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THE ALLELOPATHIC EFFECT OF THE ORDINARY AND BURNT REMAINS OF BROOM SORGHUM ON GERMINATION AND DETERMINATION OF QUANTITY AND QUALITY OF PHENOLIC COMPOUNDS

Faezeh Shahmohammadi
Ph.D. Student of Agronomy and Plant Breeding, Miyaneh Branch, Islamic Azad University, Miyaneh, Iran, Email: f.shahmohammadi66@gmail.com; https://orcid.org/0000-0003-3649-9707

Mehrdad Abdi*
Department of Agronomy and Plant Breeding, Miyaneh Branch, Islamic Azad University, Miyaneh, Iran, dr.mehrdad.abdi@gmail.com, https://orcid.org/0000-0002-8129-6901

Ali Faramarzi
Department of Agronomy and Plant Breeding, Miyaneh Branch, Islamic Azad University, Miyaneh, Iran, Email: aliifaramarzii52@gmail.com, https://orcid.org/ 0000-0001-6008-8487

Jalil Ajali
Department of Agronomy and Plant Breeding, Miyaneh Branch, Islamic Azad University, Miyaneh, Iran, Email: jalil.ajali@yahoo.com; https://orcid.org/0000-0002-7235-8170

Hassan Nourafcan
Department of Agronomy and Plant Breeding, Miyaneh Branch, Islamic Azad University, Miyaneh, Iran, Email: hassannourafcan@gmail.com ; https://orcid.org/ 0000-0003-2489-1787

Abstract: Self-poisoning is actually a negative intra-species allelopathy and happens when the released chemical materials from a plant inhibit germination and growth of the same species plant. In this regard, a research was conducted as a completely randomized factorial design with 2 replications in 2020 to evaluate the effect of various concentrations of the ordinary and the burnt aerial parts extract of broom sorghum on the seeds germination of broom sorghum, alfalfa, barley, beans, canola, wheat, and corn in the laboratory of the Faculty of Agriculture, Islamic Azad University, Miyaneh Branch. Then, the ordinary and burnt remain of phenol compounds in broom sorghum were examined at various times and concentrations. The maximum reduction in the germination and initial growth of broom sorghum was in 8% extract concentration. The burnt remain of broom sorghum increased the initial growth and germination traits of agricultural products than its ordinary type. Weight of seedling was decreased by increasing the extract concentration. The burnt remain of broom sorghum increased the seedlings weight in all plants in all the evaluated traits than the ordinary broom sorghum. This increase was higher in sorghum, alfalfa, corn, and canola than the other plants. Allelopathic traits were higher in the burnt remains than the ordinary ones. The ordinary remains increase the wet weight and

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About the authors：Mehrdad Abdi

Corresponding author- dr.mehrdad.abdi@gmail.com

the burnt remains increase the dry weight of plants. Allelopathic effect of the ordinary remain of broom sorghum on the seedling of sunflower, the burnt remain on the rootlet length of wheat, and the ratio of rootlet of wheat than the other studied traits were higher in various sampling steps. The amounts of phenol compounds in ordinary remains of broom sorghum were different in different sampling times. Ordinary remains of broom sorghum had a high amount of phenol compounds in November, December, and January. The ordinary remains of broom sorghum had the maximum amount of phenol compounds in November and December. Therefore, they probably caused the maximum rainfall in germination indexes of broom sorghum. The plant type was different in various concentrations based on the production of the phenolic compound from each other. The phenolic compound in all concentration in leaves was higher than the stem. The effect of various concentrations in two organs of stem and leaf of broom sorghum changes the number, type, and size of phenolic compounds. This difference in size, type, and amount of allelochemical substances in different organs of this plant is influenced by various levels of extract concentration on allelopathic potential of broom sorghum. Generally, it can be claimed that the extract concentration can influence on the allelopathic potential of broom sorghum by changing the quality and quality of phenolic compounds.
Keywords: allelopathic, allelochemical, germination traits, allelopathy, quality and quantity of phenolic compounds

摘要：自毒实际上是一种负面的种内化感作用，是当植物释放的化学物质抑制同种植物的萌发和生长时发生的。对此，在 2020 年进行了 2 个重复的完全随机因子设计研究，以评估不同浓度的高粱普通和燃烧地上部分提取物对高粱、苜蓿、大麦、伊斯兰阿扎德大学农业学院 Miyaneh 分校实验室中的豆类、油菜籽、小麦和玉米。然后，在不同时间和浓度下检测了高粱中酚类化合物的普通和燃烧残留物。在 8% 的提取物浓度下，高粱发芽和初始生长的最大减少。高粱烧残渣比普通高粱提高了农产品的初始生长和发芽性状。通过增加提取物浓度来降低幼苗的重量。与普通高粱相比，高粱的燃烧残留物在所有评价性状的所有植物中均增加了幼苗重量。高粱、苜蓿、玉米和油菜的增幅高于其他植物。烧焦遗骸的化感性状高于普通遗骸。普通残留物会增加植物的湿重，而燃烧后的残留物会增加植物的干重。高粱普通残留物对向日葵幼苗的化感作用、小麦根长燃烧残留物的化感作用以及小麦根部比例在不同取样步骤中均高于其他研究性状。不同采样时间高粱普通遗骸中酚类化合物的含量不同。 11月、12月和1月，普通高粱残骸酚类化合物含量较高。普通高粱残骸酚类化合物含量最高的月份是11月和12月。因此，它们可能导致高粱发芽指数的最大降雨量。基于相互之间酚类化合物的产量，植物类型在各种浓度下是不同的。叶中所有浓度的酚类化合物均高于茎。高粱茎叶两个器官中不同浓度的影响改变了酚类化合物的数量、类型和大小。这种植物不同器官中化感物质的大小、类型和数量的差异受不同水平的提取物浓度对高粱化感潜力的影响。一般来说，可以声称提取物浓度可以通过改变酚类化合物的质量和质量来影响高粱的化感潜力。
关键词：化感作用，化感化学，萌发性状，化感作用，酚类化合物的质量和数量

