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Allelopathic Influence of Sorghum Aqueous Extract on Growth, Physiology and Photosynthetic Activity of Maize (*Zea mays* L.) Seedling

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The allelopathic potential of sorghum (*Sorghum bicolor* L. Moench) was evaluated on maize (*Zea mays* L.) seedlings as allelopathic influence may be inhibitory or promotive, depending upon concentration and dose. Seeds of hybrid maize (DK-919) were sown in pots containing acid-washed sand. The pots were moistened exogenously with different concentrations of sorghum leachate, viz. 100%, 50%, 25%, 10%, 5% and 3%, with and without adjuvant (Emulan @ 5%) after 7 d of seedling emergence. The seedlings were harvested 30 d after sowing. Based on the results, application of sorghum allelopathic extract (SWE) at the lowest doses (5% and 3%) without adjuvant was the most beneficial for improvement of maize seedling growth. Addition of adjuvant in sorghum allelopathic extract showed inhibitory influence on the seedling growth of maize. Maximum increase in chlorophyll, carotenoids, proteins and sugar content was observed at lower (5% and 3%) sorghum water extract concentrations. The activities of catalase, superoxide dismutase, and peroxidase were decreased at higher concentrations of sorghum allelopathic extract. Application of sorghum allelopathic extract at lower concentrations (5% and 3%) offers a pragmatic and eco-friendly option to improve the growth of maize crop.

Key Words: sorghum allelopathy, maize growth, photosynthesis, enzymatic activities

Abbreviations: CAT – catalase, CRD – completely randomized block design, DAS – days after sowing, EDTA – ethylenediaminetetraacetic acid, IAA – indoleacetic acid, MDA – malondialdehyde, NBT – nitroblue tetrazolium, NEDD – N-1-naphthyl ethylene diamine dihydrochloride, NR – nitrate reductase, POX – peroxidase, SOD – superoxide dismutase, SWE – sorghum water extract

INTRODUCTION

Maize (*Zea mays* L.) is the third most important cereal after wheat and rice in Pakistan (Farooq 2013). It is also known as the “Queen of cereals” due to its specific nutritional value (Shah et al. 2013). Maize is gaining importance as a precious industrial crop as its grain contains 72% carbohydrates, 8.8% fiber, 10% protein, 4–6% oil and 3% sugar (Tajamul et al. 2016). In Pakistan, it is mostly cultivated for grain, on an area of 1.085 million ha, with an annual production of 4.631 million thousand tons. Maize is grown in almost all the provinces of Pakistan where Punjab and Khyber Pakhtunkhwa (KPK) contribute 68% and 57% of the total maize grain production, respectively (Government of Pakistan 2013–14).

Various endogenous and external factors influence the growth and productivity of maize crop. Abiotic stresses such as drought, water logging, extreme temperatures, salinity, phototoxic compounds and insufficient utilization of mineral nutrients decrease the yield of maize by as much as 50% (Bray et al. 2000; Jamal et al. 2006; Olgun et al. 2008; Fageria et al. 2010). Synthetic crop growth promoters (e.g., fertilizers) are used to enhance the growth and productivity of crops. However, continuous and unwise use of these artificial substances is injurious to humans, animals, and the environment resulting in negative impacts on the entire ecosystem

Table 1. Effect of different sorgaab concentrations on maize seedling growth.

