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Foliar application of crop water extract improves the performance of maize

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Abstract

Phytochemicals may promote the growth, development and productivity of crops when exogenous applied at lower concentrations. To assess this phenomenon the following study was repeated for consecutive two years to evaluate various plant water extracts (Sorghum bicolor L., Zea mays L, Orayza sativa L., and Moringa olifera L.) alone and in combinations @ 3 % in improving the performance of maize. Zea mays L. hybrid DK-919 was selected and cultivated by using standard agronomic procedures with the help of a dibbler on 11th and 3rd of August in 2014 and 2015, respectively. Results of the experiments depicted that combined application of Sorghum bicolor L., and Zea mays L. water extracts @3% notably enhanced the growth, morphology, stay green, yield related traits and grain yield of maize. In crux, the combined application of crop water extracts is recommended to improve the productivity of maize.

Introduction

Among cereal crops, *Zea mays* L. possesses momentous significance due to high yield and it stands at 3rd position after *Triticum astevum* L. and *Orayza sativa* L. in the globe (Long *et al.*, 2006). Globally, among cereal crops, it is famous as queen of cereals owing to highest yielding potential and prominent as a leading profitable crop of immense agro-economic worth due to multiple uses in the agriculture-based industries. It has become a major dietary component of millions of people in many parts of the world. On an average basis maize grain contains starch (73%), proteins (9%), oil (4%), fiber (5.8%), sugar (3.0 %) and minerals (1.7%) and this is very important for human and animal diets (Balconi *et al.*, 2007). Yield potential of *Zea mays* in Pakistan is declining day by day as compared with other maize cultivating nations like USA, Germany, Australia, Argentina, Egypt, Bangladesh and China (FAO, 2008).

Climatic and edaphic imbalances and disturbances in conjunction with the intrinsic potential of maize varieties, inadequate irrigation, availability of balanced manure/fertilizers, weeds/insect control, improper and sub-optimal plant population adversely affect growth and yield of maize in Pakistan. Globally, population is increasing at an alarming rate during last 50 years and food demand has been increased manifolds. To fulfill the food needs framers are focusing to enhance crop productivity and are using natural and synthetic substances such as fertilizers/manures, plant growth regulators, herbicides etc. for good and better yield (Kamran *et al*., 2019). Foliar application of synthetic substances enhances the crop productivity and net economic returns of the farmers. On the other hand, these inorganic and artificial substances are costly as well as possess brutal ecological intimidation and health hazards to the living being. (Foidle *et al.*, 2001; Farooq *et al.*, 2008).

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Nonetheless, overuse of these substances is posing ruthless stress and causes several diseases in humans, animals and also contaminate the soil, water and atmosphere (Judith *et al.*, 2001; Kamran *et al.*, 2019). These necessitate devising strategies for harmless, resourceful, inexpensive, eco-friendly and practical to use in crop production system. Such difficulties may be engaged to confront by using allelopathic techniques (Cheema *et al.*, 2003). The scientists are working to explore the potential of various allelochemicals, which has direct influence on the growth and productivity of the agricultural crops. These strategies can be used as an alternative of synthetic agrochemicals as these are cost effective and ecofriendly (Anwar *et al.*, 2003; Cheema *et al.*, 2012).

Phyto-chemicals (allelochemicals) known as secondary metabolites releases from leaves, stem and roots via leaching, residue decomposition, root exudation and volatilization process through leaves and may suppress/promote the growth of neighboring flora and fauna depending upon their concentration and inherent ability of

Table 1: Physico-chemical analysis of the soil

Characteristics	Unit	2014		2015	
A) Depth of sample	cm	0-15	15-30	0-15	15-30
B) Mechanical analysis					
Sand	%	46	45	45	43
Silt	%	23	21	22	20
Clay	%	27	26	28	27
Textural class		Loam			
C) Chemical analysis					
Saturation	%	34	34	34	33
EC	d Sm^{-1}	0.23	0.37	0.28	0.30
pH	-	8.4	8.3	8.3	8.3
Ex. Na	mmol/100g	0.9	1.0	0.95	0.9
Organic matter	%	0.66	0.53	0.64	0.58
Total nitrogen	%	0.042	0.033	0.040	0.036
Available phosphorus	ppm	7.0	5.0	7.5	6.0
Available potassium	ppm	120.0	130.0	140.0	148.0

