ZANCO Journal of Pure and Applied Sciences
The official scientific journal of Salahaddin University-Erbil
https://zancojournals.su.edu.krd/index.php/JPAS

ISSN (print):2218-0230, **ISSN (online):** 2412-3986, **DOI: http://dx.doi.org/10.21271/zjpas**

RESEARCH PAPER

Using Different Carbon Resources to Enhance Germination and Growth Components of Two Varieties of Sorghum bicolor L.

Shakir Bahaddin Shakir[1], Ako Hussein Mahmood[2]

[1]Department of Field crops and Medicinal Plants, College of Agricultural Engineering Sciences, Salahaddin University-Erbil, Kurdistan Region – F.R. Iraq

[2]Department of Forestry, College of Agricultural Engineering Sciences, Salahaddin University-Erbil, Kurdistan Region – F.R. Iraq

A B S T R A C T:

Sorghum is regarded as a crop with a dual purpose (grain and forage), however it hasn't been prioritized as a crop in Iraq since it relies on outdated types. The goal of this study was to assess the effects of three different carbon sources (charcoal, sawdust, and white sugar) on the plant growth and yield performance of the two varieties of *Sorghum bicolor*. The experiment was a complete randomized design (CRD) with three replicates. Overall, seed germination percentages were significantly affected by varieties and treatments. However, the highest germination was recorded in variety one 93.83%. In relevant of effectiveness of different carbon resources on growth characteristics, the outcomes were differed, for example, the effects of all treatments were non-significant for characters' fresh leaf weight and dry leaf weight compare to control treatment. Although, the highest results were recorded in sawdust treatment (18.83 g) and the lowest response for fresh leaf weight belong to control treatment (10.83 g). Sawdust treatment had also significant influence on fresh yield, dry yield, total fresh yield, and total dry yield of both studied varieties compare to control or other treatments. The outcomes indicated that using sawdust as an organic carbon resources can enhance growth and yield characters when planting sorghum as forage crops.

KEY WORDS: Charcoal, growth characters, sawdust, seed germination, white sugar, and biomass
DOI: http://dx.doi.org/10.21271/ZJPAS.35.5.17
ZJPAS (2023) , 35(5);181-189 .

1.INTRODUCTION :

Sorghum (*Sorghum bicolor* L. Moench) is a significant short-day summer annual grass and the fifth-ranked grain crop in the world (Ghani et al., 2015). A member of the Poaceae family, sorghum is a drought-tolerant fodder crop. Before spreading to other regions of the world, including Ethiopia and India, (Karthika and Kalpana, 2017).
Sorghum bicolor has been used for several purposes, including providing grain and stems as raw materials for the manufacture of sugar, alcohol, syrup, fuel, and paper as well as grain, pasture, hay, and silage for animal nutrition (Cothren et al., 2000; Habyarimana et al., 2004; Afzal et al., 2012).

* **Corresponding Author:**
Sarbaz I. Mohammed
E-mail: sarbaz.mohammed@su.edu.krd
Article History:
Received: 21/12/2022
Accepted: 20/02/2023
Published: 25/10 /2023

Sorghum is extensively grown in areas that are desert, semiarid, tropical, subtropical, and temperate. It is a sizable source of food and hay (Huang, 2018). Excellent chance to feed the cattle population with fodder so they may eat healthier According to earlier research, a range of factors, including genotype, plant density, organic mulching, fertilization, irrigation, and harvesting time, affected the quality and quantity of sorghum fodder (Singh and Sumeriya 2012).
The physical characteristics of soil and plant growth are influenced differently by various carbon supplies. For instance, sawdust mulching enhanced plant growth by raising root activity, soluble sugar, and chlorophyll content as well as by supplying the root zone with the right amount of moisture and nutrients (Ni et al., 2016).

Mulching has various benefits, including the ability to regulate soil temperature, stop soil water loss due to evaporation, prevent weed germination, and slow weed growth. Additionally, they can shield soils from erosion and compaction brought on by wind, water, and traffic (Rathinasabapathi et al., 2005). By preserving soil moisture, promoting soil biological activity, and enhancing the chemical and physical qualities of soil, mulch can increase soil quality and thus crop output. Mulching thereby enhances plant development as well as soil quality in urban or decorative environments (Cooper, 1973; Shakir,2019).

Charcoal improves the soil's ability to hold onto nutrients, increasing its nutrient content. This improves plant nutrition and decreases the leaching of nutrients (Glaser et al., 2002). If an additional fertilizer source is offered, charcoal addition to the soil will stabilize soil fertility. The release and availability of (P, K, Ca, Mg, and N) did not decrease in the soil fertilized with charcoal compared to soil treated with a mineral nutrient (Steiner et al., 2007).

The use of charcoal and various nitrogen levels considerably changed the chemical and physical characteristics of the soil on one side, and the growth and yield parameters of flax species (Salih et al., 2019). It has also been demonstrated that adding biologically accessible carbon (such as sugar or sawdust) can boost microbial activity, which aids in lowering the nitrogen level (Prober et al., 2005; Faithfull et al., 2010).