Treatment	**Shoot Length (cm)**		Root Length (cm)		Shoot Fresh Weight (mg)		Root Fresh Weight (mg)		Shoot Dry Weight (mg)		Root Dry Weight (mg)	
	WoA	**WA**	**WoA**	**WA**	**WoA**	**WA**	**WoA**	**WA**	**WoA**	**WA**	**WoA**	**WA**
Control	30.07 d-g	24.94 l	22.53 f	24.96 e	1.01 d-f	0.96f g	1.05 ef	1.03 ef	0.10 g	0.09 h	0.12 d	0.10 hi
SWE 100%	28.35 f-h	29.29 e-h	19.11 g	23.96 ef	1.00 ef	0.95 g	0.99 f	0.73 g	0.08 l	0.07 j	0.11 ef	0.10 l
SWE 50%	31.22 c-f	28.08 gh	24.04 ef	28.4 d	1.07 c	1.00 e-g	1.01 ef	1.03 ef	0.10 g	0.10 g	0.12 cd	0.10 gh
SWE 25%	31.25 c-f	26.16 hi	28.16 d	29.04 cd	1.14 b	1.02 c-e	1.08 e	1.01 f	0.11 ef	0.10 fg	0.12 c	0.11 fg
SWE 10%	33.23 bc	29.91 d-g	27.81 d	30.18 c	1.14 B	1.04 c-e	1.26 d	1.32 b-d	0.13 c	0.11 e	0.13 b	0.11 e
SWE 5%	35.17 b	32.67 b-d	38.26 b	30.16 c	1.33 a	1.05 c-e	1.35 b	1.28 cd	0.14 b	0.11 e	0.14 a	0.12 cd
SWE 3%	39.2 a	32.3 b-e	40.71 a	30.4 c	1.36 a	1.06 cd	1.44 a	1.34 bc	0.14 a	0.12 d	0.15 a	0.12 c
LSD ($p≤0.05$)	**3.13**		**1.52**		**0.0537**		**0.068**		**0.0051**		**0.0046**	

SWE – sorghum water extract, WoA – without adjuvant, WA – with adjuvant

(Judith et al. 2001). This situation calls for the adoption of safe, efficient and eco-friendly substances for the promotion of crop growth.

Allelopathy offers an eco-friendly alternative to the use of synthetic crop growth promoters. The potential of various allelopathic crops as an alternative growth and yield improvement tool in different crops has been widely exploited (Cheema et al. 2012). The phenomenon of allelopathy can be used in two ways in crop protection. At lower concentrations, the allelochemicals show the crop growth-enhancing behavior and vice-versa (Cheema et al. 2012). The allelochemicals are released from almost all the parts of plants such as the leaves, roots, stems, and fruits through volatilization, root exudation, leaching and residue decomposition (Bertin et al. 2003; Higashinakasu et al. 2004).

Sorghum (*Sorghum bicolor* L. Moench) is an important allelopathic crop, and its potential has been widely exploited in crop production (Alsaadawi and Dayan 2009). The allelopathic water extract of sorghum contains many allelochemicals such as phenolics, coumarins, chlorogenic acid, caffeic acid and ferulic acid, which affect the germination, growth and development of the target plants depending upon the concentration. Studies have reported that application of sorghum allelopathic water extract at a low concentration promotes growth (Maqbool et al. 2012) but inhibits growth at a higher concentration (Li et al. 2010). Application of sorghum water extract improves membrane stability, water relation, and grain yield at low concentrations (5% and 10%) (Kamran et al. 2016). Crop promotion due to application of sorghum water extract under sub-optimal conditions might be attributed to delayed leaf senescence, and the scavenging of relative oxygen species (Cheema et al. 2012).

Although the impact of exogenous application of sorghum water extract on crop growth and yield has been reported in several crops, no study has been reported to check the influence of sorghum water extract on maize growth. This study was therefore conducted to investigate the influence of different concentrations of sorghum water extract on the performance of maize.

MATERIALS AND METHODS

Preparation of Plant Water Extract

Mature sorghum plants were harvested from the research area of the Department of Agronomy, University of Agriculture, Faisalabad (24° 47 and 50° 47′N latitude; 81° 91′ and 82° 21′E longitude; 78 m above sea level) for the preparation of sorghum allelopathic water extract. After drying the sorghum plants under the shade, they were chaffed into 2-cm pieces with the use of an electric fodder cutter. The chaffed material was soaked in tap water for 24 h at a ratio of 1:10 (w/v). The filtrate was obtained with the use of a sieve and was considered as 100% stock of fresh sorghum allelopathic water extract. This water extract was further diluted as per treatment, with and without addition of an adjuvant (Emulan) (Cheema and Khaliq 2000; Kamran et al. 2016).

