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Effect of Smoke in Water Extract on Growth and Yield Performances of Barley (*Hordem vulgare* L.)

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Abstract

Seed germination, growth and seed vigourisity problems are the major bottlenecks that can reduce the yields of crops. Thus, this experiment was done with the objective of identifying the effect of seed treatment with water extracted smoke solutions on seedling performances and yield and yield related traits of barley cultivar (1307) under both field and laboratory conditions. The treatments included smoke water sources of–Acacia albida, *Juniperous procera* and wheat straw in four different concentrations (1:200, 1:400, 1:600, 1:800 and 1:1000 with cold water as a control); and foliar application was used with the same treatment at field study. Smoke solutions were produced by burning small quantities (50 g dry leaves/500 ml distilled water) of dried plant material from a range of species in a bee smoker attached by hose to a side-arm flask to pull the smoke through the water. The dilution of an aqueous smoke extract produced from uninterrupted bubbling of smoke from each plant had taken and steeping barley kernels in different dilutions from three plant-derived smoke-water resulted in earlier radical emerged after 48 hours and more uniform germination observed in laboratory. Foliar treatment also applied at field experiment to the stem and leaves of young seedlings by spraying with smoke-water solution after 20 days and at flowering stage. Treating barley seed with smoke-water showed a significant ($P<0.05$) improvement in speed of germination, increment in seedling vigourisity index, fresh/dry weight, number of tillers, grain yield, stem thickness and other yield related parameters compared with the control. Among all treatment smoke extracted from Juniperous in 1:800 ml concentrations showed the highest result in most of the growth parameters. This study indicated that seed treatments and foliar application with smoke-water showed promising results in improving seed germination, seedling growth and crop productivity. Thus, it was concluded that application of *Juniperous procera* extracted smoke solution at 800 ml improved both seedling germination and growths, and yields of barley as compared to the other sources.

Keywords: Application; Growth Performances; Seed Priming; Water Extracted Smoke; Acacia Albida; Juniperous procera; Wheat Straw

Introduction

Barley has been produced in Ethiopia, since ancient times and is one of the most important staple food and malting crops in the highlands of Ethiopia which is used to prepare various types of food and local and industrial beverages [1]. Seed dormancy is a quantitatively inherited trait in several plant species such as rice, popular, arabidopsis, wheat and barley [2,3]. In barley, seed dormancy and germination have been important breeding objectives since its domestication and malt utilization. Pre-harvest sprouting susceptibility is determined mainly by genotype; some varieties are resistant due to deep dormancy, others are highly susceptible, and a third group are intermediate [4]. A high level of seed dormancy is a problem in cultivars when rapid seed germination on planting is needed. In the malt house, seeds must germinate rapidly and completely upon imbibitions of water, and a high level of dormancy after harvest is economically undesirable [5]. Nevertheless, stringent phenotypic selection against seed dormancy can lead to the development of barley cultivars susceptible to pre-harvest sprouting, which is also highly undesirable [6]. During domestication, non-dormancy of seeds was selected for, so that in cultivated barley more that 90% of all seeds germinate within 4 days of imbibitions, whereas in the wild form, species spontaneum, seed germination is highly irregular Von Bothmer Barley varieties developed for animal feed have not undergone such strong selection for low dormancy, and many six-rowed varieties have variable to high levels of dormancy [7]. Coat imposed dormancy in barley may last 0.5–9 months in dry storage [8]. Barley seed dormancy is a quantitative trait that is affected by several genes, environmental factors, and by gene environment interactions [2].

Consequently, different studies were done to identify important chemicals and sources that can minimize the seeds dormancy; DeLange, et al. [9] were the first to report that compounds found in plant smoke stimulated seed germination. Several aspects of fire, such as heat, quick release of nutrients from burnt plant tissue, and compounds in ash, have been studied for their influence on seed germination, stimulates seedling vigor of grains and/ or plant growth [10-12]. Different reports were indicated that many people stores their seeds over a fireplace where seeds are exposed to smoke and heat which believed that it gives protection to the grain against insect and fungal attack, and furthermore, improves seed germination and seedling vigour [10,12]. Studies with smoke have shown that aqueous smoke solutions exhibit hormone-like responses in many species and interact with gibberellins, cytokinins, abscisic acid and ethylene in photoblastic and thermo dormant seeds Van Staden, et al. The significance of the discovery in nineties that plant-derived smoke is responsible for promoting seed germination [9] has quickly captured the attention of both basic and applied plant scientists for its novel and surprising effects.

Thus, germination of species from both fire-prone and fire-free habitats is improved by treatment with aqueous extracts of plant-derived smoke were the first to show that the active component(s) of aerosol smoke are soluble in water and that seeds soaked in an aqueous solution of smoke showed improved germination [9]. They obtained their aqueous smoke solution by forcing smoke, generated in a drum, to bubble through distilled water using compressed air. Although it is currently unknown how smoke acts to promote germination and improve seedling vigour, aerosol smoke and smoke solutions can potentially be used for a variety of applications related to seed technology [14].