1. Introduction

Broom sorghum with the scientific name of Sorghum vulgare var. technicum is a yearly plant from wheat family (Ashok Kumar et al., 2011 and 2013) and 25 species (USDA-ARS 2016) and is an important food and forage crop in rainfed agriculture (Riyazaddin et al., 2016). This is a high profit and strategic product in Miyaneh region used to prepare traditional brooms and provide grain for poultry and fodder for livestock (Jamshidi, 2002). Allelopathy is a control or stimulation by chemicals that are released by a plant/microorganism on the growth and germination of the other plant seeds (Farooq et al., 2011a and 2011b). Alternatively, allelopathy is stated as an interactive direct and indirect reaction of two plants and stimulating or inhibiting the effect of one plant on another by releasing chemical compounds to the environment (Jabran et al., 2015 and Cheng and Cheng, 2015). Auto-allelopathy is an interesting aspect of allelopathy in the agricultural systems by which a plant inhibits another plant's growth and germination by releasing chemical compounds. The root and aerial organs of sorghum release chemical compounds in other species of sorghum which have negative effects on the germination and growth of other plants (Reigosa et al., 2013). Self-poisoning is an intra-species allelopathy and happens when a plant type releases chemical compounds (Putnam, 1985) inhibiting germination and growth or delay it. Despite auto-allelopathy, it can't have positive and stimulating effects and is mostly observed during agronomical operations without plowing or plowing the area where plant debris remains on the ground. It decreases the yield of the yearly or perennial agronomical plants in sequential cultivation (Hashemizadeh, 2011). The plants residual is one of the significant resources of allelopathy compounds, enters soil immediately after harvesting, and influences the germination (Mighani, 2004). They are the main resources of allelopathy. Burnt remains can influence on the existed allelopathic compounds in the remains (Hashemizadeh, 2011). Moreover, burning the remains may reduce severe inhibitory effect of plants remain and ad some other nutrition to the soil. Therefore, some farmers burn the remains in sequential cultivation (York and Heald, 2007). The poisoning effect of the made compounds from plants won't stay in the soil for a long time. Degradation of crop remains depends on their species, climatic conditions, and management factors. The toxicity of the plant remains will reduce chronically (Kohli et al., 2001). The phenolic compounds are the main parts of the allelopathic traits of plants (Dyke and Rooney, 2006). The main objective of the allelopathic research is to provide a reason for the interference of chemicals under natural conditions and the introduction of allelopathic compounds that inhibit the growth of other plants and microorganisms in the natural or agricultural ecosystems. Another objective of this science is separation and identification of allelopathic compounds of plants or microorganisms or the existed compounds in the environments and their simulating effects which have been a little studied (Mighani, 2004). Allelopathy is actually a negative intra-species and happens when the released chemical compounds from a plant have an inhibitory effect on the germination and growth of the same species plants. Using the allelopathic traits of plants can have an important role in the control and management of weeds. These plants can have negative effects on the germination and growth of the adjacent weeds by releasing the produced secondary metabolites around them and limit their density. Therefore, using these plants and their remains can reduce the consumption of weed fertilizers (Macêdo et al., 2020). Allelopathy is produced during the metabolism of plants and may grow, survive, and reproduce the invasive species (Zheng et al., 2015 and Cheng and Cheng, 2015). The phenolic compounds are derived from the chemical metabolic paths and acetic acid (Li et al., 2010 and Singh and Geetanjali, 2015). Compounds with allelopathic traits of cells influence various division, physiology, and biochemistry such as growth, activity germination, root development, respiration, and photosynthesis. Moreover, concentration of allelopathic materials is reported in aerial parts of sorghum more than its root, and leaves are the main resource of allelopathic compounds (Ben Hammouda et al., 2001; Bonanomi et al., 2006; Kumar et al., 2009 and Jabran et al. 2015). Sorghum can produce allelopathic compounds from its rhizomes and leaves, and many observations show that root and remains secretion of this plant in soil inhibit germination and growth of several plant species (Lehle And Putnam, 1982). Kohli et al (2001) stated that the allelopathic effect of sorghum remains continue for several weeks after harvesting and plant growth inhibitive material are released from root, branch, leaf, and seeds during germination of sorghum. Allelopathic traits of the burnt remains were less than the ordinary remains. In addition, the ordinary remains of broom sorghum increase the wet weight and the burnt remains increase the dry weight of plants. Burning the broom sorghum remains reduced the allelopathy by 77% (Hashemizadeh et al., 2010). Allelopathic traits of broom sorghum enter the soil after harvesting and may influence the fluctuated germination and growth of plants (Roth, 1999 and Ghafarbi et al., 2012). The allelopathic effects are observable in all organizing levels of a living organism by physiological responses and cellular and molecular levels (Głąb et al., 2017). For example, some allelochemicals can influence the surrounding species seed germination by controlling the cell division and inhibiting the hydrolysis of nutrition resources (Irshad and Cheema, 2004). Others inhibit the respiratory chain by changing enzyme activity and electron transfer in photosynthesis (Hejl and Koster, 2004). However, the molecular target location of most allelochemicals is not well understood (Bertin et al., 2007; Kato-Noguchi and Peters, 2013; Romagni et al., 2000; Toyomasu et al., 2008).

Ethanolic extract of sorghum root has an inhibitory effect on wheat and corn and reduces the germination and growth of plants (Solymosi, 2004 and Solymosi and Bertrand, 2012). The aquatic extract of sorghum stem inhibit the seed and germination of wheat, rootlet growth, and vigor index as well as the inhibitory effect on germination, rootlet growth, and shoot of corn and lentil. In addition, its deteriorated remains reduce germination and growth of rootlet and shoot of other plants that were reported by other researchers such as Valizadeh (2010), Latifi et al. (2010), and Judi (2015). The inhibitory effects of aerial parts are more than the root of sorghum (Mardan, 2009). By burning the remains, the effect of allelopathic materials reduce and, in some cases, germination and initial growth of plant increased (Hashemizadeh et al., 2010). The ordinary remain of broom sorghum reduced the seedling growth of sorghum by 100% and burnt remains by 88% (Safaju et al.,, 2013). The broom sorghum is a good resource of phenolic compounds such as phenolic acids, flavonoids, and tannins (Chu et al., 2000).