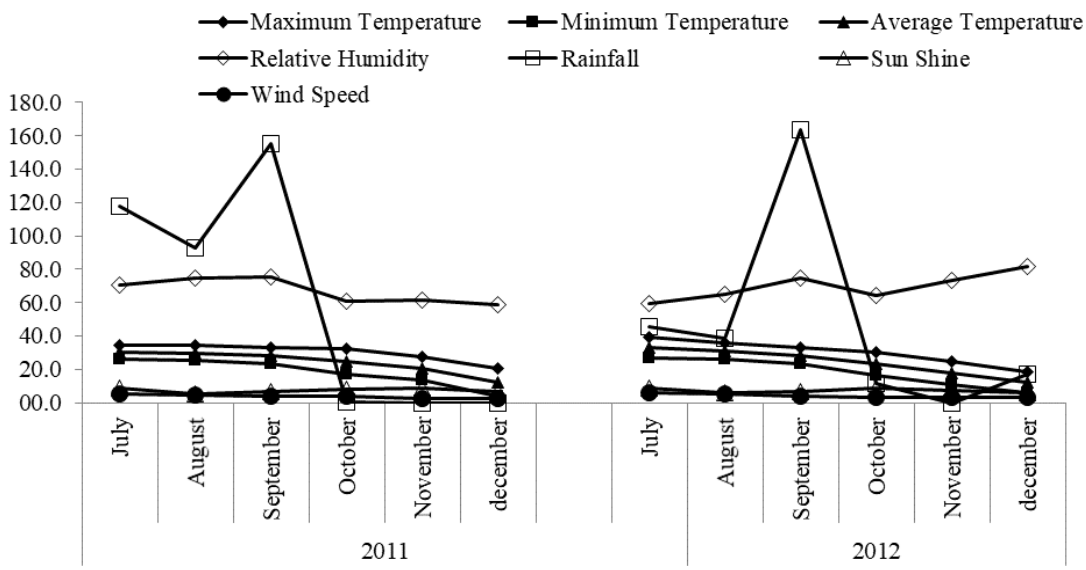

Figure 1: Weather data during both experimental years

the plant to produce allelochemicals (Bertin*et al.*, 2003; Higashinakasu *et al.*, 2004: Yu *et al.*, 2003; Bhadoria, 2014; Farooq *et al.*, 2014). At lower concentrations these biochemical enhance the growth of crops as well as microbial activity in the soil rhizosphere and vice versa (Kamran *et al*., 2019). Root exudates of allelopathic plants interact with microorganism and develop a nutrient auction mechanism between roots and microbes for biological nitrogen fixation and chelating. Aqueous extracts of *Sorghum bicolor* L., *Brassica napus* L., *Oraza sativa* L., *Zea mays* L., *Triticum aestivum* L., and *Moringa olefera* L., boost up crop growth and productivity at lower concentrations thus possibly will be used as natural growth enhancers (Farooq *et al.*, 2013), however, at higher concentrations these phyto-chemicals alone and in combinations have strong inhibitory effects (Kruse *et al.*, 2000; Alam and Islam, 2002; Turk *et al*., 2003; Yokotani*et al.*, 2003; Tinnin and Muller, 2006; Iqbal *et al.*, 2009; Jabran and Farooq, 2012; Kamran *et al*.,2018).

Keeping in view the above literature, hypothesis may be made that aqueous plant extracts at lower concentration possess strong growth enhancing ability at low concentration. Various studies have been conducted to explore this particular aspect in several crops, but this feature is lacking in maize. Therefore, the present trial was laid down to inspect the influence of aqueous extracts of rice, sorghum, maize and moringa at lower concentrations was also investigated against maize.

Materials and Methods

General details

This field study was conducted out for consecutive two years (2014 & 2015) at Agronomic Research Area, University of Agriculture, Faisalabad, Pakistan with four replications in randomized complete block design (RCBD) by using net plot size of 7 m x 2.8 m. Before cultivation of maize crop, soil sampling (0-15 cm and 15-30 cm) was taken and sent to Soil and Chemistry Section, at Ayyub Agricultural research Institute, Faisalabad to analyze soil physico-chemical properties (Table 1). Hydrometer technique was used to determine sand, silt and clay (%) devised by Moodie *et al.,* in 1959. International Textural Triangle was used to identify soil texture (Brady, 1990). Soil chemical properties were determined by adopting Homer and Pratt (1961) procedure. Weather information during both the trial years is provided in Figure 1.

Preparation of aqueous plant extract

Aqueous plant extract was prepared by collecting plants viz: sorghum, rice, maize, and moringa leaves from agronomic Research Area, University of Agriculture, Faisalabad. Dried plant material was cut down into small pieces (2 cm) by using fodder cutter and drench into tap water with 1:10 ratio for 24 hours. After that extracts were filtered by means of strainer and concerted (20 times) after heating and stored in cool and dry place for experimental use (Cheema and Khaliq, 2000). Moringa leaf extract was prepared by harvesting leaves and small twigs of moringa tree after keeping freezer for 24 hours. Locally made-up extraction apparatus was used for grinding of frozen moringa leaves in Allelopathy Lab, Department of Agronomy, University of Agriculture, Faisalabad. Whole extract was filtered through muslin cloth to collect clean moringa leave extract (MLE) exclusive of all green material (Price, 2007).

The collected filtrates stored at ambient temperature for 2-3 days and used according to the experiment's requirement with and without an adjuvant (Emulan) to explore their growth promotery potentials alone and various combinations according to the treatments Foliar spray of water was kept as control for treatment comparisons.

Crop husbandry

Owing to high yielding Dk-919 was selected and cultivated on beds subsequent to fine, well prepared soil by means of dibbler on 22nd and 23rd of July in 2014 and 2015, respectively. The experiment was comprised of the following treatments; T1: Control; T2: Water spray; T3: Rice water extract (RWE); T4: Sorghum water extract (SWE); T5: Maize water extract (MWE); T6: Moringa leaf extract (MLE); T7: Rice water extract + Sorghum water extract; T8: Rice water extract + Maize water extract; T9: Rice water extract + Moringa leaf extract; T10: Sorghum water extract + Maize water extract; T11: Sorghum water extract + Moringa leaf extract; T12: Maize water extract + Moringa leaf extract.

All the agronomic parameters were adopted according to recommendations. Fertilizers were also applied according to the maize recommendations i.e.: @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 diammonium phosphate (DAP), sulphate of potash (SOP), while ½ dose of urea was soil mixed at the time of soil preparation. While 2/3rd nitrogen dose was splits up into two equal doses i.e., one third after 25 DAS and left behind urea applied at the flowering stage at 55 DAS. After 10 days 1st irrigation was applied, and reaming was given according to the cop need. To maintain plant population as well as plant to plant (22.5 cm) distance thinning was made at 3-4 leaf stage. To manage maize borer and shoot fly attack in maize crop Furadan (3-G) @20 kg ha^{-1} was used.