Seed priming is an effective tool to minimize time between germination and emergence which resulted in synchronized emergence [15]. Treating seeds with smoke promotes germination smoke can also stimulate flowering, root initiation [16], and seedling vigour [17,18]. Findings on the mechanisms involved in smoke action are not conclusive, but smoke enhances the passage of solutes through the seed membranes of some species [19]. Smoke can also act on the seed coat in a way similar to scarification, thereby increasing seed on coat permeability to water and oxygen [20]. This mechanism may be dependent on species [19,21]. Seed priming treatments have been used to accelerate the germination and seedling growth in most of the crops under normal and stress conditions [22]. Farooq, et al. reported that primed crops grew more vigorously, flowered earlier and yielded higher; seed priming improved emergence, stand establishment, tillering, allometry, grain and straw yields, and harvest index. To get rapid and uniform germination and seedling establishment it is important to treat with some solutions. Thus, this study was developed to identify the effects of seed priming and foliar application of water extracted smoke on germination and growth performances of barely.

Materials and Methods

Description of the Study Area

A field experiment was conducted during 2015/16 of the main cropping season at Eteya (Gonde) sub-center of Ethiopian seed enterprise (ESE) in Arsi Zone of Oromia Regional State. The site is located 152 km from Addis Ababa in South-Eastern part of Ethiopia and 30 km from Asella town. The site soil is classified as clay loam type, and situated at an altitude of 2255 m.a.s.l and located at 8^{o}3’N and 39^{o}12’S with the annual average rainfall of 812mm (Table 1). Laboratory experiments were conducted at National seed laboratory, Addis Ababa, Ethiopia.

	Monthly Rainfall in mm					
	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall in (mm)	35.1	48.21	45.5	1.8	29.5	1
Minimum Temperature in (°C)	11.82	10.49	4.91	8.88	8.76	6.05
Maximum Temperature in (°C)	23.93	24.02	21.88	25.61	22.73	23.02

Source: Ethiopian Seed Enterprise (Eteya Gonde), 2015.
Table 1: Metrological data of the study area (Ethiopian seed enterprise; Eteya Gonde).

Experimental Materials and Procedures

Seed samples of improved food barley seed variety (HB-1307) was obtained from Ethiopian seed enterprise particularly at Eteya (Gonde) store (Table 2). A smoke derived plant of Acacia was collected from Arsi University, Juniperous from Asella seed laboratory and wheat straw where purchased from Asella town. The experiment was conducted both in the laboratory and at field. An aqueous smoke extracts obtained from burnt plant material i.e., *Accacia albida*, *Juniperous procera*, and wheat straw was utilized for the experiment. The dilution of an aqueous smoke extract produced from uninterrupted bubbling of smoke from each plant 50 gram leaf material through 500ml water for 45 minutes [21]. The butenolide [3-methyl-2H-furo (2,3-c) pyran-2-one] was isolated from plant-derived smoke according to the method outlined by Van Staden, et al. [14] and 0.1mM or 1ml concentration solution was used by diluting smoke extract with distilled water to the concentrations of 1:200, 1:400, 1:600, 1:800 v/v and 1:1000 ml cold water including control with dry seed and soaked for 24 hours before sawing. Foliar treatment was also applied to the stem and leaves of young seedlings by spraying with smoke-water or butenolide solution after 20 days of germination and at flowering stage according to the previously mentioned solutions.

Property	Values
Days to flowering (after planting)	83
Days to maturity	137
Plant height (cm)	106 cm
Yield (Qt ha^{-1})	
-Research field	48 $Q.ha^{-1}$
-Farmer field	35$Q.ha^{-1}$
Fertilizer rates (kg ha^{-1})	
-N	46
-P_2O_5	41
Year of release	2006 by HARC

Source: Annual Variety Release and Registration Book by Ministry of Agriculture 2006 Regulatory Directorate.
Table 2: Main characteristics of the food barley variety namely, HB-1307 (EH-1700/F_{71}.B_1.63).

Experimental Treatments and Design

The study was conducted both in the laboratory and under field condition. The field treatments were consisted of 14 levels of the smoke solutions as treatments on one Barley variety (HB-1307; EH-1700/F_{71}.B_1.63**)**. The experiment was laid out as a Randomized Complete Block Design (RCBD) with three replications. Each plot contained an area of 1.5mx3m= 4.5m^2 and a total crop area of 189m^2 with the spacing between adjacent plots and blocks were 0.5m and 1m, respectively and there were 7 rows per plot. The laboratory study was under taken at Addis Ababa National Seed Quality Control and Testing Laboratory of Ministry of Agriculture. Out of these tests only speed of germination was done in four replications and the other tests were performed in three replications. The laboratory study included standard germination percentage, speed of germination, shoot length and root length(cm), dry weight(mg), vigor index I, vigor index II and fresh weight. In order to test the quality of barley seed before priming with the smoke water the samples were examined the physical purity, moisture percentage and thousand weight tests.

Experimental Treatments in Field and Laboratory:

- **Treatments**: **T1-** Control (Dry seed) and **T2-** cold water (1000) ml
- **With smoke water**

Accacia ----- 800 ml→**T3**, 600 ml→ **T4**, 400 ml→ **T5**, 200 ml →**T6**

Juniperous ----- 800 ml→**T7**, 600 ml→ **T8**, 400 ml→ **T9**, 200 ml →**T10**

Wheat straw --- 800 ml→**T11**, 600 ml→ **T12**, 400 ml→ **T13**, 200 ml →**T14**

Procedures of Aqueous Smoke Solution: After collection, materials from each plant species were placed into an individual paper bags. The woody species were chipped and the leaves were cut into small pieces. Each sample was mixed thoroughly to maximize homogeneity and allowed to air dry. Aqueous smoke solution was prepared by mixing plants among which *Juniperous procera*, Acacia, and wheat straw Baker in a 100 mm diameter and 200 mm depth beekeeper's smoker according to the treatment levels. The produced smoke was forced through a plastic hose fitted to the mouth of the smoker by applying pressure on bellow (air holding and pumping part of the smoker) into a 500 ml Erlenmeyer flask containing 250 ml of double distilled water. The mouth of the flask was plugged with a smoke tight rubber material whose center has been hollowed to allow the entry of plastic hose to the flask. The smoke was forced to bubble into 250 ml of double distilled water for 45 minutes (Figure 1). The resulted smoke water was maintained as stock water in a refrigerator and the latter used to prepare cold aqueous smoke extract of different dilution levels.