Due to the planting of crops such as barley, sunflower, corn, alfalfa, wheat, beans, and broom sorghum, which are considered by farmers in fluctuation with crops, a research about allelopathy and self-harm of the ordinary and burnt remains of broom sorghum was conducted on the growth and germination traits of several agricultural plants. Therefore, it is essential to determine the type and amount of the obtained phenolic compounds by allelopathy and self-harm of the ordinary and burnt remains of broom sorghum to determine the compounds resources and their unique traits. In this regard, the quality and quantity of phenolic compounds of broom sorghum obtained by the self-harm, and allelopathy of the ordinary and burnt remains of broom sorghum and its effect on the germination traits of several agricultural plants were determined.

2. Materials and method

This research was executed in the laboratory, greenhouse, and farm of the agriculture faculty of Islamic Azad University, Miyaneh Branch. The seeds of the studied plants were prepared from the Agricultural Jihad of Miyaneh city. The plant remains of broom sorghum were collected from around of Miyaneh city, transferred to the laboratory, and washed by distilled water. Half of the collected remains were burnt in a metal container without adding any additives and another part was dried in the oven of 50 °C for 48 h. The dried and burnt remains were powdered by the mixer and passed through the laboratory sieve of 20-mesh. 15 g ordinary and burnt powders of broom sorghum was separately mixed with 150 ml distilled water and put in a shaker for 24 h in heat. A 6000 rpm micro-centrifuge was used to purify for 20 minutes at 50 °C to obtain a concentrated aqueous base extract (10% concentration). 4, 6, and 8% dilutions were prepared by adding distilled water to the mother extract. Distilled water was used as a control treatment. Broom sorghum remains were collected from the surrounding gardens after harvest and then 4, 6, and 8% concentrations of the burnt and ordinary remains were prepared. To disinfect the tested seeds, first, the seeds were washed with soap and water, and then the seeds were placed in 70% ethanol for 2 minutes. Then it was rinsed four times with sterile distilled water. Afterward, the seeds were soaked in 2.5% sodium hypochlorite solution for 15 minutes and rinsed four times with distilled water. 10 seeds were placed in Petri dishes with a diameter of 8 cm in diameter on sterile filter paper and 50 ml concentrations of different extracts were added to each petri dish. In addition, the Petri dishes were sealed with parafilm and placed in a germinator at 21 °C to reduce evaporation. The traits of germination, length of rootlet and shoot, wet weight, and vigor of seedling were calculated in the laboratory condition and 10 days after cultivation by the following formula:

1-Germination percentage after division of the germinated seeds on total seeds multiplied by 100.

$$\%GP = \frac{\sum G}{n} \times 100$$

G: number of the germinated seeds, N: total number of seeds

2-Seedling vigor (rootlet length+ shoot length)* germination percentage

3-Rootlet and shoot length was measured by collis after 10 days.

4-Weight of seedling was measured by digital scale with 0.001 precision and their mean was calculated.

In the second part, the phenolic compounds of the burnt and ordinary broom sorghum were studied at various times and concentrations. 10

ml of 1% aqueous extract of each organ of stem and leaf of sorghum mixed with 1.5 ml of 20% sodium carbonate plus 0.5 ml of Folin–Ciocalteu reagent to measure the phenolic compounds, and it was kept in room temperature for 1 h to complete the reaction (Jahantigh and Kiyarostami, 2006). Then the light absorption of the extracts at a wavelength of 288 nm was read using a spectrophotometer (Hach DR5000, USA). The standard curve was plotted using concentrations of 0, 0.01, 0.02, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.09, 0.1, 0.11, 0.12, 0.13, 0.14, 0.15, 0.16, 0.17, 0.18, 0.19, and 0.2 mg / ml vanillic acid. The read wavelengths from the extracts were calculated using the regression line equation obtained from the standard vanillic acid curve (Figure 1). Gas chromatographic device (PerkinElmer, USA) with sampleratomatic (AOC-2oi, USA) was used to separate the phenolic compounds of broom sorghum varieties. The used column was 30 meters long and had an inner diameter of 0.25 mm containing 100% polydimethylsiloxane, which had a potential difference of 70 electron volts. Its mobile phase is helium gas with a purity of 99.99%, which moved at a speed of 1 mm per minute. The injector temperature was 250 °C with a source temperature of 280 °C. The oven temperature was planned to increase from 110 to 200 °C with a speed of 5 °C/min, which reached 280 °C in isolation after 9 min. Output peaks of materials were detected based on the retention time of the standards and their value was determined based on the area below the curve. The statistical design used in this experiment was factorial in a completely randomized design with two replications. The results were analyzed using MSTAT-C and SPSS-18 software and the mean was compared with Duncan's test at a 5% sig. level.

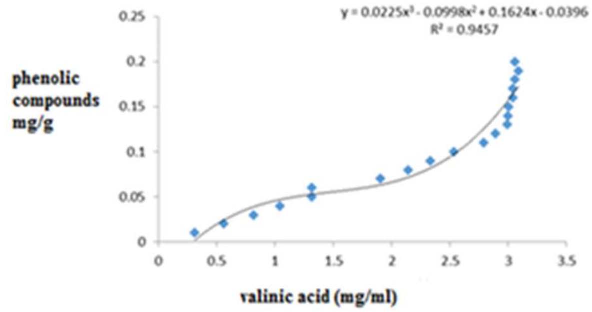


Fig.1- the plotted standard curve using vanillic acid

3. Results and discussion

The results of the variance analysis of germination and initial growth traits influenced by different concentrations of ordinary and burnt remains of broom sorghum showed the significant difference in 1 and 5% sig. level between factor a (extract concentrations) and factor c (agricultural plants) based on all the evaluated indexes. The significant difference was observed in 1 and 5% sig. level between various levels of plant remains based on germination percent, shoot length, and seedling vigor, between b×a based on the germination percentage, shoot length, the ratio of rootlet/shoot, and weight of seedling, between c×a levels based on all traits except seed vigor, and between three-way c×b×a levels only based on the traits of germination percentage and weight of seedling (Table 1).