Experimental Details

The experiment which used completely randomized block design (CRD) with three replications was conducted in the Allelopathy Laboratory, Department of Agronomy, University of Agriculture, Faisalabad, Pakistan. Ten seeds of hybrid maize (DK-919) were sown

Table 2. Effect of different sorgaab concentrations on maize seedling growth.

Treatment	Assimilation Rate (μmol CO_2 m^{-2} s^{-1})		Stomatal Conductance, gs (mmol H_2O m^{-2} s^{-1})		Evapotranspiration (mmol H_2O m^{-2} s^{-1})		Chlorophyll a		Chlorophyll b		Chlorophyll a+b	
	WoA	WA	WoA	WA	WoA	WA	WoA	WA	WoA	WA	WoA	WA
Control	12.93 d	10.97 d	173.33 d-f	146.67 f-h	4.43 e-g	3.81 fg	1.93 f	1.89 f	0.63 ef	0.53 f	1.17 fg	1.05 g-l
SWE 100%	10.63 d	10.93 d	131.67 gh	127.67 h	4.08 fg	3.6 g	1.06 g	1.02 g	0.82 ef	0.89 e	1.01 hi	0.8 j
SWE 50%	16.37 bc	15.37 c	199. a-d	163.67 e-g	5.12 c-e	4.68 d-f	2.07 e	2.04 e	2.27 bc	1.32 d	1.33 e	1.08 g-l
SWE 25%	16.13 bc	15.47 c	209.33 a-c	163 e-g	5.49 b-d	5.18 c-e	2.19 d	2.1 e	2.37 b	1.32 d	1.64 d	0.93 lj
SWE 10%	17.63 bc	15.8 c	219.67 a-c	188.33 c-e	5.81 bc	5.45 b-d	2.36 c	2.09 e	1.96 c	1.31 d	1.81 c	1.14 f-h
SWE 5%	18.2 ab	16.13 bc	223 ab	172.33 d-f	6.17 ab	5.49 b-d	2.44 b	2.23 d	2.39 ab	1.45 d	2.3 b	1.25 ef
SWE 3%	19.99 a	17.62 bc	226.65 a	192.65 b-e	6.74 a	5.82 bc	2.68 a	2.33 c	0.63 ef	0.53 f	2.47 a	1.83 c
LSD ($p \leq 0.05$)	2.32		32.15		0.88		0.079		0.34		0.415	

SWE – sorghum water extract, WoA – without adjuvant, WA – with adjuvant

in each plastic pot (9 cm × 10 cm) filled with 350 g of sand. After full germination, thinning was done to maintain six plants in each pot. Sorghum water extract, with and without an adjuvant (Emulan), was exogenously applied at various concentrations, viz. 100%, 50%, 25%, 10%, 5% and 3%, after 7 d of seedling emergence. The pots were irrigated with 100 mL of distilled water per pot as and when required to avoid water stress for the duration of the experiment. The seedlings were carefully harvested 30 d after sowing (DAS), and the data were recorded.

Seedling Growth

A measuring tape was used to determine seedling shoot length and root length in centimeter (cm), later expressed in millimeter (mm). The fresh and dry weights of seedlings were calculated by using an electric balance.

Determination of Pigment and Protein Content

Photosynthetic pigments (chlorophyll *a, b*) and total chlorophyll were determined based on the procedure used by Arnon (1949). Fresh leaves of maize were cut into small pieces (0.5 cm) and then kept overnight in 80% acetone solution at -10 °C. Supernatant absorbance after extract centrifugation (14000 × g for 5 min) was recorded at various wavelengths (663, 645 and 470 nm) by using a spectrophotometer. Photosynthetic pigments (chlorophyll *a* and *b* content) were determined with the help of formulae described by Lichtenthaler and Wellburn (1983).