Figure 1: Arrangement of the apparatus used for smoke extraction.

Field Management: Land preparation was done after the onset of rains. Seeds were sown in rows by hand using recommended seeding rate of 125 kg/ha on July 11, 2015 and Diammonium phosphate (DAP) fertilizer was applied at a rate of 100 kg/ha at sowing time. Weeds were controlled by hand weeding uniformly. All the agronomic practices recommended for seed production, such as weeding, cultivation and rouging were undertaken from land preparation through seed processing and drying.

Data Collection

Data for samples had taken from Ethiopian seed enterprise at Eteya Gonde field and at national seed laboratory; and was collected primarily from the germination and vigor tests both in the laboratory and in field experiment for yield and yield related parameters. Average normal seedlings were counted from the three replications of all tests throughout the evaluation period in order to estimate germination percentage and four replications were used for germination speed. In addition the samples were tested for their seed purity, moisture content, shoot length and root length (cm), dry weight (mg), vigour index I, vigour index II, fresh weight.

Field Data: The following growth parameters were collected like days to heading (number of days from crop emergence to 50% heading or panicle emergence), days to maturity (number of days from crop emergence to physiological maturity), determination of chlorophyll amount (photosynthetic rate versus chlorophyll content, both on a unit leaf area basis, measured on the youngest, fully expanded leaves (exclude the veins) in the field using an apparatus spad-502 from 20 average plants were in the flowering stage, 4l-52 days from planting), stem thickness (determined at maturity and measured by automatic calibration taken from two parts of the stem above the lower and the middle nodule from 10 randomly selected plants in the central harvested rows), plant height (measured at physiological maturity from the soil surface to the tip of the spike from 10 randomly selected plants in the central harvest rows), and population density (determined by counting all the plants from the yield harvested rows).

At maturity plants were harvested and threshed manually to record yield and yield related parameters like number of grains per spikelet, productive tiller number, grain yield per hectare, biological yield (whole above-ground plant biomass was harvested from each plot), and harvest index (the ratio of grain yield to biological yield).

Laboratory Data:

- **harvesting and threshing:** plants from the central three rows of each plot were subjected to yield evaluation and seed quality analysis. Seed moisture content was determined using the digital moisture meter in the field so as to determine harvesting. After harvest, threshing, and drying, seeds of the same treatments from the three replications were separately weighed and bulked together whereby sampled for laboratory analysis. Seed yield and 1000 kernel weight of the crop were determined in kg ha^{-1} and grams, respectively at adjusted moisture content (MC %) of 12.5% using the following relationship and converted to hectare [23].
- **Quality parameters:**
  Germination % using ISTA rule: The seedlings were evaluated in to normal seedling and abnormal seedling, dead and fresh ungerminated seed at the end of incubation period. Finally, each sort of germination components calculate on percentage bases (ISTA).

$$Germination\% = \frac{Total\ number\ of\ normal\ seedlings}{Total\ number\ of\ seeds\ planted} \times 100$$

- **Speed of germination:** Four replicates of 25 seeds per replication planted on sand media from each sample and kept in germination room for 7 days. Each day normal seedlings were removed at predetermined size and time identified normal seedlings. An index was calculated by dividing the number of seedlings removed each day by the number of days Maguire. Seed lots having greater germination considered as more vigorous. The following formula was employed to calculate speed of germination (SPG):

$$X = \frac{Number\ of\ normal\ seedling + ... + Number\ of\ normal\ seedling\ on\ the\ final\ day\ count}{Day\ of\ first\ count\ days\ at\ final\ count}$$

- **Seedling root and shoot length Test (cm):** For this test, seedling shoot length and root length were measured after final count in standard germination test. Only ten normal seedlings were randomly selected from each replicate. Shoot length was measured from the point of attachment to the tip of the seedling. Similarly, root length was measured from the point of attachment to the root. The average shoot and root length was computed by dividing the total shoot and root lengths by the total number of normal seedlings, respectively [24].
- **Seedling dry weight:** Seedling dry weight was measured after the final count in the standard germination test. At the end of each test, number of normal and abnormal seedlings were counted and germination percentage was calculated ISTA. Only ten normal seedlings were randomly selected from each replicate and were cut free from their cotyledons thereby placed in envelopes and dried in an oven maintained at 70^0c for 24 hours. Then dry weight was measured in mg using Sensitive balance and the average seedlings dry weight for each treatment in each replicate was determined [25].
- **Seedling fresh weight:** Only ten normal seedlings were randomly selected from each replicate. And the fresh weight was measured in mg using sensitive balance and the average seedlings fresh weights for each treatment in each replicate were determined.
- **Seed vigour index:** Seed vigour index was calculated by adopting the method suggested by Abdulbaki, et al.
- **Vigor index I and vigor index II:** For each treatment two vigor indexes were calculated. Seedling vigor index I was calculated by multiplying the standard germination with the average sum of shoot length and root length after 7 days of germination, and vigor index II by multiplying the standard germination with mean seedling dry weight. Seed vigor index I was calculated by the following formula:-

$$Vigor\ Index\ I = \text{Standard } germination\ (SG\%) \times Mean\ (shoot\ length + Root\ length)\ (cm)$$

