of allelopathic plants, exhibited extra inhibitory effect on seed germination, germination time, shoot length and dry biomass of the tested species. These findings are corroborated with statement of Kandhro et al. (2015) that allelopathic effect of sorghum and sunflower posed higher phytotoxic effects on weeds with water extracts. Rashid et al. (2020) indicated extra inhibitory influence in combined extracts could be due to action of various allelochemicals present in the plant species. Keeping in view the combined application of weed management, Iqbal et al. (2020) concluded that sorghum and sunflower water extract with herbicide may also be applied for effective weed management and increase in yield, which in turn reduce the herbicide application by 67%. Consequently, reduced herbicide dosage is very beneficial for environmental protection, human health risks reduction and decreasing the herbicide tolerant weed biotypes.

Conclusion

Johnson grass aquatic extract in combination with lower dose of herbicide substantially reduced maize weeds and produced maximum stem girth, cob length, kernel weight and biological yield. Best results were obtained with Johnson grass aquatic extract at 20 L ha^{-1} with herbicide 1 L ha^{-1}. Sunflower and Johnson grass application on weed management and yield enhancement had high allelopathic potential in maize crop. Therefore, aquatic extracts may be applied to control weeds in maize crop for enhancement of growth and yield parameters to overcome the issues of food security for human beings that is based on low input, high production and environment friendly.

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