Studies have revealed that the addition of sugar significantly reduces the germination of exotic weed seeds within the seed bank, and that the addition of carbon also reduces inorganic nitrogen and exotic plant biomass (Blumenthal et al., 2003; Prober et al., 2009; Mahmood et al.,2018; Shakir, 2019). The type of carbon that is introduced to the soil matters because the rate at which it becomes available to microorganisms affects the soil's health and plant growth (Eschen et al., 2006). For example, a carbon source that is easily available, like sugar, can activate microbial activity within hours (Dalenberg & Jager, 1981), whereas other sources, like more complicated compounds such as humic acid, have structures that take longer to decompose (Magill & Abel, 2000). This study aims to investigate the impacts of three different carbon supplies (charcoal, sawdust, and white sugar) on plant growth and yield performance of the two varieties of *Sorghum bicolor*.

2.MATERIALS AND METHODS

The study was conducted in June 2021 at Girdarasha field (Altitude: 415 meters above sea level, Longitude: 4401 00′ 45.5 ″ E, Latitude: 360 06′ 48.9 ″ N) (Latitude 36. 10116 N, Longitude 44.00925 E, and elevation of 415 meters above sea level) which belongs to College of Agricultural Engineering Sciences, Salahaddin University-Erbil. Certificated seeds of two varieties of *S. bicolor* (V1= money maker and V2= Jowari) were purchased from a relabel seed agent sources. A guarantee of purity, germination (%), and identity were approved. After collection stage, seeds were cleaned from any impurities of all kinds, and put in paper bags and kept in a dry condition under 25 °C in laboratory until plantation date. The soil in the experiment is classified as yellow brown soil and was cleared and hoed manually before the onset of the experiment. A clay field soil media was prepared for all treatments. A total of 48 plastic pots (40 cm length x 15 cm high) were filled with the soil media equally. Ten seeds of each variety of *S. bicolor* were planted in different treatment factors. During the experimental period (93 days), no fertilizer was applied, watering and weeding practices were consistent regularly according to their needs.

Four main treatments were established, treatments include: control (untreated soil), charcoal approximately 1.5 cm layer, white sugar about 5 g per box and an approximated 1cm layer of sawdust treatment as separate treatments. The experiment was complete randomized design (CRD) with three replicates.

Germination was monitored daily for a period of 6 weeks with collecting data for germination percentage. The germination percentage was estimated according to (Ismail and Kardoush, 2011). Growth parameters such as plant height (cm), and leaf numbers for all seedlings were measured. The plant height was measured from the soil surface to the highest living apical shoot using a measuring tape in centimeter units. Leaf number for each seedling was counted manually. Fresh and dry weight were measured for stem, leaf, and total plant for both varieties of *S. bicolor* plants at the end of trial.

Statistical analysis:

Data were analyzed according to analysis of variance (ANOVA) with MINITAB 19 statistical package (Minitab, 2014) using a General Linear Model (GLM). All data were tested for normality using the Ryan-Joiner similar to Shapiro–Wilk test (a = 0.05). Tukey's test with a significance level of 0.05 was applied to test for significance between the all factor means and their interactions.

3.RESULTS

A. Effects of varieties and treatments on seed germination percentage

The impacts of varieties and various organic carbon supplies on seed germination percentages are depicted in Fig. 1 and 2. In general, it is evident that both varieties had high germination rates. However, as indicated in figure 1, the variety one had significantly greater germination percentages (93.83%) than the variety two which was reported (85.17%).

In the relevant of effectiveness of different carbon resources on seed germination percentages as exposed in figure 2, we found that treatments slightly effected positively to increase the percentage of seed germination for both varieties when compared to control or (untreated) treatment. The highest percentage of seed germination belong to sawdust treatment which was (96.00 %), and the lowest seed germination percentages belong to sugar treatment which was only (83.00 %). However, other treatments were not significantly differing to control treatments.