Seed vigor index II was calculated as:-

$$Vigor\ Index\ \text{II} = \text{Standard } germination\ (SG\%)\ \times Mean\ seedling\ dry\ weight\ (mg)$$

- **Physical purity test:** The physical purity was conducted by taking 120gm barley seed as working sample. Then, the sample was divided into pure seed, other crop seed and inert matters [26]. After weighing each separated components of two duplicates, the percentage of physical purity on weight basis was calculated.

$$Purity\ \% = \frac{weight\ of\ pure\ seed\ fraction}{The\ sum\ of\ the\ weight\ of\ all\ components} \times 100$$

- **Moisture test:** The submitted sample was thoroughly mixed and reduced to working sample and tested for its moisture determination by using oven methods. This test was conducted as per [27] rule. The determination of the seed moisture content by oven method carried out for two replicates for 10g of working sample was weighed with a large container and dry for a period of 2 hours at the temperature of 130 ± 2 ^{0}C. Then, by using weighing balance, the weight in gram of the container, cover and contents after drying the moisture in % was calculated by using the following formula.

$$Moisture\ \% = \frac{(M2 - M3)}{M2 - M1} \times 100$$

Where

M_1 = weight of empty container with lid.

M_2 = weight of container with seed and lid before drying.

M_3 = weight of container with seed and lid after drying.

- **Thousand Kernel weight:** Two replicates of 1000 seeds from the pure seed fraction counted manually and the average kernel weight was calculated.

Data Analysis

All the measured variables were subjected to analysis of variances (ANOVA) using SAS 2009 standard procedures of version 9.2. Least Significance Differences (LSD) at 5% significance level was used to separate the significant means.

Results

Effect of Smoke-Water on Growth, Yield and Quality Components of Barley

The mean square values for germination, growth, yield and quality parameters showed that a variation in water extracted smoke application on barley seeds under both laboratory and field studies. The crop had no significant difference in seedling root length and date of heading, but had detectable differences in the speed of germination, seedling shoot length, vigourisity, fresh and dry weights, plant height, chlorophyll content, spikelet number, stem thickness, total population density, number of tillers, grain yield, biological yield and harvest index (Tables 2-6). The difference between the treatments in relation to seedling shoot length and vigour index-I were significantly differed at P<0.05 significance level. Seedling root length and date of heading did not show significant variations.

Influence of Smoke-Water of Different Plants on Barley Seed Germination

Application of smoke water which was extracted from three different plants significantly affected the germination of barley seed (Table 3). The higher speed of germination was recorded from barley seeds treated with different sources of smoke water with the mean values of 10.63 to 10.79; but the lowest germination speed was obtained from those treated with cold water and from those grown on the control plot.

Those seeds treated with different smoke water were not significantly differed from each other (10.63-10.79) except from those seeds treated with cold water and control (5.94-7.02). A maximum speed of germination was recorded in seeds primed with Acacia-200 ml which improved the speed of germination by 34.93% and 44.94% over the cold water treated and control plot, respectively.

Treatment	Speed of Germination
1. Control	5.94^{c}
2. Cold water(1000ml)	7.02^{b}
3. Acacia 200ml	10.79^{a}
4. Acacia 400ml	10.63^{a}
5. Acacia 600ml	10.75^{a}
6. Acacia 800ml	10.75^{a}
7. Juniperous 200 ml	10.71^{a}
8. Juniperous 400 ml	10.75^{a}
9. Juniperous 600 ml	10.67^{a}
10. Juniperous 800 ml	10.63^{a}
11. Wheat straw 200 ml	10.75^{a}
12. Wheat straw 400 ml	10.71^{a}
13. Wheat straw 600 ml	10.67^{a}
14. Wheat straw 800 ml	10.75^{a}
Significance 5%	***
CV	2.41

SG: speed of germination. Means followed by the same letters in the same column are not significantly different $p < 0.05$. LSD= List Significant Differences.

Table 3: Effect of smoke-water on barley seed germination in the laboratory experiment.

Influence of Smoke Water of Different Plants on Seedling Growth

There was significant difference in shoot length, vigour-I and vigour-II, fresh seedling weight, dry seedling weight; but seedling root length did not show significant difference (Table 4). The highest shoot length was recorded from those treated with Acacia extracted smoke solution at 400 and 800 ml, Juniperous at 400 and 600ml, and wheat straw at 800 ml; but the lowest shoot length was recorded from those treated with cold water and those grown on the control plot. Also highest vigour index-I was recorded from those treated with wheat straw and Juniperous extracted smoke solutions at a concentrations of 800 ml and 600 ml (2681.28 and 2667.56 cm), respectively and the lowest vigour index-I was recorded from the control plot (2265.76 cm). In the case of vigour index-II and fresh and dry seedling weights the highest were recorded for those treated with Juniperous extracted smoke solution at a concentration of 800 ml application (20.42, 1.76 mg and 0.21 mg) with the lowest values of 9.57, 0.871 mg and 0.098 mg obtained from the control plot, respectively (Table 4). The smoke water supplied kernels (24 h steeping in S.W) had significantly improved the shoot length growth which ranged from 15.35% to 9.86%, and showed in increased vigor index I and vigour index-II by 15.5% and 53.12% as compared to the untreated kernels. The highest fresh and dry weights were improved by 50.48% and 52.89%, respectively as compared to the lowest weights obtained from the seedlings grown on the control plot. Generally shoot seedlings were longer, vigour index I and vigour index II also increased after primed in smoke solutions extracted from Acacia, Juniperous and wheat straw as compared with distilled water and non-primed control.