Sugar Content

The sugar content was recorded by adopting the procedure of Hedge and Hofreiter (1962). The plant samples (0.25 g) were homogenized in 2.5% ethanol (95%), and then were centrifuged. Sugar content was estimated in the supernatant (1 mL) after mixing with 4 mL reagent (anthrone). The sample was subsequently heated for 8 min on boiling bath. The absorbance was noted at 620 nm after cooling by preparing the standard curve from glucose.

Lipid Peroxidation

Leaf samples (200 mg) were homogenized by using 0.1% (w/v) trichloroacetic acid (5 mL), and afterward centrifuged for 10 min. The supernatant obtained after centrifugation was separated in Eppendorf tubes. The supernatant (1 mL) was mixed with thiobarbituric acid (4 mL of 0.5%) and trichloroacetic acid (20%); incubation (95 °C) of the mixture was done for half an hour. Centrifugation (10000 g for 10 min) was done after rapid cooling. The supernatant absorbance was estimated (532 nm), and at 600 nm, correction was made for non-specific absorbance. Level of malondialdehyde (MDA) was considered as an indicator of lipid peroxidation (nmol g-1 fresh weight). MDA content was calculated by means of extermination coefficient of 155 mM cm^{-1} (Heath and Packer 1968).

Nitrate Reductase (NR)

NR activity was determined based on the method of Jaworski (1971). Fresh leaves (0.25 g) were incubated in 4.5 mL of medium containing 100 mM phosphate buffer of pH 7.5, KNO_3 (3%) and propanol (5%). About 0.4 mL aliquot was treated with 0.3 mL of 3% sulphanilamide in 3 N HCL and 0.3 mL of 0.02% N-1-naphthyl ethylene diamine dihydrochloride (NEDD). The absorbance was estimated at 540 nm. NR activity was determined by typical arc arranged from $NaNO_2$ and expressed as μ mol NO2 g^{-1} FWh^{-1}.

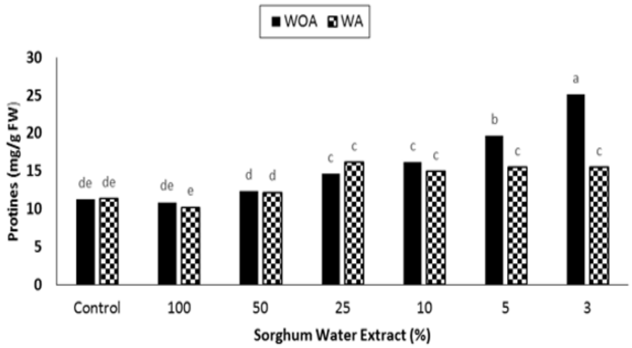

Fig. 1. Effect of various concentrations of sorghum water extract and adjuvant (Emulan) on protein content (mg/g FW) of maize.

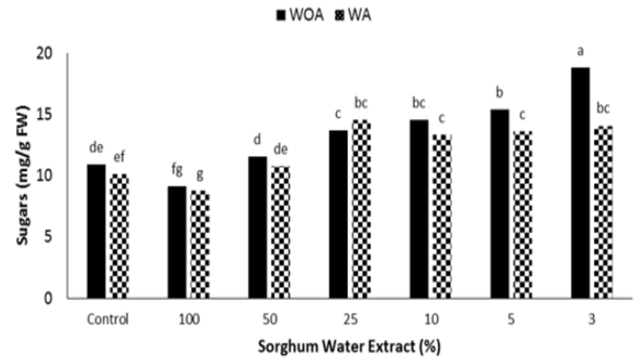

Fig. 2. Effect of various concentrations of sorghum water extract and adjuvant (Emulan) on sugar content (mg/g FW) of maize.