After physiological maturity appearance maize harvested by hand tied up and kept in the sun for drying. Cobs separated from stem; sun dried to lessen grain moisture detach grains from pith during shelling.

Observations

The chlorophyll (a & b) was determined by means of spectrophotometric procedure devised by Sartory and Grobbelaar (1994). Random leave samples were collected from maize plants after grinding: paste was prepared and separated by adding 50 ml acetone (100%) in one gram, kept it in homogenizer @ 1000 rpm for one minute, filtered homogenate centrifuged (@ 2500 rpm) for 10 minutes in centrifugal machine. The supernatant was separated, and the absorbance was read at 400-700 nm on Schimadzu uv-260 spectrophotometer. e crop was harvested at its physiological maturity. Observations on growth and yield parameters of the crop were recorded using standard procedures. The data recorded for various variables was subjected to statistical analysis using the analysis of variance technique by using "MSTAT-C" (Anonymous, 1986) whereas the means were compared through LSD test at 0.05 p (Steel *et al*., 1997) and uniform for all the treatments. The crop was harvested at its physiological maturity. Observations on growth and yield parameters of the crop were recorded using standard procedures. The data recorded for various variables was subjected to statistical analysis using the analysis of variance technique by using "MSTAT-C" (Anonymous, 1986) whereas the means were compared through LSD test at 0.05 p (Steel *et al*., 1997).

Plant height was calculated with help of meter rod by random selection of 10 maize plants from each plot in each replication and average height was noted in cm. Ten randomly selected ears from each plot were taken; grain rows of each ear were counted and averaged to get number of grains rows per ear. Average grain number per ear was calculated from the total number of grains of ten randomly selected ears from each plot. Grain pith ratio was calculated by simply dividing the grain weight by pith weight. Three samples of each of 1000-grains were taken randomly from the seed lot of each plot, weighed and then averaged. Grain yield was recorded on plot basis in kg and then converted to t ha^{-1}. Crop from each plot was harvested manually. Ears 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 Mg ha^{-1}. Harvest index (%) was calculated by using the following formula of Beadle (1987). Representative grain samples were taken from each plot and starch concentration was determined by using Gluco-amylase method (Anonymous, 1990). Protein content (%) of maize grain samples was determined by Kjeldahl's method (Anonymous, 1990). Nitrogen content was determined which was converted to protein by multiplying with the factor 6.25.

Oil concentration of the representative grain samples taken from each plot was determined by the Soxhlet method as described by Low (1990). The data were analyzed by using "MSTATC" statistical package on a computer (Anonymous, 1986). Data of each laboratory trial were analyzed separately while in case of field experiments combined analysis of two years data were performed. Least significant difference (LSD) test (Steel *et al.*, 1997) was applied in field experiments while Duncan's Multiple Range test was used for laboratory trials. Economic analysis was carried out on the basis of variable costs and prevailing market prices of herbicide and maize crop. Marginal analysis was done to calculate the marginal net benefits and marginal rate of returns. Marginal analysis was carried-out according to procedures devised by CIMMYT (1988).

Results

All the parameters (growth, yield and quality) significantly promoted by foliar spray of aqueous plant extracts. Year effect was non-significant for all the recorded parameters excepting plant height and cobs per plant (Table 2). It was observed that foliar application of SWE and MWE each at 3% in combination showed maximum promotion in plant height during both year of experimentation and minimum was observed in control (Table 2). Data regarding plant population revealed that the final number of plants m^{-2} was almost uniform and was non-significant in all the treatments under study (Table 2). Plant water extracts significantly improved the grain rows per cob. Highest grain rows per cob was noted from combined application of 3% SWE and 3% MWE and minimum grain rows per cob were found in control which was statistically similar during both years (Table 2). Number of cobs per plant showed that all plant water extracts significantly affected number of cobs per plant during the study years and maximum number of cobs was found from the combined application of SWE and MWE each at 3% followed by 3% SWE alone during both the year of experimentation. Whereas, MLE and SWE alone each at 3% were statistically at par during the study year 2014 and minimum number of cobs was determined in control (Table 2).

Cob length of maize was also significantly affected by all the treatments during both years of experimentation. Among the plant water extracts used, combined application of SWE and MLE each at 3% produced longer cobs followed by MLE alone, combined SWE and MLE, combined MWE and MLE and MWE alone each at 3% which were statistically similar with each other during the year of studies. While, minimum cob lengths were observed in control (Table 2). Data regarding number of grains per cob depicted that all the plant water extract treatments produced significantly higher number of grains per cob. Maximum number of grains per cob was found with the combined application of SWE and MWE each at 3% followed by 3% MLE alone and with combined application of MWE and MLE each at 3% and both were statistically at par with each other during the study year. While, minimum number of grains per cob was found in control (Table 2). All plant water extract treatments significantly influenced grain pith-ratio as compared with control. A significant increase in grain-pith ratio was recorded in plots where combined application of SWE and MWE each at 3% was sprayed and it was followed by 3% MLE alone during both the year of experimentations and minimum grain pith-ratio was observed in control (Table 2).

