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Full Length Article

Influence of Foliage Applied Allelopathic Water Extracts on the Grain Yield, Quality and Economic Returns of Hybrid Maize

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Abstract

Allelochemicals at low concentrations can promote the crop growth and productivity. In this study, allelopathic extracts of sorghum, maize, rice and moringa each at 3% were applied alone and in various combinations at 30 and 50 days after sowing (DAS) of maize crop. No spray and water spray were included as controls for comparison. Application of allelopathic extracts significantly improved plant height, number of grains and grain rows per cob, number of grains per row, 1000-grain weight, grain yield, protein, starch, oil and leaf chlorophyll contents of maize as compared to control during both the years of study. Maximum increase in grains per cob, grain rows per cob, 1000-grain weight, grain number and grain yield (35%) was noted by combined application of sorghum and moringa water extracts. Economic analysis revealed that combination of sorghum and moringa extracts was the most economical followed by combination of maize and moringa extracts and moringa extract alone. In conclusion, sorghum and moringa extract combination at 3% may be foliage applied for harvesting better maize yield of good quality with comparatively higher economic returns.

Keywords: Allelochemicals; Crop water extracts; Sorghum, Moringa, Maize

Introduction

The use of agrochemicals such as fertilizers, pesticides and other synthetic growth regulators has been increased manifold to fulfill the food demands. Use of natural or synthetic substances in crop production systems is also increasing to harvest good yield of better quality. Different growth regulating substances like nitrogenous or phosphatic fertilizers, hormones and other organic/inorganic compounds as seed treatment, foliar or soil application are getting popularity day by day. However, these chemicals are not affordable by farmers due to high prices (Foidle *et al.*, 2001; Phiri, 2010). Moreover, overuse of these substances is posing severe threats to ecological optima and increasing the environmental pollution problems (Phiri, 2010). This necessitate to use alternative approaches to be safe, efficient, cost effective, eco-friendly and feasible to use. The phenomenon of allelopathy may be employed to tackle these problems (Cheema *et al.*, 2012).

Allelopathy involves the production of secondary metabolites from plants, which affects the growth of neighboring plants and microorganisms either by inhibiting or by promoting their growth. Production of these allelochemicals depends on inherent capacity of the plants (Yu *et al.*, 2003; Bhadoria, 2011). The action of allelochemicals is concentration dependent and at lower concentrations they promote the growth of target species and vice versa (Cheema *et al.*, 2012). Allelochemicals are released by all plant parts including leaf, stem, root, and fruit through leaf volatilization, root exudation, leaching and residue decomposition (Bertin *et al.*, 2003; Farooq *et al.*, 2013). Plant water extracts can exogenously be applied to improve plant growth at lower concentrations (Anwar *et al.*, 2003; Cheema *et al.*, 2012).

Among allelopathic plants, sorghum (*Sorghum bicolor* L.) is a potent allelopathic crop and its water extract has been reported to improve plant growth (Mahmood *et al.*, 2010; Mubeen *et al.*, 2012). Exogenous application of sorghum water extract at 30 and 45 days after sowing (DAS) increased 22–42% grain yield of maize (Jahangeer, 2011) and it also considerably promoted growth and yield when applied at 5 and 10% at 30 and 50 DAS in maize (Maqbool *et al.*, 2012). Rice (*Oryza sativa* L.) water extracts also possess allelopathic potential because of the presence of allelochemicals like salicylic acid, *p*-coumaric acid and benzoic acid. In a study, rice water extracts (2.5 and 3%) promoted the germination and root growth of wheat (Chung *et al.*, 2002; Ren *et al.*, 2008). Similarly, chemicals present in maize crop are also allelopathic in nature. Moringa (*Moringa oleifera* L.) allelopathy also has gained attention of the scientific community as it is innate source of plant

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growth regulators. Leaves of moringa contain a large amount of zeatin, which is a natural and cheap source of cytokinin (Foidle *et al.*, 2001; Yasmeen *et al.*, 2014). Significant improvement in growth and yield (20–35%) was observed in various crops like tomato, peanut, maize, wheat, rice, onion and sugarcane when 3% moringa leaf extract (MLE) was exogenously applied (Foidle *et al.*, 2001; Yasmeen *et al.*, 2011; Rehman *et al.*, 2015a, b) being rich in growth regulating hormones like zeatin, antioxidants including ascorbate, phenolics and nutrients (K, Ca, Mg, Zn, Fe) (Makkar *et al.*, 2007, Nouman *et al.*, 2014; Rady *et al.*, 2013).