Table 1- results of evaluated traits variance in the laboratory

S.O.V	df	Mean of Square					
		Germination percentage	Root length	Shoot length	Root/ Shoot	Seedling weight	Seed vigor
Rep	1	420.5**	7.031	7.031	0.008	0.01	30196.5
Factor a	3	4101.03**	89.75	89.75	0.577	1.468**	5971815.5
Error	3	3.167	91.36	91.36	0.393	0.005	3048421.1
Factor b	1	385.03**	8	8	0.009	0.0001	2412855.3*
AB	3	157.7**	1.667	1.667	0.272*	0.093**	297967.2
Factor c	7	208.8**	34.196**	34.196**	0.49**	3.066**	1385408.6*
AC	21	51.16**	4.756	4.756	0.039	0.238**	532587.7
BC	7	25.21**	19.304**	19.304**	0.522**	0.064**	689651.4
ABC	21	17.12**	1.304	1.304	0.073	0.039**	434202.3
Error	60	0.233	3.715	3.715	0.083	0.00003	399298.5
C.V%		1.57	30.12	3.95	26.15	1.26	29.8

** and ** show significant difference at probability level 1 and 5%, respectively.*

Germination percentage

Irregularities in respiration lead to limited metabolic energy and ultimately reduced germination (Bogatek et al., 2005). The results showed that control treatment with 97% had the maximum and 8% concentration treatment with 70.13% had the minimum germination percentage. In other words, germination percentage reduced by increasing the extract concentrations which are in agreement with the results of Radwan et al. (2019) research who showed that the higher extract concentrations (7 and 10%) germination percentage significantly reduced than the control treatment. Moreover, the burnt remains of sorghum than its ordinary type increased germination percentage by 4% in the studied agricultural products. Among the evaluated plants, sorghum with 90.06% had the highest and barley with 78.79% had the lowest germination percentage (Table 2). The results of the three-way effect showed that increasing the extract concentrations decreased the germination percentage. Burnt remains of broom sorghum in all evaluated plants increased the germination percentage of plants than the ordinary remains of sorghum. This increase was greater in sorghum, alfalfa, corn, and canola than other plants (Figure 2). Chiang et al (2003) reported that the plants' extract influences on the seeds germination because of various chemical compounds in them. Chemical compounds (secondary metabolites) can affect seed germination and plant yield (Willis, 2007). Ghasemi et al. (2012) showed that the high concentrations of aqueous extract of C. procera significantly reduced the germination percentage and growth of plants root. Aslam et al. (2016) reported that the higher concentration of C. procera controlled the germination of mustard seeds, while the lower concentrations were similar to the control treatment. Mangal et al. (2014) noted that increasing the concentration of Calotropis gigantea L leaf reduced the seed germination and root length of Calotropis gigantea L plant.