Data regarding 1000-grain weight exposed that all plant extract influenced significantly by increasing grain weight as compared to control. Significantly heavier grains were recorded with combined application of SWE and MLE each at 3% followed by MLE at 3% alone and lightest grain weight was found in control during years of study (Table 2).All treatments significantly increased number of grains per row as compared with control. Maximum number of grains per row was observed with combined application of SWE and MWE each at 3% followed by 3% MLE alone and both were statistically at par with each other during both the year of experimentation. The next best treatment was where combined MWE and MLE each at 3% were applied and it was statistically same with MLE alone at 3% during 2014-15. While, minimum grains per row were observed in control (Table 3). The data relating to grain yield showed that all the plant water extract treatments showed significant results. Combined application of SWE and MWE each at 3% promoted grain yield 36.36% as compared with control and it was followed by MLE application each at 3% giving 30.90% increase in maize grain yield and MWE and MLE each at 3% giving yield 30.30% and both were statistically at par during the study years. The increase in maize grain yield under different plant water extract treatments may be attributed due to improvement in LAI, number of cobs per plant, number of grains per cob and 1000-grain weight. The lowest maize grain yield was recorded in control plots owing to no application of plant water extracts. (Table 3)

All plant water extract treatments significantly influenced stover yield of maize over control. The highest stover yield was recorded in plots where combined SWE and MWE each at 3% were applied followed by 3% MLE alone and minimum stover yield was noted in control followed by water spray during both the year of experimentation (Table 3).The data concerning harvest index of maize showed significant improvement among different plant water extract treatments. The harvest index produced by combined application of SWE and MWE each at 3% found to be maximum as compared to control during both the year of study followed by combined application of RWE and MWE at 3% which produced good harvest index and it was statistically same with MWE alone at 3% during 2014 and also with combined application of RWE and MWE each at 3% during 2015. Minimum harvest index was noted in control (Table 3). All treatments significantly affected the protein contents of maize grain as compared with control during both the years of study. The highest protein contents in maize grain were obtained with the combined application of SWE and MLE each at 3% followed by 3% MLE alone during both the year of study. While control resulted minimum grain protein contents and both were statistically similar (Table 3). All plant water extracts significantly influenced the starch content of maize grain as compared with control during both the years of study. The highest starch content in maize grain was obtained with the combined application of SWE and MWE each at 3% and followed by 3% MLE alone. While lowest starch contents in maize grain was observed in control (Table 3). The oil content of maize grain was significantly improved by all plant water extracts as compared with control during both the years of study. The highest oil content was obtained in plots applied with MWE and MLE each at 3% in combination and it was followed by SWE and MLE each at 3% which was statistically at par with combined application of SWE and MWE, RWE and MLE, RWE and MWE, RWE and RWE and SWE each at 3%. Whereas, minimum grain oil content was observed in control (Table 3).

Different treatments receiving plant water extracts significantly influenced chlorophyll-a contents in maize. Almost all plant water extracts improve the chlorophyll-a contents in maize leaves except control. Maximum chlorophyll-a content improvement was noted with combined application of SWE and MWE each at 3% followed by combined application of 3% MWE and 3% MLE, 3% SWE and 3% MLE in combination and also 3% MLE alone. While, minimum chlorophyll-a contents were noted in control (Table 3). All plant water extract treatments significantly affected chlorophyll-b content in maize during the both years. Maximum chlorophyll-b content increase was found where combined application of SWE and MWE each at 3% was applied followed by MLE at 3% alone and SWE and MLE at 3% in combination and minimum chlorophyll-b content was observed in control followed by water spray (Table 3).All plant water extract treatments significantly improved total chlorophyll contents in maize as compared to control. However, maximum total chlorophyll contents were observed in combined application of SWE and MWE each at 3% followed by 3% MLE alone and MWE and MLE each at 3% and minimum total chlorophyll contents was observed in control (Table 3).

In addition to effectiveness of a technique its acceptance and adoption will ultimately depend upon the economic returns. For determining the economical treatments economic and marginal analyses were performed. In present study all plant extracts gave higher net returns as compared with control (Table 4 & 5) during both the years of study. Among allelopathic water extracts application of SWE and MWE combination gave higher net returns (Rs. 179061 ha^{-1} and 174296 ha^{-1}) during both years and it was followed by MLE alone during both year of study giving net benefit of Rs. 173832.5 $ha^{-1}$and 166825 ha^{-1} respectively. Combined application of MLE and MWE, MLE and SWE also gave higher net returns (Rs. 173515ha^{-1} and 165896 ha^{-1}) during 2014 and 2015, respectively. While minimum net benefit was obtained from control with net benefits (Rs. 135055 $ha^{-1}$and Rs. 129615 ha^{-1}) followed by water spray (Rs. 130267.5 $ha^{-1}$and Rs. 140081.9 ha^{-1}) during study years, respectively.

Marginal analyses revealed (Table 6 & 7) that, combination of SWE and MWE were superior among all the plant extracts with maximum marginal rate of return (20874.4 & 327723.53%) during 2014 and 2015, respectively. Combinations of RWE and SWE, RWE and MWE, SWE and MLE, SWE and MWE, had good marginal rate of return (14640, 12070.6, 2924.19, 2894.12%) during 2014 and SWE alone also had good MMR (9626.19-20874.4%) during both the years of study. Application of water as foliar spray during both years was also economical due to MRR (163.13-551.25 %). Rest of treatments was dominated due to less benefit and higher cost that vary, so these were uneconomical treatments at prevailing plant water extract prices.