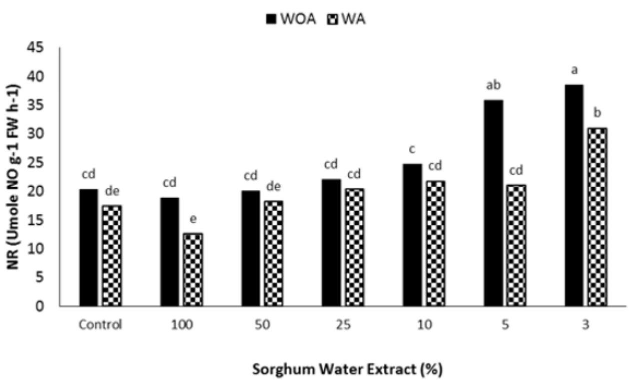

Fig. 3. Effect of various concentrations of sorghum water extract and adjuvant (Emulan) on nitrogen reductase activity (Umole NO g^{-1} FW h^{-1}) of maize.

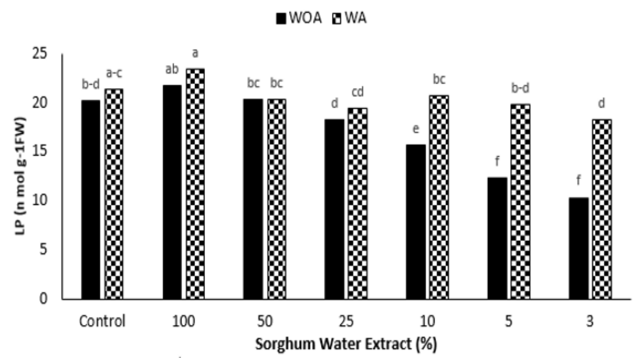

Fig. 4. Effect of various concentrations of sorghum water extract and adjuvant (Emulan) on lipid peroxidation (mg/g FW) of maize.

Antioxidant Enzyme Assay

Leaves of test plants (500 mg) were homogenized in sodium phosphate (10 mL of 0.1 M) buffer (pH = 7.0) for enzyme extract preparation. Filtration was subsequently done for this homogenized extract. During centrifugation (15000 g for 30 min), the temperature was kept constant (40 °C). The collected supernatant was analyzed for superoxide dismutase (SOD), catalase (CAT) and peroxidase (POX). SOD activity was estimated by photochemical assay of nitroblue tetrazolium (NBT) (Beyer and Fridovich 1987). The homogenized mixture (4 mL) contained nitroblue tetrazolium (63 μM), sodium carbonate (0.5 M), ethylenediamine tetra acetic acid (EDTA) (0.1 mM), methionine (13 mM), riboflavin (13 μM) and lucid supernatant (0.5 mL). The mixture was put into test tubes, and kept in fluorescent lamps for half an hour; the absorbance was noted at 560 nm. The procedure of Cakmak and Marschner (1992) was followed for determination of catalase (CAT) action. CAT activity was noted by estimating the rate of fading of H2O2 for 1 min at 240 nm and predicted by means of a disappearance coefficient of 39.4 $mM^{-1}cm^{-1}$ as enzyme unit/g fresh weight. Peroxidase (POX) activity at 430 nm was determined by using the spectrophotometer. The reaction mixture to measure POX activity consisted of enzyme extract (2 mL), sodium phosphate buffer (2 mL), 0.1-N pyrogallol (1 mL) and 0.02% H_2O_2 (0.2 mL).

Statistical Analysis

All the data were analyzed by using "MSTAT-C" statistical package. The means were separated by using the least significant difference (LSD) test (Steel et al. 1997).