Treatment	Seedling growth parameters					
	Seedling	Seedling	Vigour index-I	Vigour index-II	Fresh seedling weight (mg)	Dry seedling weight (mg)
	Shoot length (cm)	Root length (cm)				
1. Control	13.35^{c}	9.77^{a}	2265.76^{c}	9.57^{i}	0.871^{i}	0.098^{i}
2. Cold water(1000ml)	13.91^{c}	11.02^{a}	2442.81^{bc}	11.21^{h}	0.892^{i}	0.114^{h}
3. Acacia 200ml	14.99^{ab}	10.53^{a}	2500.96^{ab}	16.17^{c}	1.578^{bc}	0.119^{gh}
4. Acacia 400ml	15.69^{a}	10.98^{a}	2613.99^{ab}	12.28^{g}	1.259^{g}	0.125^{g}
5. Acacia 600ml	15.13^{ab}	11.13^{a}	2573.48^{ab}	12.25^{g}	1.260^{g}	0.125^{g}
6. Acacia 800ml	15.61^{a}	11.19^{a}	2625.75^{ab}	11.70^{gh}	1.167^{h}	0.165^{c}
7. Juniperous 200 ml	14.81^{ab}	11.13^{a}	2542.77^{ab}	13.30^{f}	1.46^{f}	0.136^{f}
8. Juniperous 400 ml	15.42^{a}	11.36^{a}	2624.44^{ab}	14.60^{d}	1.56^{cd}	0.149^{d}
9. Juniperous 600 ml	15.77^{a}	11.45^{a}	2667.56^{a}	14.18^{de}	1.547^{cd}	0.145^{de}
10. Juniperous 800 ml	15.31^{ab}	10.88^{a}	2566.95^{ab}	20.42^{a}	1.759^{a}	0.208^{a}
11. Wheat straw 200 ml	15.15^{ab}	11.21^{a}	2583.93^{ab}	13.49^{ef}	1.48^{ef}	0.138^{ef}

12. Wheat straw 400 ml	14.95^{ab}	10.90^{a}	2533.63^{ab}	14.01^{de}	1.52^{de}	0.143^{de}
13. Wheat straw 600 ml	15.09^{ab}	11.45^{a}	2600.92^{ab}	18.39^{b}	1.63^{b}	0.188^{b}
14. Wheat straw 800 ml	16.26^{a}	11.10^{a}	2681.28^{a}	15.78^{c}	1.57^{cd}	0.161^{c}
Significance 5%	**	NS	**	***	***	***
CV(%)	5.79	5.94	4.38	2.94	2.25	2.94

Source: Where, RL= root length SL= shoot length, VI= vigor index one, VII= vigor index two, SDW= seedling dry weight, SFW= seedling fresh weight. Means followed by the some letters in the same column are not significantly different p < 0.05. LSD= List Significant Difference.

Table 4: Effect of smoke-water application on seedling growth, vigourisity, fresh and dry weights of barley seed in laboratory.

Effect of Smoke-Water on Growth Parameters (Field Experiment)

All the plants treated with smoke solutions had significant (P<0.01) variations except date of heading. Application of smoke water extracted from different plant types to barley seedlings on the field also showed significant variations on the growth parameters and chlorophyll content of the crop (Table 5). Highest chlorophyll content was observed on barley plants treated with smoke water extracted from Acacia at 200 ml solution (35.97) and lowest was from the control (30.33). This highest chlorophyll was increased by 13.35% and 15.68% as compared to those treated with cold water and control, respectively. The highest stem thickness was obtained from those plants treated with Acacia 200 ml solution (3.82 mm) and the lowest from the cold water treated and control (3.30 and 3.18) respectively which was increased over those grown on cold water treated and control plots by 13.61% and 16.75%, respectively. Primed seeds and foliar application of aqueous smoke solutions of Acacia at 200 ml and 800 ml and Juniperous at 800 ml gave highest plant height of barley. Acacia extracted smoke solution application to barley seeds at 200 ml increased plant height by 9.08% and 11.29% as compared to those seeds primed in distilled water and those non primed (control), respectively. Highest population density of barley seedlings was obtained from those treated with smoke solution derived from Acacia at a concentration of 800 ml which improved the population of plants over those grown on the control plot by 26.58%. The smoke water treatments improved plant height, Stem-thickness showed significant increase in response to all the smoke-related treatment in comparison with those grown on the control plot.