However, only a few studies showing potential of allelopathic plant water extracts to promote growth and productivity in maize are available. Moreover, no study on comparison of the efficacy of fresh water extracts at low concentrations in improving growth and yield of maize has been conducted. This study examined the growth promoting potential of sorghum, maize, rice and moringa extracts on maize at lower concentrations alone and in combination with each other for two growing seasons. Moreover, economic feasibility of foliage applied crop water extracts was also evaluated.

Materials and Methods

This study was conducted at Agronomic Research Area, University of Agriculture, Faisalabad, Pakistan during 2011 and 2012. The experiment was conducted in randomized complete block design with four replicates in plots measuring 7.0 m × 2.8 m. Experimental soil was silty clay loam, with pH (8.4), organic matter (0.67%), total N (0.042%), AB-DTPA extractable phosphorus (7.5 mg P_2O_5 kg^{-1}), and available potassium (148 mg K_2O kg^{-1}). Weather data during the course of study are given in Table 1.

The plant material of sorghum, rice, maize and the leaves of moringa were collected from Agronomic Research Area, University of Agriculture, Faisalabad, Pakistan. Sorghum, rice and maize plant herbage harvested at maturity after drying, and then chaffed into 2 cm pieces by using fodder cutting machine and stored in shade. This chaffed plant materials were soaked in tap water for 24 h with 1:10 (w/v) ratio and then taken with the help of sieve. For the preparation of moringa leaf water extract, young leaves/twigs of moringa were plucked from healthy and fully grown moringa trees located randomly at University of Agriculture, Faisalabad, Pakistan and were frozen for two days. These frozen leaves were grinded in a locally fabricated extraction machine. The extract was collected and filtered by passing through a muslin cloth to remove all the green matter (Price, 2008). Sorghum, maize, rice and moringa extracts each at 3% were applied alone and in various combinations; no spray and pure water spray being taken as control. Maize hybrid DK-919 was sown using dibbler in 70 cm spaced single rows on a well prepared seed bed on 11^{th} and 3^{rd} of August during 2011 and 2012, respectively. Nitrogen, phosphorus and potash manures were added at 150 kg N, 100 kg P_2O_5 and 100 kg K_2O ha^{-1} in the form of urea and diammonium phosphate and sulphate of potash, respectively. Full dose of phosphorus, potash and $1/3^{rd}$ of nitrogen as diammonium phosphate (DAP), sulphate of potash (SOP) and urea, respectively was drilled at sowing time. Remaining dose of nitrogen ($2/3^{rd}$) was used in two equivalent splits, *i.e.* $1/3^{rd}$ after 25 DAS and $1/3^{rd}$ as top dressing at flowering (after 55 DAS). First irrigation of 7.5 cm was applied at 10 DAS (days after sowing) of crop, while rest of the irrigations were applied when needed. At 3–4 leaf stage, plant to plant distance was maintained at 22.5 cm by manual thinning to ensure a uniform plant population. Furadan (3-G) was applied @ 20 kg ha^{-1} after thinning of crop to protect the crop from maize borer and shoot fly. Crop was harvested manually at physiological maturity. The crop plants were tied into piles and kept for sun drying. The cobs were separated from husk and were dried under sun for easy shelling. After sun drying, cob sheller was used to shell cobs and separate grains from the piths.

Morphological and Biochemical Observation

Leaves of maize at anthesis (BBCH-61) were collected for chlorophyll determination. Sample (1 g) was taken and grinded in 10 ml acetone solution (85%) for 12 h and then samples were run on the spectrophotometer. Chlorophyll *a* and *b* contents were determined as described by Arnon (1949). For plant height, ten plants were selected randomly from every plot and height of these plants was measured individually from ground surface to the top of the plant by using meter rod and averaged. Total number of plants and cobs from each plot were counted and then cob number per plant was calculated. Ten randomly selected cobs from each plot were taken for count of grain rows per cob and averaged. Average grain number per cob was calculated from the total number of grains of ten randomly selected cobs from each plot. Average 1000-grain weight was determined by taking three random samples from the seed lot of every plot. Grain yield from each plot was determined in kg and converted into tons ha^{-1}. Crop from each plot was harvested manually. Cobs were detached from all plants. Stalks were air dried and weighed to determine the stover yield in kg per plot. These values were transformed to tons per hectare. Harvest index (%) was determined by using the procedure of Beadle (1987). Representative grain samples were taken from each plot and starch concentration was noted by following Gluco-amylase technique (Anonymous, 1990). Protein content (%) of maize grain samples was determined by Kjeldahl's method (Anonymous, 1990). Determined nitrogen contents were changed into protein after multiplication of factor 6.25 with nitrogen contents. Oil concentration of the representative grain samples was calculated by the Soxhlet technique as defined by Low (1990).