RESULTS

Seedling Growth

Application of sorghum water extracts (SWE) significantly affected the shoot length, root length, and fresh/dry weights of maize seedlings (Table 1). SWE with and without adjuvant (Emulan) at higher concentrations (25–100%) inhibited the seedling growth of maize; while at

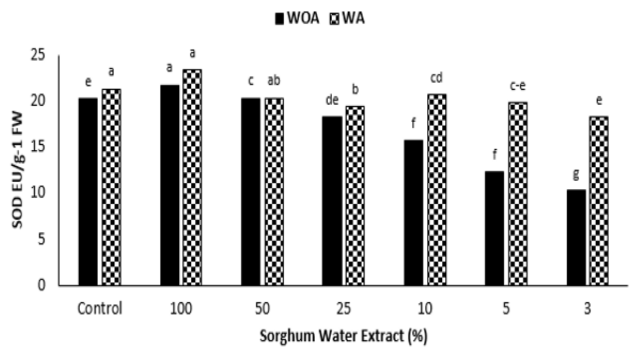

Fig. 5. Effect of various concentrations of sorghum water extract and adjuvant (Emulan) on superoxide dismutase activity (U/g-1 FW) of maize.

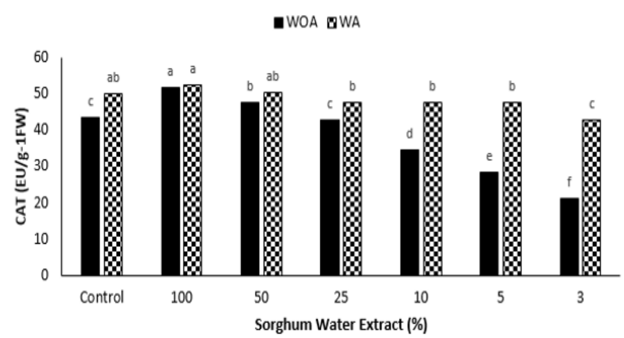

Fig. 6. Effect of various concentrations of sorghum water extract and adjuvant (Emulan) on catalase activity (U/g-1 FW) of maize.

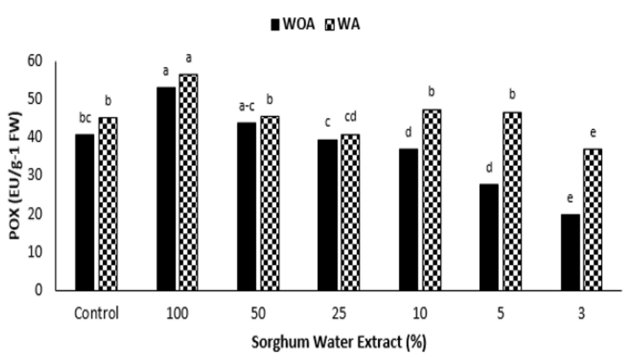

Fig. 7. Effect of various concentrations of sorghum water extract and adjuvant (Emulan) on peroxidase activity (U/g^{-1}).

lower concentrations (3%, 5% and 10%), growth promotion was observed compared with the control. Mostly, the use of SWE with adjuvant was not beneficial and it decreased the growth, fresh and dry weights of maize seedlings even at low concentration. Maximum growth promotion in maize seedlings was recorded at 3% SWE without adjuvant, followed by 5% SWE without adjuvant. SWE at 5% without adjuvant also performed better and was statistically at par with 3% SWE without adjuvant. The minimum seedling growth was observed in treatments applied with 100% SWE with adjuvant, followed by SWE treatments without adjuvant at 100%. These results indicated that the SWE treatments without adjuvant promoted seedling growth and addition of adjuvant (Emulan) was not effective in growth promotion even at lower concentrations compared with the other treatments.

Photosynthetic Traits

The photosynthetic pigments, viz: chlorophyll a, chlorophyll b, total chlorophyll and carotenoids were influenced by different concentrations of sorgaab (sorghum water extract) with and without adjuvant. Results revealed a maximum increase in chlorophyll a, b, total chlorophyll and carotenoid content (0.38, 2.8, and 1.11 times, respectively) at lower SWE concentration (3%) without adjuvant compared with the control (Table 2). Application of SWE at high concentration (100%) with adjuvant negatively influenced the photosynthetic traits. These results indicate that SWE without adjuvant at 3% promoted the photosynthetic pigments (chlorophyll a, b, total chlorophyll and carotenoids). However, SWE with adjuvant (Emulan) was not effective in the promotion of photosynthetic pigments even at lower concentrations compared with the other treatments.