Growth parameters					
Treatment	**Chlorophyll**	**Stem thickness (mm)**	**Date of heading**	**Total pop density**	**Plant height (cm)**
1. Control	30.33^{g}	3.18^{h}	68.67^{ab}	3,383332^{j}	69.633^{f}
2. Cold water(1000ml)	31.17^{fg}	3.30^{g}	68.33^{ab}	3,427776^{j}	71.367^{ef}
3. Acacia 200ml	35.97^{a}	3.82^{a}	67.67^{b}	4,299998^{d}	78.50^{a}
4. Acacia 400ml	32.63^{edf}	3.73^{b}	69.33^{a}	3,569443^{i}	76.867^{abc}
5. Acacia 600ml	33.43^{bcd}	3.55^{de}	69.00^{ab}	4,194443^{e}	76.967^{abc}
6. Acacia 800ml	34.7^{abc}	3.73^{b}	68.00^{ab}	4,608331^{a}	78.167^{a}
7. Juniperous 200 ml	31.63^{efg}	3.59^{cd}	69.00^{ab}	3,861110^{g}	74.833^{bcd}
8. Juniperous 400 ml	35.03^{ab}	3.78^{ab}	68.00^{ab}	4,413887^{bc}	76.23^{abcd}
9. Juniperous 600 ml	32.50^{edf}	3.61^{cd}	69.00^{ab}	4,130554^{e}	74.47^{cd}
10. Juniperous 800 ml	34.77^{abc}	3.76^{ab}	69.00^{ab}	4,472220^{b}	78.07^{a}
11. Wheat straw 200 ml	33.13^{cde}	3.46^{f}	69.00^{ab}	3,741665^{h}	73.733^{de}
12. Wheat straw 400 ml	33.30^{cd}	3.61^{cd}	69.00^{ab}	3,944443^{fg}	76.133^{abcd}
13. Wheat straw 600 ml	33.37^{cd}	3.48^{ef}	69.33^{a}	3,966665^{f}	73.7^{de}
14. Wheat straw 800 ml	33.60^{bcd}	3.62^{c}	69.33^{a}	4,344443^{cd}	77.7^{ab}
Significance 5%	***	***	NS	***	***
CV	2.97	3.59	1.36	1.55	2.35

Source: Where, CL= chlorophyll, ST= Stem thickness, DH= Date of heading, TPP= Total population density, PH= Plant height. Means followed by the same letters in the same column are not significantly different; P < 0.05. LSD= List Significant Differences.

Table 5: Effect of smoke-water on chlorophyll content, stem thickness, date of heading, total population density, plant height of barley in the field condition.

Effect of Smoke-Water Solutions on Yield and Yield Components of Barley

Yield and yield components of barley showed significant (P<0.01) variations due the applications of water extracted smoke on the crop in the field (Table 6). Number of tillers, seed per spike, grain yield, biological yield and harvest index showed improvement with the application of smoke-water extracts from different plant types than those grown with cold water application and those grown without any treatment. Highest number of tillers per plant (9.06) was obtained from those plants treated with smoke water extracted from wheat straw at 400ml solution and lowest from those treated with cold water and control; which increased by 31.57% and 33.11%, respectively (Table 6). Seed per spike are among the yield components which was affected significantly by the applied smoke water and the highest mean values shown in Juniperous at 400 ml application (44) which are higher than the other remaining treatments, and the lowest mean values was recorded from those treated with cold water and those grown on the control (39.33 and 38.33), respectively. Application of Juniperous tree extracted smoke solution improved seed per spike by 12.88% and 10.61% than those obtained from the cold water treated and control, respectively. Application of Acacia smoke solutions at levels of 200 ml and 800 ml, and Juniperous solutions of at 400 ml and 800 ml levels produced higher grain and biological yields of barley crop than the other treatments and lowest grain and biological yields were recorded from those planted on the control plot (Table 6). Application of smoke-water extracted from Juniperous plant at 800 ml solution increased barley grain yield by 23.87% and 29.76% as compared to those treated with cold water and grown on the control, respectively. Application of smoke solution extracted from Acacia at 200 ml and 800 ml levels, Juniperous at 400 ml and wheat straw at 800 ml significantly produced higher harvest index of barley crop as compared to the other treatments; and lowest was produced from those treated with Juniperous at 200 ml and those grown on the control plot.

	Yield attributes				
Treatment	Seed per Spikelet	No of tillers	Grain yield (qt)	Biological yield (qt)	Harvest Index
1. Control	38.33^{g}	6.06^{e}	30.49^{g}	113.33^{f}	0.269^{e}
2. Cold water(1000ml)	39.33^{g}	6.20^{e}	33.05^{f}	121.66^{e}	0.272^{ed}
3. Acacia 200ml	42.67^{abcd}	8.67^{ab}	41.91^{ab}	143.33^{ab}	0.292^{a}
4. Acacia 400ml	41.33^{de}	7.93^{abcd}	35.63^{de}	131.66^{cd}	0.271^{ed}
5. Acacia 600ml	42.00^{bcde}	7.97^{abcd}	36.88^{cde}	132.22^{cd}	0.279^{cde}
6. Acacia 800ml	43.33^{abc}	7.93 ^{abcd}	42.86^{ab}	145.83^{ab}	0.294^{a}
7. Juniperous 200 ml	41.67^{cde}	7.03^{de}	36.19^{cde}	134.44^{cd}	0.270^{e}
8. Juniperous 400 ml	44.00^{a}	7.27^{bdce}	43.05^{ab}	146.66^{a}	0.293^{a}
9. Juniperous 600 ml	42.00^{bcde}	6.73^{de}	38.16^{c}	138.33^{bc}	0.276^{cde}
10. Juniperous 800 ml	43.67^{ab}	8.57^{abc}	43.41^{a}	149.94^{a}	0.291^{ab}
11. Wheat straw 200 ml	40.67^{ef}	7.17^{cde}	34.66^{ef}	126.66^{de}	0.274^{ed}
12. Wheat straw 400 ml	41.33^{de}	9.06^{a}	37.97^{cd}	134.99^{c}	0.28^{bcd}
13. Wheat straw 600 ml	41.33^{de}	7.73^{abcd}	38.24^{c}	134.16^{cd}	0.285^{abc}
14. Wheat straw 800 ml	42.67^{abcd}	7.97^{abcd}	40.88^{b}	138.6^{bc}	0.295^{a}
Significance 5%	***	***	***	***	***
CV	2.48	11.25	3.88	3.53	2.34

SPS: Seed per spikelet, NT= Number of tillers GY= Grain yield, BY= Biological yield, HT= Harvest Index. Means followed by the same letters in the same column are not significantly different p < 0.05. LSD= List Significant Difference.