Meteorological Data

The meteorological data for the growth period of the experimental crop were collected from the meteorological station, Agronomy department, University of Agriculture, Faisalabad (Table 1) located in the vicinity of experimental area.

Statistical Analysis

All the data was analyzed by using "MSTATC" statistical package on a computer (MSTATC, 1991). Data of each laboratory trial were analyzed separately while in case of field experiments combined analysis of two years data were performed. LSD (Least significant difference) test (Steel *et al.*, 1997) was applied in field experiments, while DMR (Duncan's Multiple Range) test was used for laboratory trials.

Economic Analysis

The experimental data were analyzed by using methodology described in CIMMYT (1988). For economic point of view, cost of production of maize was calculated during both the years of study. Net income was computed to examine the most profitable treatment.

Results

Allelopathic plant water extracts significantly improved plant height, cobs per plant, grains per row, grains per cob, grain yield, leaf chlorophyll contents, grain protein, starch and oil contents (%). However, year effect for all the parameters was non-significant except plant height, grains per cob, cobs per plant and harvest index of maize, therefore, data were pooled for these.

Although, all plant water extracts improved plant height, grain rows per cob, cob per plant, grains per cob of maize when applied either alone or in combinations. However, maximum increase in plant height, grain rows per cob, cobs per plant and grains per cob was observed by combined application of fresh sorghum and moringa extracts at 3% than rest of the treatments during both years (Table 2). On the other hand, minimum plant height, grain rows per cob, cob per plant, grains per cob of maize was recorded in control. However, maximum increase in 1000-grain weight, grains per row, grains per cob, grain yield, stover yield, and harvest index was observed with combined application of fresh sorghum and moringa extract each at 3% during both the years. While, minimum grain values for these traits was observed in the controls followed by water spray (Table 2, 3).

Chlorophyll-*a* and *b* contents were also significantly influenced by sorghum, rice, maize and moringa extracts. Maximum chlorophyll-*a* and *b* contents were observed with combined application of fresh sorghum and moringa extract (3%) followed by 3% MLE alone. However, minimum chlorophyll-*a* and *b* content was noted in control followed by water spray (Table 3). Protein, starch and oil contents of maize grain were also improved by exogenous application of fresh sorghum, rice, maize and moringa extracts each at 3% as compared with control. The highest protein and starch contents were recorded with combined application of fresh sorghum and moringa extracts each at 3%. However, highest oil contents were noted with combined application of fresh maize and moringa extracts at 3%. Lowest protein, starch and oil contents of maize grain were observed in control followed by water spray (Table 4).

Economic analysis of fresh sorghum, maize, rice and moringa extracts showed that combined application of sorghum and moringa extract at 3% provided higher net profits followed by combination of maize and moringa extracts and moringa leaf extract alone at 3% (Table 5). According to the benefit cost ratio, combination of sorghum and moringa extracts was the best treatment followed by maize and moringa extract combination and moringa leaf extract alone during both years of study, respectively (Table 5).

Discussion

Allelopathic plant water extracts application at low concentration improved the performance of maize which might be attributed to the presence of various secondary metabolite including phenolics such as indole-3-acetic acid (IAA) (Casimiro *et al.*, 2001), vanillic acid, *p*-hydroxybenzoic acid, *p* hydroxybenzaldehyde, *p*-coumaric acid, ferulic acid (Sene *et al.*, 2001), tannic acid (Santiago *et al.*, 2005), and chlorogenic acid (Bushman *et al.*, 2002) present in sorghum water extract (Cheema, 1988). Allelopathic crop water extracts delay the expression of senescence related genes, increase plant photosynthesis duration (Lim *et al.*, 2007) and scavenge harmful effects of reactive oxygen species (ROS) (Rice-Evans *et al.*, 1996). Moreover, exogenous application of allelopathic water extracts improves the photosynthesis and respiration rate by improving oxygen absorption capacity and stabilizing chlorophyll contents (Kaya *et al.*, 2009). Many other physiological attributes such as conductance of stomata, CO_2 assimilation and leaf transpiration are also affected positively by phenolic compounds applied at low concentration (Yu *et al.*, 2003). These might be the possible reasons for improvement in the chlorophyll contents of maize due to exogenous application of allelopathic water extracts.