Protein and Sugar Contents

Protein and sugar contents were significantly influenced by the application of various concentrations of SWE with and without adjuvant. Maximum protein and sugar content (25.13 mg/g FW and 18.17 mg/g FW, respectively) was found at 3% SWE without adjuvant compared with the other treatments (Fig. 1 and 2), while minimum (10.22 and 8.77 mg/g FW) was found with 100% SWE application with adjuvant compared with the control treatment. There was a linear trend of increase in sugar content with decrease in the SWE concentration. Protein production rate was also increased at lower concentration of SWE without adjuvant.

Nitrate Reductase Activity

Application of SWE at lower concentration (3%) without adjuvant enhanced the nitrate reductase (NR) activity. Maximum increase (38.55 Umole NO g^{-1} FW h^{-1}) in NR activity (89.6%) was found where sorgaab was exogenously applied at a lower dose (3%) without adjuvant compared with the rest of the treatments. The minimum NR (12.56 Umole NO g^{-1} FW h^{-1}) was observed at higher concentrations (100%) of sorgaab with adjuvant.

Overall, the higher concentrations of sorgaab with and without adjuvant resulted in decreased NR activity (Fig. 3).

Lipid Peroxidation

Malonaldehyde (MDA) content was significantly influenced by the exogenous application of sorgaab without and with adjuvant in a concentration-dependent manner (Fig. 4). Maximum MDA content (23.41 n mol g^{-1} FW) was observed with application of a higher concentration of sorghum leachates (100%) with adjuvant. However, at a lower concentration of sorgaab (3%), there was a decrease in MDA content (10.32 n mol g^{-1} FW) and a similar trend was found with decreasing concentration of sorghum leachate.

Antioxidant Enzyme Activities

At higher concentration of sorgaab, antioxidant enzymes, viz. SOD, CAT and POX, speeded up the oxidative damage compared with the control. SOD activity decreased (10.32 EU g^{-1} FW) significantly as a result of exogenous application of sorgaab at lower concentration (3%) without adjuvant. Maximum stimulation in CAT activity was observed at higher concentrations of sorgaab with and without adjuvant while the minimum (21.23 EU g^{-1} FW) was observed with 3% SWE. Increased POX activity was also observed in maize seedlings which caused oxidative damage by enhancing activities of antioxidant enzymes at higher sorgaab concentrations. Maximum POX activity (56.34 EU g^{-1} FW) was observed at 100% SWE with adjuvant, while minimum (19.78 EU g^{-1} FW) was found at 3% SWE without adjuvant compared with the control. Maximum increase (14.43%, 4.46% and 24.82%, respectively) in antioxidant enzymes, viz. SOD, CAT, and POX, was recorded at higher concentration of sorghum leachates (100%) compared with the control (Fig. 5–7).

DISCUSSION

Growth of maize seedlings was significantly influenced by the application of various SWE concentrations (100%, 50%, 25%, 10%, 5%, and 3%) with and without addition of an adjuvant (Emulan). All SWE concentrations without adjuvant at low concentrations (3%, 5%, and 10%) exhibited the growth enhancing potential; while higher concentrations (50–100%) of SWE inhibited the seedling growth of maize.

In the present study, maximum shoot length, root length, fresh root/shoot weight and dry root/shoot weight of maize plant seedlings were obtained with application of lower doses of SWE without adjuvant (3%). This result might be due to the presence of indole-3-acetic acid (IAA) (Casimiro et al. 2001), benzoic acid (Cheema 1988), *p*-hydroxybenozoic acid (Guenzi and McCalla 1966), vanillic acid (Mandava 1985), *m*-coumaric acid, *o*-coumeric acid, *o*-hydrocoumaric acid, cinimic acid, *p*-coumaric acid (Cheema 1988), dihydro-*p*-coumaric acid (Guenzi and McCalla 1966), gallic acid, caffeic acid (Chou and Lin 1976), ferulic acid (Guenzi and McCalla 1966), chlorogenic acid, isocholorogenic acid (Cheema 1988) and hydroquinone (Schereiner and Reed 1908) in SWE which possesses the ability to promote crop growth. The IAA in plant water extracts may induce lateral roots to originate from mature, non-dividing pericycle cells within the parent root by increasing mitosis, cell division and cell elongation which ultimately enhance seedling growth (Casimiro et al. 2001). Benzoic acid, coumaric acid, gallic acid, and caffeic acid at low concentrations increase cell division and cell enlargement by increasing the rate of mitosis and cellulose synthesis (Farooq et al. 2013; Kamran et al. 2016), which could be the reason for improvement in the growth of maize seedlings.