Discussion

Allelopathy has been achieving considerably extra consideration in public and agricultural biomes due to its particular and excessive responses by affecting growth and yield of plants (Rice 1984; Inderjit and Duke, 2003; Narwal and Haouala, 2014). As allelopathy is the biochemical interaction among the plants involving production of secondary metabolites that have both inhibitory and promotery effects on neighboring plants (Kohli*et al.,* 1998). Rice reported that these biochemicals are produced through shikimic acid or citric acid pathway (Rice, 1984) and theses interactions includes both promotion and inhibition activity depending on their concentrations. The allelochemicals at lower doses influence the growth and development of various crops by boosting up physiological activity of the plants and this can be used as an inexpensive, safe, effective and environment friendly source of natural growth enhancer (Oudhia *et al.,* 1988). Allelochemicals affect the growth pattern of plants and organisms and potential of these allelopathic plants extracts can be used to promote growth and other processes of plants (El Atta and Basher, 1999; Farooq *et al.,* 2014; Kamran *et al.,* 2016). Growth promotery potential found to be more when these extracts applied at lower concentrations and suppressive effect or inhibition of growth increases by increasing extracts concentration (Chung and Miller, 1995; Narwal and Haouala, 2014), as allelochemicals have stimulatory effects at low concentrations (Narwal, 1994). Allelochemicals (secondary metabolite) like ferulic acid (pehenylpropanoid group) are made up via phenylalanine as intermediate, and include coumarins (e.g., scopoletin). Some phenolics, like salicylic acid plays fundamental role against various diseases by showing resistance against diseases (Einhellig, 2004). Phenolics are involved in the promotion of growth as these chemicals promote the efficiency of photosynthesis by increasing chlorophyll contents which ultimately enhance the plant growth and yield (Foidle, 2001).

In order to realize the growth promotery potential of plant water extracts different crops like sorghum, maize, rice and moringa were evaluated field trials and significant growth promotery effects of rice, maize, sorghum and moringa was observed on maize. Allelopathic plant extracts application resulted in better grain yield as they amended the growth pattern of maize plant which enhance the growth and development and ultimately promote the growth attributes. Phenolics present in these plant water extracts in low concentration are considered to be involved in growth promotion activities by improving photosynthates and photosynthesis process and by delaying senescence activity (Lim *et al.,* 2007).Plant water extract of moringa contain zeatin; an innate source of cytokinins has the ability to enhance the activity of antioxidant enzymes i.e. catalases which naturally fight aging and free oxygen radicals(Fuglie, 1999), and also promote cell division and cell elongation in plants (Taiz and Zeiger, 2006). Main function pehnloics and zeatin is to control the accumulation of nutrients, healing and promote growth of plants. Therefore, improved benefits are gained by exogenously application of these plant extracts. Phenolic compounds are also involved in improving protein, starch and oil contents in maize grain and found to be better where mixtures of plant water extracts were applied. Exogenously application of plant water extracts triggers different important enzymes such as glucokinase, phospho-glucose, pyruvate kinase etc. and take part in various crucial metabolic processes glycolysis, respiration and tricarboxylic acid cycle (TCA). All these metabolic processes are concentration and crop type dependant (Nardi*et al.*, 2007). Phenolics work together at low concentrations and other more phytotoxic compounds may overlook in various plant water extracts in combined formulation (Rimando*et al.,* 2001). These phenolics influence the plant cell membrane, enzyme activation, water turger pressure, carbon assimilation and photosyntahic activities in plants (Olofsdotter*et al.*, 2002).

There was significant variation among plant water extracts concentrations as higher concentration suppressed the plant while at low concentrations, they promote the plant growth by increasing root and shoot length and root and shoot dry weight of maize seedlings. Phenolics are generally considered responsible for increase in permeability of cell wall in plant, which causes the enhancement of pre-oxidation of lipids, subsequently growth retardation and even sometimes death of plant occurs due to it. It is also reported that phenolics interferes with nutrient uptake in plants which in turn may also be a reason for slow growth (Li *et al.,* 2010). They are also considered as cell ultra-structure modifiers and inhibitors of cell division and elongation (Li *et al.,* 2010). Phenomenon's like conductance of stomata, CO_2 concentration and transpiration rate in leaves are also influenced positively when allelochemicals applied exogenously at lower concentrations (Yu *et al.,* 2003). Some phenolic compounds affect the decomposition of IAA and gibberilic acid and synthesis of ethylene is also disturbed by them (Leslie *et al.,* 1998). It is also believed that they interfere with DNA and RNA integrity (Zeng*et al.,* 2001). In short, phenolics are a large and diverse group of allelochemicals that act in a series of reactions to speed up the growth of plant tissues. Chlorophyll contents present in the leaves are an important indicator of crop growth. As more the photosynthesizing machinery is available, more light energy will be harvested to produce the reducing powers that ultimately leads towards the more yield. Plant water extract treatments significantly affected chlorophyll contents of the leaves and produce maximum chlorophyll contents in maize crop (Fuglie, 2000). Plant water extracts when exogenously applied at low concentration they also improve the photosynthesis by promoting chlorophyll contents like *a*, *b* and total chlorophyll in the leaves ultimately, promote growth and yield of maize by enhancing phytosynthatic activity and absorption of oxygen in leaves. Many other phenomenon's like conductance of stomata, CO_2 concentration and leaf transpiration are also affected positively by phenolic compounds if they are present in low concentration (Yu *et al.,* 2003). Hence, better vegetative growth occurs, resulted in increasing the chlorophyll contents of the leaves leads to higher crop yield.