Improvement in the stay green of maize due to allelopathic water extract application resulted in the better growth of maize. Better growth lead towards better grain partitioning in maize which eventually enhanced the grain weight and grain number in maize plants against those without spray of allelopathic water extracts (Iqbal, 2014).

Table 1: Weather data at the experimental site during course of experimentation

Year	Month	Temperature (ºC)			Relative humidity (%)	Rainfall (mm)	Sunshine (h)
		Max	Min.	Mean			
2011	July	34.7	26.0	30.4	70.3	118.1	09.0
	August	34.1	25.5	29.8	74.7	92.6	05.4
	September	32.9	23.6	28.3	75.8	155.1	06.9
	October	32.2	17.2	24.7	61.0	00.4	08.4
	November	27.6	13.3	20.5	61.2	00.0	08.5
	December	20.9	04.2	12.5	59.1	00.0	06.9
2012	July	39.1	27.0	33.0	59.2	45.4	09.0
	August	36.2	26.4	31.3	65.0	38.5	05.8
	September	33.1	23.6	28.3	75.0	163.5	07.0
	October	30.2	16.2	23.2	64.3	11.5	08.8
	November	24.8	10.8	17.8	73.0	00.0	07.6
	December	18.8	06.1	12.4	81.5	17.2	05.8

Table 2: Influence of different fresh allelopathic plant water extracts on morphological and yield related traits of maize

Treatment	Plant height (cm)		Grain rows per cob	Cobs per plant		Cob length (cm)	Grains per cob		1000-grain weight (g)
	2011	2012	*	2011	2012	*	2011	2012	*
Control	157.85 h	152.94 h	12.62 i	1.12 f	1.00 f	15.40 h	444.47 h	464.37 h	257.44 h
Water spray	161.73 g	156.29 g	12.77 i	1.25 e	1.00 f	16.03 g	450.00 gh	504.87 g	264.76 g
Rice water extract (RWE; 3%)	162.30 fg	170.96 f	13.14 h	1.25 e	1.10 e	16.67 f	458.46 fg	523.41 f	273.11 f
Sorghum water extract (SWE; 3%)	163.35 f	181.22 c	13.91 ef	1.30 d	1.15 d	17.72 c	510.87 c	534.96 ef	279.93 d
Maize water extract (MWE; 3%)	164.75 e	177.43 de	13.74 fg	1.25 e	1.20 c	17.52 d	466.67 ef	545.15 e	2 76.55 e
Moringa leaf extract (MLE; 3%)	169.88 bc	185.65 b	14.35 bc	1.40 b	1.35 a	18.11 b	565.25 a	616.27 a	289.75 b
RWE+SWE (3%)	168.63 c	181.42 c	14.41 b	1.30 d	1.25 b	17.24 e	468.79 e	565.60 cd	277.53 de
RWE + MWE (3%)	164.93 e	176.61 e	13.66 g	1.25 e	1.15 d	16.78 f	467.34 e	572.42 bcd	283.81 c
RWE + MLE (3%)	166.98 d	182.29 c	14.16 cd	1.25 e	1.23 bc	17.06 e	485.15 d	561.00 d	289.44 b
SWE + MWE (3%)	170.23 b	185.94 b	14.09 de	1.35 c	1.20 c	17.47 d	520.97 b	574.60 bc	284.64 c
SWE + MLE (3%)	174.85 a	196.30 a	15.04 a	1.45 a	1.35 a	18.49 a	563.04 a	610.88 a	290.78 b
MWE + MLE (3%)	166.65 d	179.50 cd	13.88 f	1.38 b	1.25 b	17.76 c	559.67 b	583.63 b	296.20 a
LSD value ($p \leq 0.05$)	1.29	2.86	0.19	0.02	0.03	0.20	9.95	12.55	2.47

*Two years data were pooled as year affect was non-significant
Means not sharing a letter in common differ significantly at p ≤0.05; LSD= Least significant difference

Table 3: Influence of different fresh allelopathic plant water extracts on grain yield, leaf chlorophyll contents of maize