A significant increase was observed in total chlorophyll and carotenoid contents by foliar application of lower doses of sorgaab; while the maximum increase was observed at 3% SWE without adjuvant. Indeed, application of SWE at low concentrations stimulates the synthesis of enzymes and activates the protein and co-factors responsible for photosynthesis (Bagavathy and Xavier 2007; Thaper and Singh 2006).

Protein and sugar contents were also significantly higher due to the application of lower concentration of SWE. Increase in protein content might also be due to the presence of phenolic compounds which help to assimilate the amino acids into building block, i.e., protein, and also decrease the quantity of liberated amino acids by synthesizing protein (Singh and Thapar 2003).

NR activity was increased at lower concentration of SWE without adjuvant compared with the control and other treatments. It was observed that in maize seedlings, NR activity decreased as maize water extract concentration increased from 25% to 100%. During photosynthesis, energy-rich electron donors and carbon skeleton control the action of nitrogen reductase in plants (Singh et al. 2010). It might be due to improved photosynthesis which enhanced the energy-rich electron donors and carbon skeleton, thus enhancing nitrogen reductase activity in plants supplied with SWE at low concentrations (Singh et al. 2010).

MDA content in the leaf is the measure of lipid peroxidation, and it was observed more at the higher concentration of SWE (100%) applied with adjuvant followed by the lower rates: 50% > 25% >10%. The minimum MDA contents were observed with exogenous application of SWE at 3% without adjuvant which promoted the growth of maize seedling by decreasing the MDA content. Lower concentrations of maize water extract (3%) without adjuvant reportedly decrease the MDA content by enhancing the activity of antioxidant enzymes (Thaper and Singh 2006).

Allelochemicals enhanced the activity of antioxidant enzymes such as SOD, CAT and POX (Doblinski et al. 2003; Cruz-Ortega et al. 2002). The activity of antioxidant enzymes decreased due to a decrease in allelochemical concentration and vice-versa. CAT activity was enhanced in a dose-dependent concentration. Increased POX activity is also considered in plants under allelochemical stress which causes oxidative damage in maize seedlings and lessens the oxidative injury caused by allelopathic stress due to higher concentration. Reactive oxygen species (ROS) which cause oxidative damage could be the reason for seized biosynthesis of pigment or degradation via impaired metabolic processes. Increased production of antioxidative enzymes indicates stress condition. Plants produce antioxidant enzymes in response to oxidative stress to protect them from oxidative damage caused by ROS (Singh et al. 2010). Chlorogenic acid, isocholorogenic acid, neocholorogenic acid, and dicholorogenic acids (polyphenols) in allelopathic plant water extract also prevent the production of ROS when applied at lower concentration, while application of plant water extracts containing p-coumaric acids at low concentration strongly activates IAA. Cinnimic acid at low concentration prevents IAA from degradation, finally promoting seedling growth. Phenolic compounds, having a broad variety of functional events, predominantly act as antioxidant agents and may decrease the harmful effects of reactive oxygen species which ultimately promotes plant growth at low concentrations (Rice-Evans et al. 1997).

CONCLUSION

Sorghum water extract at lower concentration proved best in enhancing the growth, physiology, water relation and yield of maize. Therefore, it can be used to enhance the growth and yield of maize.

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