Conclusion

Briefly, it can be concluded that application of exogenous plant water extracts lower promote the growth and yield of maize. Seedling growth of maize was suppressed where higher concentrations of plant water extracts of rice, maize and sorghum were applied. Maize yield was more, whereas mixtures of plant extracts were applied has positive or promotery effect on the yield attributes of maize. Moreover, starch, protein, oil and chlorophyll contents improvement were also found by application of lower doses of plant water extracts which ultimately leads towards good and better yield of maize.

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Table 2: Influence of different allelopathic plant water extracts on morphological, yield related traits, chlorophyll contents, grain yield, grain quality and grain oil contents of maize

Treatment	Rate	Plant height(cm)		Plant Population(m^{-1})		Grain rows cob^{-1}	Cobs $plant^{-1}$		Cob length (cm)	Grains cob^{-1}	Grain-pith ratio	000-Grain weight (g)
		2014	**2014**	**2014**	**2015**	*	**2015**	**2015**	*	*	*	*
Control		180.30 g	6.10	6.10	6.20	13.20 h	1.23 g	1.05 h	17.89 g	37.55 g	2.75 g	250.81 h
Water spray		181.27 g	6.16	6.16	6.21	13.29 h	1.25 g	1.20 e	18.61 f	38.69 f	3.34 f	258.47 g
Rice water extract (RWE)	3%	193.17 f	6.18	6.18	6.21	13.58 g	1.35 e	1.25 d	19.29 d	40.78 de	3.57 e	273.08 f
Sorghum water extract (SWE)	3%	201.24 d	6.36	6.36	6.53	14.03 e	1.43 b	1.30 c	18.98 e	40.73 e	3.68 d	288.38 c
Maize water extract (MWE)	3%	193.38 f	6.33	6.33	6.33	13.62 g	1.35 e	1.15 f	19.61 b	41.33 c	3.58 e	280.30 d
Moringa leaf extract (MLE)	3%	205.93 b	6.33	6.33	6.33	14.96 b	1.43 b	1.35 b	19.71 b	41.92 b	3.87 b	291.31 b
RWE + SWE	(each 3%)	196.93 e	6.29	6.29	6.29	13.99 e	1.25 g	1.30 c	19.45 c	40.71 e	3.70 d	278.25 de
RWE + MWE	(each 3%)	197.88 e	6.31	6.31	6.21	13.63 g	1.35 e	1.15 f	19.43 cd	41.11 cd	3.67 d	277.54 e
RWE + MLE	(each 3%)	202.12 cd	6.30	6.30	6.20	13.78 f	1.30 f	1.10 g	19.36 cd	41.11 cd	3.57 e	287.79 c
SWE + MWE	(each 3%)	210.14 a	6.34	6.34	6.34	15.15 a	1.45 a	1.40 a	19.88 a	42.52 a	3.93 a	287.93 c
SWE + MLE	(each 3%)	206.66 b	6.38	6.38	6.48	14.42 d	1.38 d	1.25 d	19.65 b	40.87 de	3.71 d	294.26 a
MWE + MLE	(each 3%)	204.16 bc	6.34	6.34	6.26	14.66 c	1.40 c	1.30 c	19.61 b	41.71 b	3.80 c	286.29 c
LSD $p \leq 0.05$		**2.71**	**NS**	**NS**	**NS**	**0.12**	**0.20**	**0.03**	**0.15**	**0.33**	**0.04**	**2.76**

Table 3: Influence of different allelopathic plant water extracts on morphological, yield related traits, chlorophyll contents, grain yield, grain quality and grain oil contents of maize

Treatment	Rate	Grains row^{-1}	Grain yield	Stover yield ($t\ ha^{-1}$)	Harvest index (%)		Protein contents (%)	Starch contents (%)	Oil contents (%)	Chl a	Chl b	Chl a+b
		*	*	*	**2014**	**2015**	*	*	*	*	*	*
Control		490.19 g	3.30 h	11.64 h	28.98 f	27.10 g	5.77 j	59.99 j	4.09 f	1.82 j	0.78 f	2.63 i
Water spray		518.57 f	3.39 g	11.73 h	29.92 e	27.77 ef	5.98 i	61.53 i	4.26 e	2.11 i	0.89 e	2.98 h
Rice water extract (RWE)	3%	542.56 e	3.70 f	12.51 g	29.96 e	29.17 d	6.84 e	63.59 h	4.38 d	2.16 h	1.00 d	3.09 g
Sorghum water extract (SWE)	3%	563.17 d	4.01 d	13.48 c	31.95 c	27.63 fg	6.58 g	65.10 ef	4.47 c	2.24 ef	1.00 d	3.23 f
Maize water extract (MWE)	3%	559.02 d	3.97 e	12.73 f	32.65 b	27.91 ef	6.97 d	65.79 d	4.38 d	2.20 gh	1.16 c	3.34 e
Moringa leaf extract (MLE)	3%	595.15 ab	4.32 b	14.02 a	31.81 cd	30.06 c	7.44 b	70.00 b	4.46 c	2.33 bc	1.28 b	3.62 b
RWE + SWE	(each 3%)	582.02 c	3.97 d	12.99 e	30.31 e	31.48 b	6.89 de	65.60 de	4.52 b	2.27 de	1.17 c	3.44 d
RWE + MWE	(each 3%)	582.52 c	4.00 d	12.81 f	32.78 b	28.22 e	6.44 h	64.95 f	4.51 b	2.29 cd	1.13 c	3.51 c
RWE + MLE	(each 3%)	563.31 d	4.12 c	13.23 d	30.37 e	31.55 b	7.18 c	65.93 d	4.52 b	2.20 fg	1.16 c	3.38 de
SWE + MWE	(each 3%)	596.85 a	4.50 a	14.10 a	34.40 a	32.52 a	7.68 a	73.19 a	4.53 b	2.43 a	1.41 a	3.81 a
SWE + MLE	(each 3%)	585.85 c	4.13 c	13.46 c	31.34 d	30.48 c	6.72 f	64.28 g	4.52 b	2.35 b	1.28 b	3.53 c
MWE + MLE	(each 3%)	587.68 bc	4.30 b	13.70 b	31.60 cd	32.00 ab	7.25 c	67.81 c	4.59 a	2.36 b	1.13 c	3.55 bc
LSD p≤0.05		**7.92**	**0.07**	**0.16**	**0.36**	**0.44**	**0.08**	**0.59**	**0.03**	**0.043**	**0.047**	**0.068**