Table 6: Effect of plant derived smoke solutions on selected yield and yield components of barley.

Discussion

Laboratory Analysis for Smoke Water Effects on Crop Growth

Effects of Smoke Water Extracts: Priming seeds in aqueous smoke solutions derived from all the three plants (Acacia, *Juniperous procera*, Wheat straw) had a significant (P<0.05) effect on speed of germination, vigour index I and II, dry weight, fresh weight and shoot seedling length. Seedling root length did not statistically vary (p>0.05), but it showed greater number of lateral roots than untreated seedlings. The results indicated that the aqueous smoke solutions generated from all the three plants at different dilutions showed increased seedling lengths (combined hypocotyls) as compared to the control. These might be due to the regulatory hormone effects of the extracted aqueous solutions available in the plants.

Effects of smoke water on speed of germination: Aqueous smoke extract concentrations were significantly ($p \leq 0.01$) differed from the control and diluted water; maximum speed of germination percentages were observed for all dilutions but the average germination for all the treatments was almost similar (98%). The smoke-water treatment speed up early germination rates significantly when compared with the cold water treatment and control. Data collected from all different levels of smoke water solutions showed that on average 60% of them germinated on the second day and the rest 40% of them completed their germination on the third day. For those treated with cold water, about 36% and 64% of them had been germinated after 3rd and 4th days, respectively. However, only about 12% of those seedlings planted on the control were germinated on the third day, and 60% of them on the fourth day, and the rest 28% of them were germinated at fifth day. Data from day 2 and 3 of germination indicated that the smoke extract significantly increased germination when compared with cold water and control. This significant effect of the smoke extract treatment could be explained by the fact that the barley crop is responded positively to karrikans in promoting early germination. The most important aspect of smoke is the availability of nitrogenous compounds, nitrates, nitric oxides and cyanides Gavin, et al. which can reduces seed dormancy and increases seed germination [28.29].

The presence of karrikans was also found to induce the expression of minor genes like GAOX1, which serves as a signal for GA biosynthesis [30]; but at higher concentrations can also inhibit the germination of seeds [31]. Plant derived smoke produced that actively promotes germination of many plant species and resulted in identification of a family of structurally related plant growth regulators Light, et al. [30,32]. Seeds which have high germination rate could escape drought condition, thus helping to choose early varieties Maguire. The onset of many cellular processes in the quiescent barley seed upon imbibition gives rise to proteome changes. Apparently all components needed to resume metabolic activity are present in the dry mature seed in a potentially active form [33], including mRNA, ribosomal proteins initiation and elongation factors.

Effects of smoke solutions on shoot length: Application of smoke extracted from *Juniperous procera* at the concentration of 1:600ml and 1:400 ml, wheat straw at 1:800ml, acacia at 1:800 ml and 1:400 ml had in the same mean value with maximum response and the same effect was also observed in the case of shoot elongation. All dilutions of both smoke solutions showed significantly ($p<0.05$) higher relative shoot elongation and seedlings grown from seeds exposed plant derived smoke produced longer roots and shoots [12]. Similarly, all dilutions of smoke solutions produced longer shoots as compared to the others. Seedlings with well-developed shoot and root length would withstand any adverse environmental conditions and provide better seedling emergence and establishment in the field Zewdie. Seedlings produced a greater number of lateral roots than untreated ones. Overall, some concentrations of smoke-water and all tested concentrations of smoke water showed better vigor indices in this barley variety. A study conducted by Kulkarni, et al. [34] also indicated that smoke can be a useful treatment for improving the vigor of rice crop.

Effects of smoke water on seedling vigor, dry and fresh weight: Plants treated with smoke solutions increased vigor index significantly ($P<0.05$) as compared to those grown on the control. Those plants having higher seedling length have higher vigour index-I. Similarly seedling having higher dry weight also showed higher vigour index-II as compared to the control. Significant differences were observed for both vigor index-I and vigor index-II among all treatments; smoke extracted from Juniperous at 1:600ml and wheat straw at 1:800 ml concentrations showed the highest vigor index I and the rest smoke water dilution had in the second rank that is the same average mean vigour index and cold water (1000 ml) in third rank and the control have shown the lowest vigour index I. While, Juniperous at the concentration of 1:800ml showed the highest vigor index-II and the control have shown lowest vigor index-II. Studies have reported the effects of smoke on post germination levels (seedling vigour). It was shown that seedlings of Themeda triandra from smoke-treated seeds grew more vigorously without any abnormalities than untreated seeds [17], and a similar effect was reported for Erica species [33] Modi (2002, 2004) [10,13] also reported that smoke-treated kernels of traditional maize landraces produced more vigorous seedlings (heavier and taller) than the untreated kernels. A recent study indicated that the effect of smoke extends beyond germination and enhances seedling vigor [18].