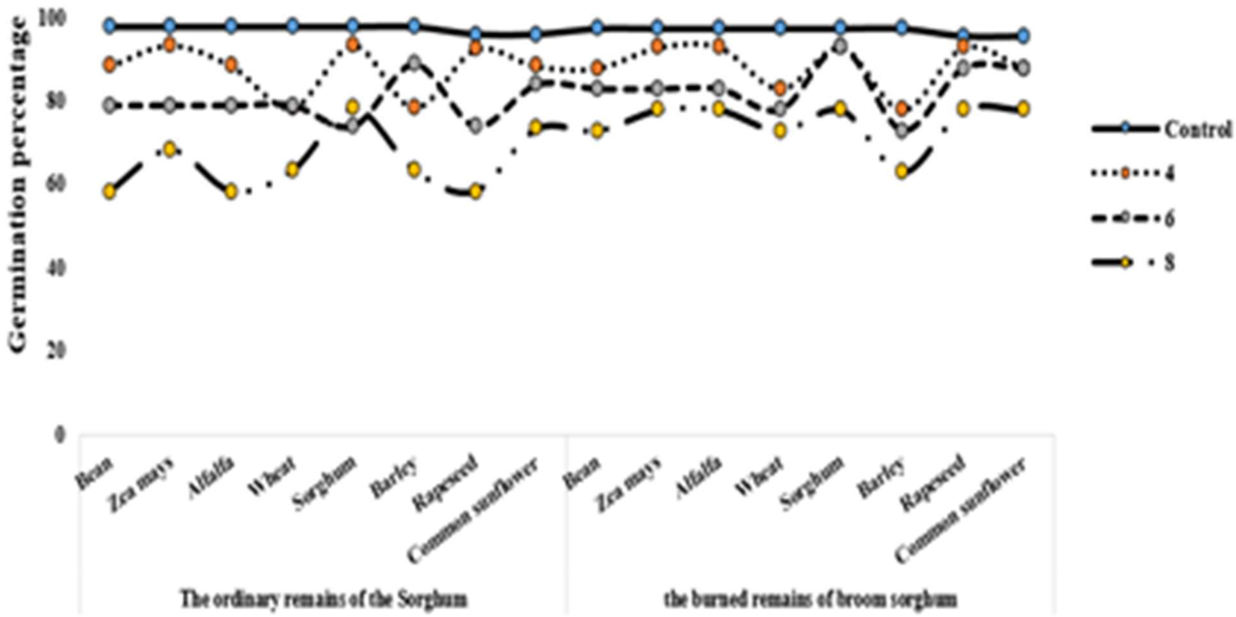


Fig. 2- comparing the three-way mean effect of germination percentage

Rootlet and shoot length

Reduction of rootlet and shoot length is probably caused by the hormonal balance damage. The seedling length growth is influenced by hormones that regulate cell longitudinal growth and cell division which are gibberellic acid and auxin. Any disturbance in the performance of these two hormones can inhibit growth (Turk and Tawaha, 2003). The control and 8% concentration treatments had the maximum and minimum rootlet length with 8 and 4.74 cm, respectively which are in agreement with the results of Radwan et al. (2009) research based on the reduction of rootlet and shoot length by increasing the extract concentration. Moreover, the burnt than ordinary remain of sorghum increased 8% of rootlet length in the examined crops. The aquatic extract of various parts as well as the rotten remains of sorghum reduce the plant rootlet (Ibrion et al., 2015). Bean and barely had the maximum and wheat had the minimum rootlet length among the examined plants (Table 2). Comparing the mean of two-way effect showed that the hybrid of the burnt remains of broom sorghum × bean with a mean of 10.5 cm had the maximum and hybrid of the burnt remains × wheat had the minimum rootlet length (Table 5). The control and 8% treatment with 11.25 and 4.74 cm had the maximum and minimum shoot length, respectively. Moreover, the brunt than the ordinary remains of sorghum increased the shoot length of the crops by 11.09%. Among the examined plants, sorghum with barely had the maximum and sunflower had the minimum shoot length (Table 2). The results of the three-way effects were that the increase in extract concentrations reduced the plumule length. The burnt remains of broom sorghum increased the plants' plumule lengths in most examined plants than the ordinary remains. This increase was higher in sorghum, alfalfa, corn, barley, and canola than other plants. The hybrid of control treatment × burnt remains of broom sorghum × sorghum with a mean of 15.5 cm had the maximum and the hybrid of concentration of 8% burnt remain of broom sorghum × sorghum with a mean of 2.5 cm had the minimum length of plumule (Figure 3). The hybrid of ordinary and burnt remains of broom sorghum × sorghum and barely had the maximum and the hybrid of ordinary remains × sunflower had the minimum shoot length (Table 5).

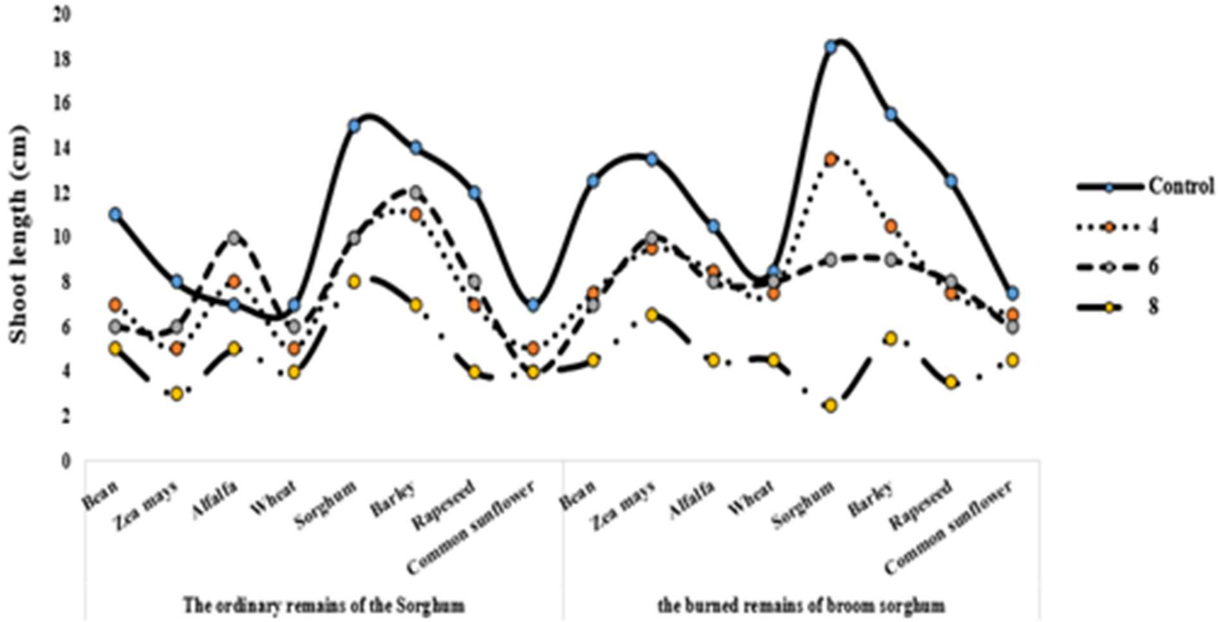


Fig. 3- comparing the three-way mean effect of Shoot length

The ratio of rootlet/shoot

8% concentration treatment with a mean of 0.932 had the maximum ratio. The burnt than ordinary remains of sorghum increased by 2.11% than the crops. Among the examined plants, bean had the maximum and wheat and canola had the minimum ratio (Table 2). The hybrid of the burnt remains of broom sorghum × concentration 8 with a mean of 1.79 had the maximum and the hybrid of the burnt remains of broom sorghum × concentration 4 had the minimum radicle/ plumule length ratio (Figure 4).

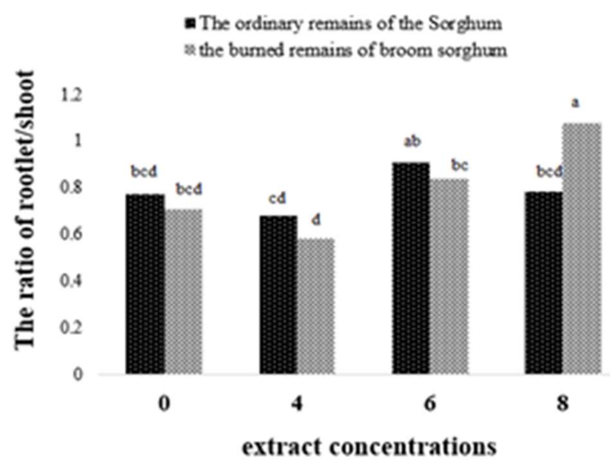


Fig 4- comparing the mean of two-way effect of radicle/plumule ratio

Weight of seedling

The results showed that the control treatment with 0.772 g had the maximum and 8% concentration treatment with 0.273 g had the minimum weight of seedling. Moreover, the burnt than ordinary remains of sorghum reduced the seedling weight of crops partially. Sunflower and bean had the maximum and barely and canola had the minimum weight of seedling among the examined plants (Table 2). The weight of the seedling was reduced by increasing the extract concentrations. The burnt than ordinary remains of the broom sorghum in all the examined plants increased the weight of the seedling. This increase was higher in sorghum, alfalfa, corn, and canola than the other plants (Figure 5). Hashemizadeh et al. (2010) in studying the allelopathic effect of broom sorghum remains and its allelopathic effect on wheat, barley, and tomato concluded that the ordinary and burnt remains significantly reduced the initial growth and germination of plants. The allelopathic traits of the burnt than ordinary remains was less. The ordinary remains increased the wet weight and the burnt remains increased the dry weight of plants which are in agreement with the obtained results from this research.