Table 4. Economic analysis for the year of 2014

	CK	WS	RWE	SWE	MWE	MLE	RWE+SWE	RWE+MWE	RWE+MLE	SWE+MWE	SWE+MLE	MWE+MLE	Remarks
Grain yield	3.38	3.53	3.94	4.37	4.11	4.43	3.86	4.42	4.12	4.57	4.07	4.41	t ha^{-1}
Adjusted yield	3.04	3.18	3.55	3.94	3.69	3.99	3.47	3.98	3.71	4.11	3.66	3.97	10% less To bring at farmer level
Income Rs. ha^{-1}	**114075**	**119222**	**133059**	**147572**	**138544**	**149513**	**130106**	**149259**	**139050**	**154238**	**137278**	**148838**	Rs. 37500 /t
Straw Yield	11.65	11.81	13.16	13.73	12.59	13.99	13.35	12.94	13.42	14.11	13.1	14.11	t ha^{-1}
Adjusted Yield	10.49	10.63	11.84	12.35	11.33	12.59	12.02	11.65	12.08	12.7	11.79	12.7	10% less To bring at farmer level
Income Rs. ha^{-1}	20980	21260	23680	24700	22660	25180	24040	23300	24160	25400	23580	25400	Rs. 2000/ t
Gross Income	**135055**	**140481.9**	**156739.4**	**172271.9**	**161203.8**	**174692.5**	**154146.3**	**172559.4**	**163210**	**179637.5**	**160858.1**	**174237.5**	Rs. ha^{-1}
Cost of SWE	0	0	0	168	0	0	84	0	0	84	84		Rs. 168/hac SWE
Cost of MWE	0	0	0	0	185	0	0	92.5	0	92.5	0	92.5	Rs. 185/hac MWE
Cost of RWE	0	0	195	0	0	0	97.5	97.5	97.5	0	0	0	Rs. 195 /hac RWE
Cost of MLE	0	0	0	0	0	460	0	0	230	0	230	230	Rs. 230/hac MLE
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**	**595**	**568**	**585**	**860**	**581.5**	**590**	**727.5**	**576.5**	**714**	**722.5**	Rs. ha-1
Net benefit	**135055**	**140081.9**	**156144.4**	**171703.9**	**160618.8**	**173832.5**	**153564.8**	**171969.4**	**162482.5**	**179061**	**160144.1**	**173515**	Rs. ha^{-1}

CK =Control, **WS** = Water application, 2 spray (30 and 50 DAS), **RWE** = 3% Rice water extract, 2 sprays (30 and 50 DAS),
SWE = 3% Sorghum water extract, 2 spray (30 and 50 DAS), **MWE** = 3% Maize water extract, 2 spray (30 and 50 DAS),
MLE = 3% Moringa leaf extract, 2 spray (30 and 50 DAS)
RWE+SWE = Rice water extract + sorghum water extract at 3%, 2 spray (30 and 50 DAS)
RWE+MWE = Rice water extract + Maize water extract at 3%, 2 spray (30 and 50 DAS),
RWE+MLE=Rice water extract + Moringa leaf extract at 3%, 2 spray (30 and 50 DAS),
RWE+MLE= Rice water extract + Moringa leaf extract at 3%, 2 spray (30 and 50 DAS),
SWE+MWE= Sorghum water extract + Maize water extract at 3%, 2 spray (30 and 50 DAS),
SWE+MLE= Sorghum water extract + Moringa leaf extract at 3%, 2 spray (30 and 50 DAS),
MWE+MLE= Maize water extract + Moringa leaf extract 3%, 2 spray (30 and 50 DAS)