Field Data Analysis for Smoke Water Effects on Crop Growth and Yields Performances

Effects of Smoke on Growth Performances of Barley: All the smoke-related treatments had significant ($P<0.001$) effect on growth attributes except date of heading. The smoke water treatments improved plant height, stem thickness and population density as compared to those grown on the control plot. It is also interesting that all smoke-related treatments improved stem-thickness of teff in a much similar fashion as that of the commonly used plant growth promoters such as ethephon [36,37]. The smoke-induced increase in stem-thickness with simultaneous increase in the number of tillers can improve resistance to lodging Kashiwagi, et al. [37]. Promoting tillering capacity (a trait positively correlated to grain and dry biomass) may entail significant yield improvements and may assist in combating chronic lodging problems of barley production.

Effects of smoke water on yield and yield components of barley: All the smoke-related treatments had significant ($p<0.01$) effect on the yield and yield components. There was an improvement on number of tillers, seed per spike, grain yield, biological yield and harvest index as compared to the control and cold water applied plants. Smoke water extracted from *Juniperous procera* at 1:800 ml and 1:400 ml levels followed by Acacia at 1:200 ml and 1:800 ml levels had a great effect in producing higher grain yield and dry biomass per hectare than those grown on the control plot. The results of the present study clearly showed that smoke treatment of barley seeds or treating seeds with plant-derived smoke solutions significantly promoted a number of growth and agronomic parameters of the crop which directly or indirectly related to yields. All smoke water applied increased the yields of barley and the highest total yield (43.41qha^{-1}) was produced by Juniperous at a concentration level of 1:800 ml followed by those applied Juniperous extract at 1:400 ml, acacia extract at 1:800 ml and 1:200 ml levels, whereas significantly lower total yield (33.05 and 30.49 qha^{-1}) was obtained from those treated with cold water and control, respectively. Final grain yield is largely determined by grain number, which is set by tiller survival and fertile spikelet number and survival.

In this study on the effect of plant-derived smoke solutions on germination of barley showed that the barley cultivar used (HB-1307) responded positively to smoke treatments. The smoke solutions tested also improved post-germination vigour indices of barley and most of the on field growth parameters examined for both the seed priming with aqueous smoke and foliar application of smoke-water showed a pronounced effect on growth of barley crop. These combinations of applied smoke-water clearly have a positive effect and the treatments were significantly increased, resulting in an improved grain and biological yields of the crop than those grown on the control. This study indicated that a useful and inexpensive technique for enhancing yield production of both cereal and vegetable crops. Several other studies revealed that smoke-water or smoke-derived compound can possibly be used in improving and promoting the growth of agriculture and horticulture crops such as red rice [38], indigenous maize [15], indigenous rice [34], commercial bean [12], okra [32] and onion [39]. Furthermore, Kulkarni, et al. [32] reported that the smoke-water treated tomato plants increased growth until the fruiting stage, fruited earlier and increasing number of fruit. These results indicated that smoke-water has potential to be used in promoting the growth of horticulture and other agricultural crops, for the production of healthy and vigorous seedling [14].

All smoke treated plants had significant ($p<0.01$) effect on growth like plant height, stem-thickness, number of seed per spikelet and population density which showed significant increase in response to all the smoke-related treatments. In comparison with the control, the positive role of smoke in promoting stem-thickness implied that effectively reducing grain yield losses due to lodging in other cereals, such as rice, wheat and barley, providing that they are responsive to smoke treatments. The smoke water significantly increased the total biomass of barley by increasing the biological yield (149.94 qt ha^{-1}) which was recorded from those treated with Juniperous at 1:800 ml level of application. Besides, the significant increase in spike length, number of seeds per spike, number of fertile tillers and biological yield contributed to the significant increment of the total grain yield. This is also in agreement with the report of Alam, et al. [40] who reported higher crop yield is the ultimate goal for cereal cultivation and a number of strategies are underway to increase this attribute. Crop yield in cereals is mainly determined by optimum plant population, number, and the size of grains. A number of reports shown that seed priming enhanced the crop productivity by either increasing the emergence number, size of grain, or a combination of the former Ashraf, et al; Athar, et al. [41].

Effects of smoke water on photosynthetic pigments: Application of smoke water significantly increased chlorophyll contents of the leaf in all the primed treatments as a better reading of chlorophyll measurement was observed from those treated plants than the non-primed control and cold water treated. Smoke water extracted from acacia at a level of 1:200 ml showed the highest detection through chlorophyll measurement on the leaf followed by those treated with both Acacia at 1:800ml and Juniperous at 1:800 ml. The highest chlorophyll result which was recorded from those treated with smoke water derived from acacia at 200 ml (35.97) improved the chlorophyll content by 15.68% and 13.35% as compared to those obtained from the control and cold water treated, respectively. However, all the smoke-related treatments increased the accumulation of chlorophyll in the leaves as compared to the control. Chlorophyll plays a crucial role for the photosynthetic processes including light harvesting and energy conversion, and thus, the content of chlorophyll is a potential indicator of a range of stresses [42-47].

Conclusion

All the smoke-related treatments were significantly promoted stem-thickness as well as number of tillers per spikelet, plant height, population density, and grain and dry biomass responded positively to smoke-water treatments. The dilution of smoke water gave higher total yield (43.41 qt ha^{-1}) through application of Juniperous extracted smoke water at a concentration of 1:800 ml than the others; whereas lower total yield (33.05 and 30.49 qt ha^{-1}) was obtained from those treated with cold water and from the control, respectively. The combination of priming seed and foliar spraying with aqueous smoke solution or butenolide is a useful and inexpensive technique for enhancing seedling growth and crop productivity. Thus, it could be concluded that application Juniperous extracted smoke water solution at the level of 800 ml concentration has increased the seedling growth, yield and yield attributes, and chlorophyll contents of barley crop than the other plant sources and smoke water solution levels.

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