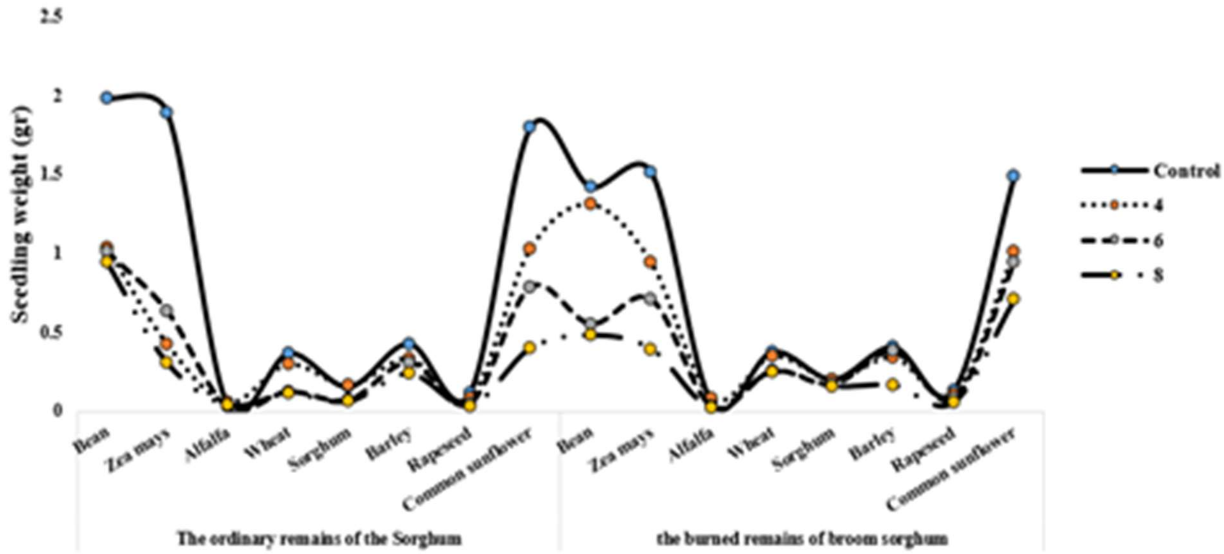


Fig 5- comparing the mean of the three-way effect of seedling weight

Seedling vigor

The control treatment with 1874.03 had the maximum seedling vigor. The burnt than ordinary remains of the broom sorghum increased the seedling vigor by 12.88%. Barely and sorghum among the examined plants had the maximum and minimum seedling vigor, respectively (Table 2).

Table 2- comparing the mean of simple effects

Seed vigor (Traits)	Seedling weight	Root/ Shoot	Shoot length	Root length	Germination percentage	Factor a
1874.03 ^{a}	0.772 ^{a}	0.741 ^{c}	11.25 ^{a}	8.00 ^{a}	97.00 ^{a}	**Control**
1161.75 ^{b}	0.484 ^{b}	0.633 ^{d}	8.06 ^{b}	5.06 ^{b}	88.19 ^{b}	**4**
1189.41 ^{b}	0.381 ^{c}	0.874 ^{b}	7.94 ^{c}	6.69 ^{ab}	81.62 ^{c}	**6**
632.53 ^{b}	0.273 ^{d}	0.932 ^{a}	4.75 ^{d}	4.25 ^{b}	70.13 ^{d}	**8**

Seed vigor (Traits)	Seedling weight	Root/ Shoot	Shoot length	Root length	Germination percentage	Factor b
1130.8	0.479	0.787	7.53	5.75	82.5	**The ordinary remains of the Sorghum**
1298.1	0.477	0.804	8.47	6.25	85.97	**the burned remains of broom sorghum**

Seed vigor (Traits)	Seedling weight	Root/ Shoot	Shoot length	Root length	Germination percentage	Factor c
1332.81 ^{abc}	1.094 ^{a}	1.078 ^{a}	7.56 ^{b}	7.81 ^{a}	83.19 ^{cde}	**Bean**
1285.25 ^{abc}	0.849 ^{b}	0.965 ^{ab}	7.69 ^{b}	6.94 ^{ab}	85.81 ^{b}	**Zea mays**
1167.38 ^{a}	0.043 ^{e}	0.749 ^{bcd}	7.69 ^{b}	5.75 ^{abc}	84.44 ^{c}	**Alfalfa**
812.25 ^{d}	0.265 ^{cd}	0.596 ^{d}	6.31 ^{c}	3.69 ^{c}	80.69 ^{de}	**Wheat**
1576.19 ^{a}	0.147 ^{cde}	0.716 ^{cd}	10.81 ^{a}	6.31 ^{ab}	90.06 ^{a}	**Sorghum**
1495.06 ^{ab}	0.325 ^{c}	0.728 ^{bcd}	10.56 ^{ab}	7.69 ^{a}	78.19 ^{e}	**Barley**
1118.06 ^{abc}	0.080 ^{e}	0.605 ^{d}	7.81 ^{b}	4.75 ^{bc}	85.69 ^{bc}	**Rapeseed**
928.44 ^{cd}	1.021 ^{a}	0.924 ^{abc}	5.56 ^{d}	5.06 ^{bc}	85.81 ^{b}	**Common sunflower**

Table 3- comparing the mean of two-way effect of B× C

Root/ Shoot	Root length		B×C
0.706 ^{cdef}	5.125 $^{d-h}$	**Bean**	**The ordinary remains of the Sorghum**
1.206 ^{ab}	6.875 ^{bcde}	**Zea mays**	
0.669 ^{cdef}	5.0 ^{efgh}	**Alfalfa**	
0.723 ^{cdef}	4.125 ^{gh}	**Wheat**	
0.638 ^{def}	6.75 ^{bcde}	**Sorghum**	
0.74 ^{cdef}	8.125 ^{b}	**Barley**	
0.66 ^{def}	5.375 ^{ab}	**Rapeseed**	
0.956 ^{bc}	4.625 ^{fgh}	**Common sunflower**	
1.45 ^{a}	10.5 ^{a}	**Bean**	**the burned remains of broom sorghum**
0.725 ^{cdef}	7.0 ^{bcd}	**Zea mays**	
0.83 ^{cde}	6.5 $^{b-f}$	**Alfalfa**	
0.47 ^{f}	3.25 ^{h}	**Wheat**	
0.795 ^{cde}	5.875 $^{c-g}$	**Sorghum**	
0.718 ^{cdef}	7.25 ^{bc}	**Barley**	
0.55 ^{ef}	4.125 ^{gh}	**Rapeseed**	
0.983 ^{cd}	5.5 $^{c-g}$	**Common sunflower**	