Table 5 Economic analysis for the year of 2015

	CK	WS	RWE	SWE	MWE	MLE	RWE+SWE	RWE+MWE	RWE+MLE	SWE+MWE	SWE+MLE	MWE+MLE	Remarks
Grain yield	3.22	3.25	3.46	3.65	3.48	4.22	4.09	3.57	4.11	4.43	4.2	4.18	t ha^{-1}
Adjusted yield	2.90	2.93	3.11	3.29	3.13	3.80	3.68	3.21	3.70	3.99	3.78	3.76	10% less to bring at farmer level
Income Rs. ha^{-1}	108675	109688	116775	123188	117450	142425	138037.5	120487.5	138712.5	149512.5	141750	141075	Rs. 37500 /t
Straw Yield	11.63	11.66	11.86	13.24	12.86	14.04	12.62	12.68	13.03	14.09	13.81	13.28	t ha^{-1}
Adjusted Yield	10.47	10.49	10.67	11.91	11.57	12.63	11.36	11.41	11.73	12.68	12.43	11.95	10% less to bring at farmer level
Income Rs. ha^{-1}	20940	20980	21340	23820	23140	25260	22720	22820	23460	25360	24860	23900	Rs. 2000/ t
Gross Income	**129615**	**130667.5**	**138115**	**147007.5**	**140590**	**167685**	**160757.5**	**143307.5**	**162172.5**	**174872.5**	**166610**	**164975**	Rs. ha^{-1}
Cost of SWE	0	0	0	168	0	0	84	0	0	84	84		Rs. 168/hac SWE
Cost of MWE	0	0	0	0	185	0	0	92.5	0	92.5	0	92.5	Rs. 185/hac MWE
Cost of RWE	0	0	195	0	0	0	97.5	97.5	97.5	0	0	0	Rs. 195 /hac RWE
Cost of MLE	0	0	0	0	0	460	0	0	230	0	230	230	Rs. 230/hac MLE
Spray application cost	0	300	300	300	300	300	300	300	300	300	300	300	150 Rs./Man/day ha^{-1}
Sprayer rent	0	100	100	100	100	100	100	100	100	100	100	100	Rs. 50/spray
Cost that vary	**0**	**400**	**595**	**568**	**585**	**860**	**581.5**	**590**	**727.5**	**576.5**	**714**	**722.5**	Rs. ha-1
Net benefit	**129615**	**130267.5**	**137520**	**146439.5**	**140005**	**166825**	**160176**	**142717.5**	**161445**	**174296**	**165896**	**164252.5**	Rs. ha^{-1}

CK =Control, **WS** = Water application, 2 spray(30 and 50 DAS), **RWE** = 3% Rice water extract, 2 sprays (30 and 50 DAS), **SWE** = 3% Sorghum water extract, 2 spray (30 and 50 DAS), **MWE** = 3% Maize water extract , 2 spray (30 and 50 DAS), **MLE** = 3% Moringa leaf extract , 2 spray (30 and 50 DAS), **RWE+SWE** = 3% Rice water extract +3% sorghum water extract, 2 spray (30 and 50 DAS), **RWE+MWE =** 3% Rice water extract + 3% Maize water extract, 2 spray (30 and 50 DAS), **RWE+MLE**=3% Rice water extract + 3% Moringa leaf extract, 2 spray (30 and 50 DAS), **RWE+MLE**= 3% Rice water extract + 3% Moringa leaf extract, 2 spray (30 and 50 DAS), **SWE+MWE**= 3% Sorghum water extract + 3% Maize water extract, 2 spray (30 and 50 DAS), **SWE+MLE**= 3% Sorghum water extract + 3% Moringa leaf extract, 2 spray (30 and 50 DAS), **MWE+MLE**= 3% Maize water extract + 3% Moringa leaf extract, 2 spray (30 and 50 DAS)

Table 6: Marginal Analysis (2014)

Treatments	Cost that vary (Rs.)	Net profit (Rs.)	Marginal cost	Marginal net benefits	Marginal rate of returns (%)
CK	0	126548			
WE	400	128753	400	2205	551.25
SWE	568	163822	168	35069	20874.4
SWE+MWE	576.5	164068	8.5	246	2894.12
RWE+SWE	581.5	164800	5	732	14640
MWE	585	161105	-	-	D
RWE+MWE	590	165826	8.5	1026	12070.6
RWE	595	159880	-	-	D
SWE+MLE	714	169452	124	3626	2924.19
MWE+MLE	722.5	147319	-	-	D
RWE+MLE	727.5	162198	-	-	D
MLE	860	168198	-	-	D

Cost that vary= It is the sum of the costs (both costs and opportunity costs) that vary for a particular treatment; Marginal costs= The increase in net benefit which can be obtained by changing from one production alternative to another; Marginal benefits = The increase in variable cost which occurs in changing from one production alternative to another.

$$\text{Marginal rate of return} = \frac{\text{Marginal benefits}}{\text{Marginal costs}} \times 100 = (\%)$$

D = Dominated treatment = Treatment which has higher costs but lower net benefits; **Rs.** = Rupees; WE=water extracts

Table 7 Marginal Analysis (2015)

Treatments	Cost that vary (Rs.)	Net profit (Rs.)	Marginal cost	Marginal net benefits	Marginal rate of returns (%)
CK	0	129615			
WE	400	130268	400	652.5	163.13
SWE	568	146440	168	16172	9626.19
SWE+MWE	576.5	174296	8.5	27856.5	327723.53
RWE+SWE	581.5	160176	-	-	D
MWE	585	140005	-	-	D
RWE+MWE	590	142718	-	-	D
RWE	595	137520	-	-	D
SWE+MLE	714	165896	-	-	D
MWE+MLE	722.5	164253	-	-	D
RWE+MLE	727.5	161445	-	-	D
MLE	860	166825	-	-	D

Cost that vary= It is the sum of the costs (both costs and opportunity costs) that vary for a particular treatment; **Marginal costs**= The increase in net benefit which can be obtained by changing from one production alternative to another; **Marginal benefits** = The increase in variable cost which occurs in changing from one production alternative to another

$$\text{Marginal rate of return} = \frac{\text{Marginal benefits}}{\text{Marginal costs}} \times 100 = (\%)$$

D = Dominated treatment = Treatment which has higher costs but lower net benefits; **Rs**. = Rupees

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