Treatment	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest index (%)		Chl-*a* contents (mg g^{-1})	Chl-*b* contents (mg g^{-1})
	*	*	2011	2102	*	*
Control	3.24 i	1.12 f	29.45 f	29.93 h	1.91 i	0.75 f
Water spray	3.40 h	1.25 e	29.57 f	30.48 g	2.00 h	0.94 e
Rice water extract (RWE; 3%)	3.99 g	1.25 e	30.15 de	30.94 f	2.11 g	0.90 e
Sorghum water extract (SWE; 3%)	4.09 f	1.30 d	30.70 c	32.30 c	2.33c	0.96 e
Maize water extract (MWE; 3%)	4.01 g	1.25 e	30.49 c	30.56 fg	2.14 fg	1.17 d
Moringa leaf extract (MLE; 3%)	4.28 bc	1.40 b	32.25 b	32.99 b	2.47 b	1.26 b
RWE+SWE (3%)	4.20 de	1.30 d	30.30 de	31.74 de	2.23 de	1.17 d
RWE + MWE (3%)	4.24 cd	1.25 e	30.00 e	33.10 b	2.24 d	1.22 bcd
RWE + MLE (3%)	4.15 ef	1.25 e	30.72 c	32.07 cd	2.24 d	1.17 d
SWE + MWE (3%)	4.20 de	1.35 c	30.42 cd	31.48 e	2.23 d	1.25 bc
SWE + MLE (3%)	4.36 a	1.45 a	32.62 a	34.93 a	2.52 a	1.35 a
MWE + MLE (3%)	4.32 ab	1.38 b	32.08 b	33.23 b	2.18 ef	1.20 cd
LSD value ($p \leq 0.05$)	0.06	0.02	0.36	0.43	0.05	0.06

*Two years data were pooled as year affect was non-significant
Means not sharing a letter in common differ significantly at p ≤ 0.05; LSD= Least significant difference

Thus, higher grain yield in maize due to exogenous application of allelopathic water extract might be attributed to better stay green which improved the crop growth, grain portioning and eventually the yield. Several other studies has reported that phenolics stimulate plant growth by enhancing cell division, cell elongation, root size, root branching which enhance the water absorption, turgor pressure, nutrient uptake, and photosynthetic activity (Pupponen-Pimia *et al*., 2001; Abrahim *et al.,* 2003; Anwar *et al.,* 2003; Cheema *et al.,* 2012). Combine application of sorghum and moringa water extract was more effective than the sole or combined application of other allelopathic water extracts. Indeed, both sorghum and moringa possess large amount of phenolics and plant growth regulators/minerals respectively, which are not present or rarely found in the allelopathic water extracts of

Table 4: Influence of different fresh allelopathic plant water extracts on grain quality of maize

Treatment	Protein contents (%)	Starch contents (%)	Oil contents (%)
Control	6.05 j †	60.64 h†	3.90 g†
Water spray	6.10 i	61.03 g	3.99 f
Rice water extract (RWE; 3%)	6.44 h	64.10 f	4.41 e
Sorghum water extract (SWE; 3%)	6.53 g	66.10 d	4.46 d
Maize water extract (MWE; 3%)	7.34 e	65.54 e	4.46 d
Moringa leaf extract (MLE; 3%)	7.90 b	69.91 b	4.75 ab
RWE+SWE (3%)	6.37 f	65.80 de	4.49 cd
RWE + MWE (3%)	6.76 f	68.52 c	4.53 bc
RWE + MLE (3%)	7.34 e	65.87 de	4.52 bc
SWE + MWE (3%)	7.39 d	68.70 c	4.50 cd
SWE + MLE (3%)	8.21 a	73.33 a	4.55 b
MWE + MLE (3%)	7.60 c	69.95 b	4.60 a
LSD value ($p \leq 0.05$)	0.04	0.05	0.05

†Two years data were pooled as year affect was non-significant
Means not sharing a letter in common differ significantly at $p \leq 0.05$; LSD= Least significant difference

Table 5: Economic analysis for application of various fresh water extracts in maize