The phenolic compounds are found in the plant in various concentrations and motivate various reactions in the plant species which shows the allelopathic effect (Macías et al., 2007). The obtained results from variance analysis, of the phenol compounds of ordinary remains of broom sorghum at various times, showed that the amount of phenol compounds was significant in 1% (Table 6). In other words, the amount of phenol compounds in the ordinary remains of broom sorghum was different in different sampling times, and these samplings had different effects in five subsequent months after harvesting on the amount of the ordinary remains of broom sorghum. A significant difference was observed in the phenol compounds of the ordinary remains of broom sorghum in various samplings (Table 6). Comparing the mean effect of sampling time on the phenol compounds showed that (Table 4) the hybrid of ordinary remains of broom sorghum in November had the maximum amount of phenol compounds. The ordinary remains of broom sorghum had the maximum amount of phenol compounds in November and December. Therefore, they probably caused the maximum rainfall in germination indexes of broom sorghum (figure 6). Latifi et al. (2010) reported the inhibitory traits of the prepared extract from the stem of broom sorghum on the growth of the wheat rootlet. Latifi et al. (2010) in studying the allelopathic effects of broom sorghum on White goosefoot, Amaranthus, and wheat concluded that the leaf and the underground parts of the broom sorghum inhibit wheat germination in the first and second step of sampling and weeds completely. A little reduction in its allelopathic effect was recorded only in the extract of the third step. The stem extract had a little allelopathic effect on two species of weeds. The germination of Goosefoot and Amaranthus was 36.6 and 55%, respectively.

Table 6- variance analysis of the phenolic compounds of the burnt and ordinary remains of the broom sorghum in various times

Prob	F. value	MS	SS	df	S.O.V
0.000	0.167	0.004**	0.015	4	Factor b (Sampling time)
	6294.3	6.00E-7	2.4E-6	4	Error
				10	Total
	1.11				C.V%

** show significant difference at probability level 1 respectively.

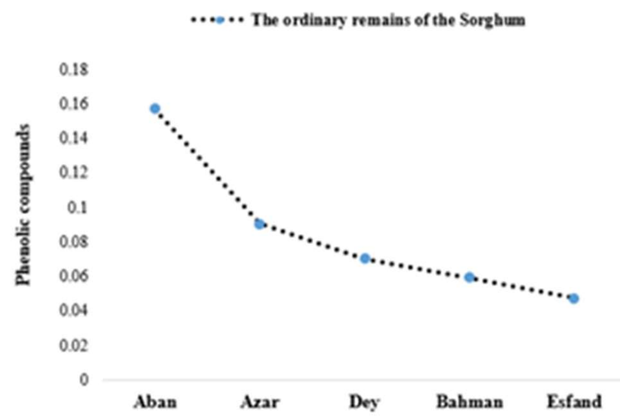


Fig 6- Effect of sampling time on the amount of phenolic compounds

The obtained results from variance analysis of the phenolic compounds of the stem and leaves of broom sorghum in various concentrations showed that the phenolic compounds were significant in 1% sig. level based on the part, concentration, and the two-way effect of these two factors (Table 7). As a result, the type of the pant part was statistically different in various concentrations based on the amount of phenolic compounds. The results of comparing the two-way effect (concentration × plant parts) of broom sorghum on the phenolic compounds showed that (Figure 7) the phenolic compounds of leaf were higher than stem in all concentrations. The control treatment had the maximum phenolic compounds in leaf, and 4% concentration had the minimum phenolic concentration in the stem. Mardan (2009) reported in a research, about the allelopathic effect of broom sorghum, that germination and growth of the seedlings of weeds reduced and the allelopathic effect of the extract from the aerial parts was higher than root. Hashemizadeh et al. (2010) in examining the dynamism of the allelopathic effect of root, and leaves of sorghum on wheat to study the allelopathic effect of broom sorghum on the wheat for 1 2 3, and 4 months after cultivation concluded that the root extract in the third step was higher than other inhibitor steps for wheat germination. In addition, the aerial parts in the third step inhibit the germination of wheat seeds. In the first three steps, the negative allelopathic effect of the extract of the aerial parts was significantly higher than it in root. Totally, the allelopathic traits of broom sorghum gradually increased in the first 3 steps of plant growth and reduced in the fourth step. Valizadeh et al. (2010) reported and announced that root has an inhibitory effect than leaves and stems during a test about the negative and inhibitory effect of broom sorghum on germination, rootlet length, and shoot length of corn, peas, and lentil.

Table 7- variance analysis of the phenolic compounds of the stem and leaf of broom sorghum in various concentrations

Prob	F. value	MS	SS	df	S.O.V
0.001	25.13	0.007**	0.007	1	**Factor a (Plant residues)**
0.009	7.652	0.0023**	0.007	3	**Factor b (Different concentrations)**
0.008	7.022	0.002**	0.006	3	**a × b**
		0.00025	0.002	8	**Error**
			0.022	15	**Total**
	7.71				**C.V%**

** show significant difference at probability level 1 respectively.

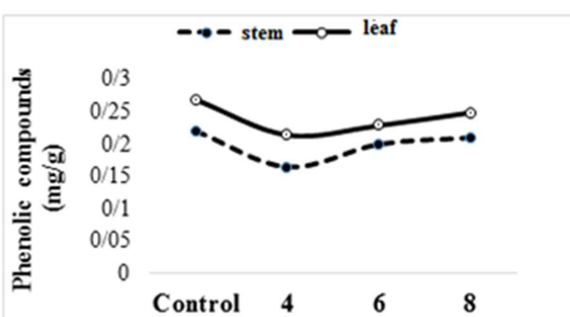
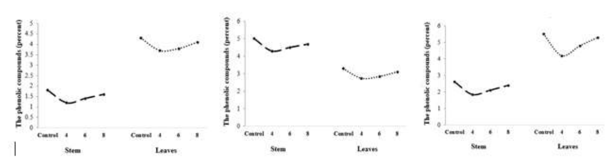
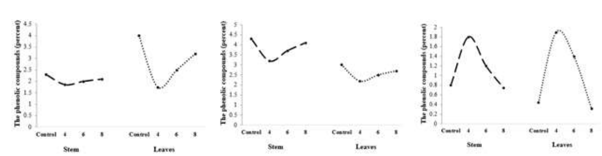