	CK	WS	RWE	SWE	MWE	MLE	RWE+ SWE	RWE+ MWE	RWE+ MLE	SWE+ MWE	SWE+ MLE	MWE+ MLE	Remarks
Grain yield	3.25	3.40	3.99	4.09	4.01	4.29	4.20	4.25	4.15	4.20	4.36	4.33	t ha^{-1}
Adjusted yield 10% less	2.92	3.06	3.59	3.68	3.61	3.86	3.78	3.82	3.74	3.78	3.92	3.89	To bring at farmer level
Income Rs. ha^{-1}	109519	114750	134663	138038	135338	144619	141581	143269	140063	141750	146981	145969	Rs. 37500 /t
Straw Yield	10.98	11.24	12.32	12.98	13.17	13.99	12.85	13.09	13.29	13.40	14.18	13.68	t ha^{-1}
Adjusted Yield 10% less	9.88	10.12	11.08	11.68	11.85	12.59	11.56	11.78	11.96	12.06	12.76	12.31	To bring at farmer level
Income Rs. ha^{-1}	19755	20232	22167	23364	23697	25173	23121	23553	23913	24111	25524	24624	Rs. 2000/ t
Gross Income	129274	134982	156830	161402	159035	169792	164702	166822	163976	165861	172505	170593	Rs. ha^{-1}
Cost of SWE	0	0	0	16	0	0	8	0	0	8	8		Rs. 8/ha SWE preparation charges
Cost of MWE	0	0	0	0	16	0	0	8	0	8	0	8	Rs. 8/ha MWE preparation charges
Cost of RWE	0	0	20	0	0	0	10	10	10	0	0	0	Rs. 10/ha RWE preparation charges
Cost of MLE	0	0	0	0	0	460	0	0	230	0	230	230	Rs. 230/ha MLE preparation charges
Spray application cost	0	300	300	300	300	300	300	300	300	300	300	300	150 Rs. /man/day/ha
Sprayer rent	0	100	100	100	100	100	100	100	100	100	100	100	Rs. 50/spray
Cost that vary	0	400	420	416	416	860	418	418	640	416	638	638	Rs. ha^{-1}
Total benefit	129274	134582	156410	160986	158619	168932	164284	166404	163336	165445	171867	169955	Rs. ha^{-1}
Net benefits	70298	75606	97434	102010	99643	109956	105308	107428	104360	106469	112891	110979	Rs. ha^{-1}
Benefit cost ratio	1.19	1.27	1.64	1.72	1.68	1.84	1.77	1.81	1.75	1.79	1.89	1.86	(%)

CK =Control, WS = Water application, RWE= Rice water extract, SWE= Sorghum water extract, MWE= Maize water extract, MLE= Moringa leaf extract; Cost that vary= It is the sum of the costs (both costs and opportunity costs) that vary for a particular treatment

the other plants used in the study (Yasmeen *et al.*, 2011; Cheema *et al.,* 2012). Moringa is rich in plant growth regulators like zeatin, ascorbic acid, amino acids and minerals (Ca and K) (Fuglie, 1999; Foidle *et al.,* 2001) which improve the plant growth, as observed in this study.

Protein, starch and oil contents in maize were also improved by exogenous application of allelopathic water extracts. Indeed, exogenous application of allelopathic water extracts at low concentration activate various enzymes like pyruvate kinase, isomerase, phosphoglucose, PPi-dependent phosphofructokinase and glucokinase, which play important role in many important processes involved in grain filling (Pupponen-Pimia *et al.,* 2001).

Better economic returns, lower cost and safety to the environment make any treatment/amendment feasible for its use to improve growth and yield of crops. In this study, foliar application of plant water extracts alone or in combination enhanced net benefits as compared with than control (Table 5). In this regard, combined application of sorghum and moringa extracts each was more profitable which provided higher net benefits, and followed by combined application of maize and moringa extracts, and by sole application of moringa extract. Indeed, allelopathic water extract application improved morphological and yield related traits which resulted in improved grain yield, and eventually better economic returns (Majeed *et al.,* 2012). Higher cost and lesser benefits were involved in other plant water extracts and their combinations, which indicates their low crop promotion activity due to lesser allelochemicals as compared to sorghum and moringa water extract.

Overall higher plant height, grains per cob and harvest index was observed during the second growing season which was due to lower temperature and more relative humidity (Table 1) and contributed towards better growth and improved grain filling.

Conclusion

Plant water extracts alone and in combination with each other improved growth and productivity of maize. Performance of sorghum alone and its combination with moringa at 3% was better than rest of the treatments. In crux, combination of sorghum water extract with moringa water extract at 3% is the best combination to obtain higher yields of maize and it may be used as low cost option to boost maize yields at farmer field.

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