Fig 7- comparing two-way effect (concentration × plant parts) of broom sorghum on the phenolic compounds

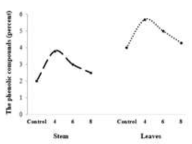
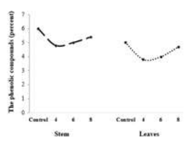
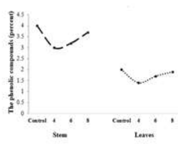
Chromatographic examination of phenolic acids isolated from broom sorghum is shown in Figure 8. The results showed that the type and number of the detected compounds in the stem and leaf of broom sorghum influenced by various concentrations in the plant parts were different. The detected compounds are shown in figure 8. The effect of the extract various concentrations in two parts of stem and leaf of broom sorghum changed the number, type, and amount of the phenolic compounds. In addition, the difference in the type and size of the allelochemical materials in various plants of the plant influence on the allelopathic potential of broom sorghum through the effect of various concentrations of the extract. Totally, it is claimed that the extract concentrations can influence on the allelopathic potential of the broom sorghum by changing the quality and quantity of the phenolic compounds.



Phenolic compounds of cinamic acid | **Phenolic compounds of p-hudroxy Benzoic acid** | **Phenolic compounds of benzoic acid**



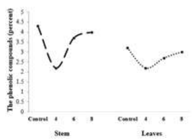
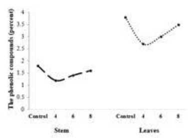
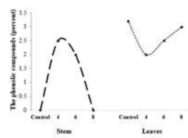
Phenolic compounds of vanilic acid | **Phenolic compounds of hesperidin** | **Phenolic compounds of rutin**

Phenolic compounds of Gallic acid

Phenolic compounds of m-coumaric acid

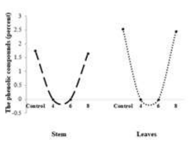
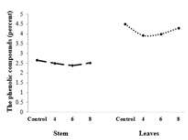
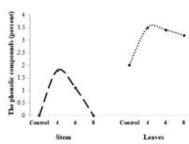
Phenolic compounds of Myricetin

Phenolic compounds of caffeic acid

Phenolic compounds of Homogentistic acid

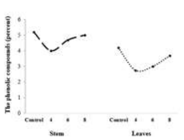
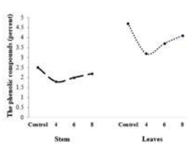
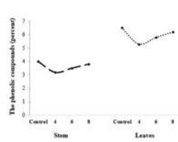
Phenolic compounds of Pyrogallo

Phenolic compounds of Gentistic acid

Phenolic compounds of Ferulic acid

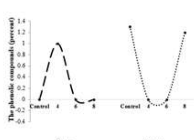
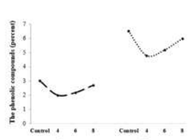
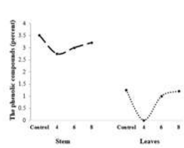
Phenolic compounds of Syringic acid

Phenolic compounds of Pelagonidin-3,5-glusiside

Phenolic compounds of Cyanidi-3,5-diglusiside

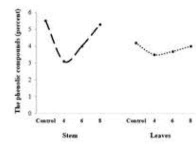
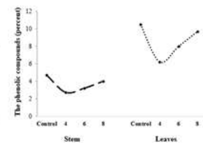
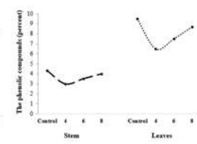
Phenolic compounds of Chlorogenic acid

Phenolic compounds of Leteolinidin

Phenolic compounds of Leteolinidin-5-gluciside

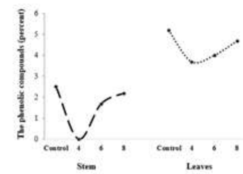
Phenolic compounds of Cyanidin

Phenolic compounds of Peonidin

Phenolic compounds of Apigeninnidin

Phenolic compounds of Leuteolin



Phenolic compounds of Petunidin

Continuity of Fig-8

4. Conclusion

The maximum reduction in the germination and initial growth traits of broom sorghum was in 8% extract concentration. The burnt than ordinary remains increases the germination and initial growth traits of the crops. Increasing the extract concentrations reduced the shoot weight. The burnt than ordinary remains of broom sorghum increased the weight of seedling among all the examined plants. This increase was higher in sorghum, alfalfa, corn, and canola than the other plants. The allelopathic traits of the burnt were less than the ordinary remains. The ordinary remains increase the wet weight and the burnt remains increases the dry weight of plants. The allelopathic effect of the ordinary remains on the shoot length of sunflower, the burnt remains of sorghum on the rootlet length of wheat, and the ratio of rootlet to the shoot of wheat were higher than the other studied traits in various steps of sampling. The amounts of phenol compounds in ordinary remains of broom sorghum were different in different sampling times. Ordinary remains of broom sorghum had a high amount of phenol compounds in November, December, and January. Ordinary remains of broom sorghum had the maximum amount of phenol compounds in November and December. Therefore, they probably caused the maximum rainfall in germination indexes of broom sorghum. The type of plant parts were statistically different in various concentrations based on the amount of the produced phenolic compounds. The phenolic compounds in leaf were higher than stem in all concentrations. The effect of extract various concentrations in two parts of stem and leaf of broom sorghum changed the number, type, and size of the phenolic compounds, and the difference in number, type, and size of the allelochemical materials in various parts of this plant are influenced by the effect of extract various concentrations on the allelopathic potential of broom sorghum. Generally, it can be claimed that the extract concentration can influence on the allelopathic potential of broom sorghum by changing the quality and quantity of the phenolic compounds.

Conflict of interests: None declared

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