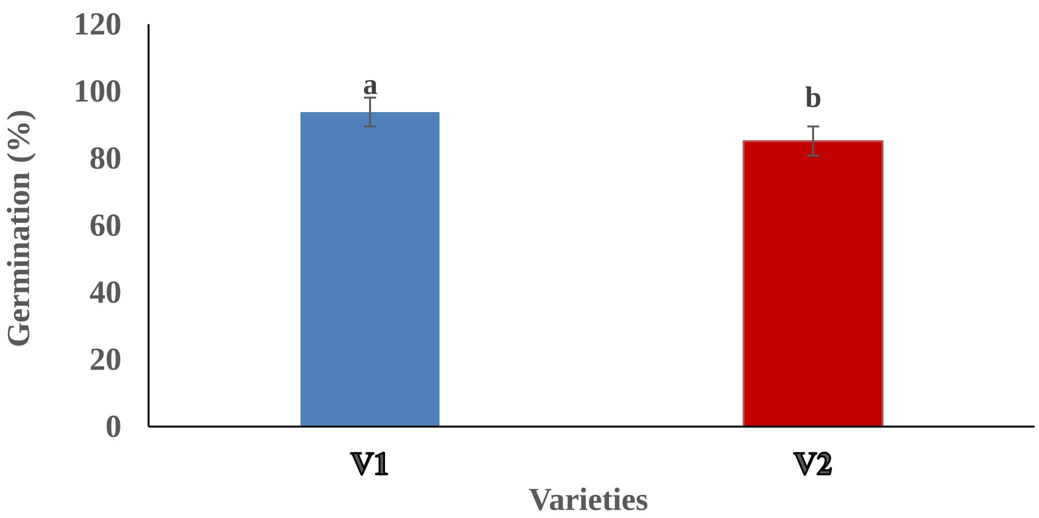

Fig. 1. The effects of variety on the germination percentages of both *Sorghum bicolor*'s variety seeds. Vertical bars represent ± standard error of the mean. Means that do not share a letter are significantly different.

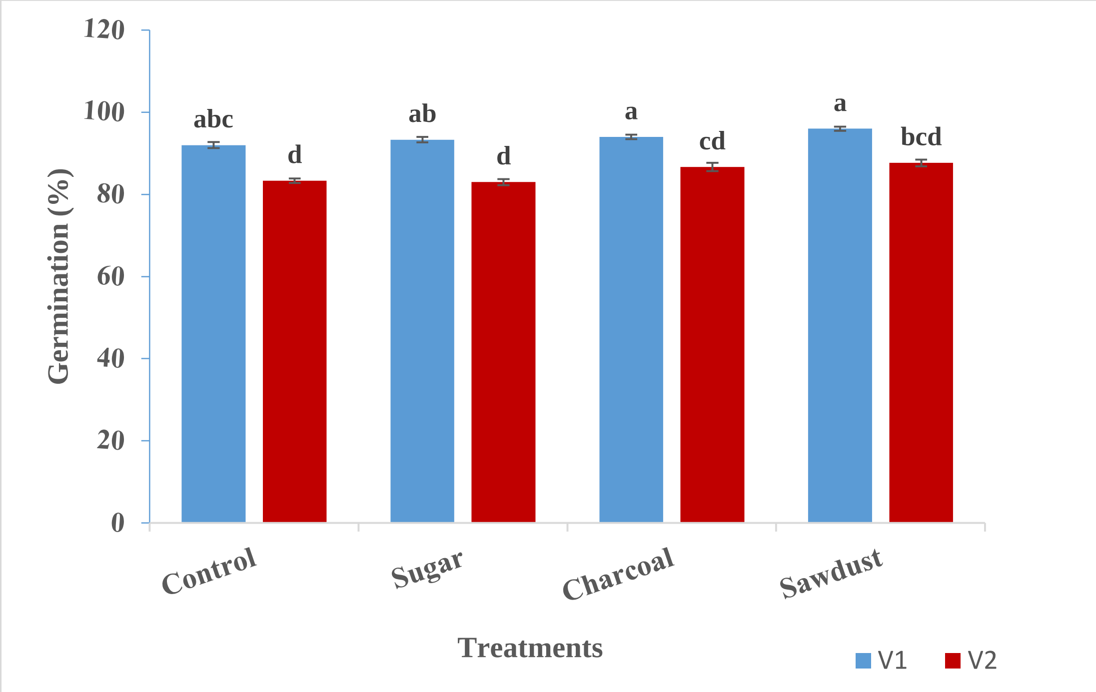

Fig.2. Interaction effects of different carbon resources verses variety on the germination percentages of both *Sorghum bicolor*'s variety seeds. Vertical bars represent ± standard error of the mean. Means that do not share a letter are significantly different.

*B.*Effects of varieties and treatments on plant high and leaf number

Fig. 3 and 4, show the reactions of both varieties of *Sorghum bicolor* in terms of plant height and the number of leaves per plant in relation to their interactions with different organic carbon sources. Generally, both varieties were affected positively by using different carbon resources in regarding plant compared e with the control treatment, but variety one responded with better results than variety two. Plant height mean was significantly higher in verity one under sawdust treatment (150.67 cm) than those in control treatment either in variety one or two (93.33 cm and 76.67 cm respectively) as clarified in Fig. 3.

Leaf numbers was significantly affected by the combination of different organic carbon resources and varieties as illustrated in Fig. 4. Overall, leaf numbers per plant was higher in variety one compare to variety two when plants were treated by different organic carbon recourses. The maximum leaf number were noted in variety one under sugar treatment and the minimum leaf numbers were recorded in control treatment at both varieties (14.67 leaves per plant and 8.33 leaves per plant respectively). Charcoal, sawdust and sugar were not significantly affected on leaf number per plant in both varieties.

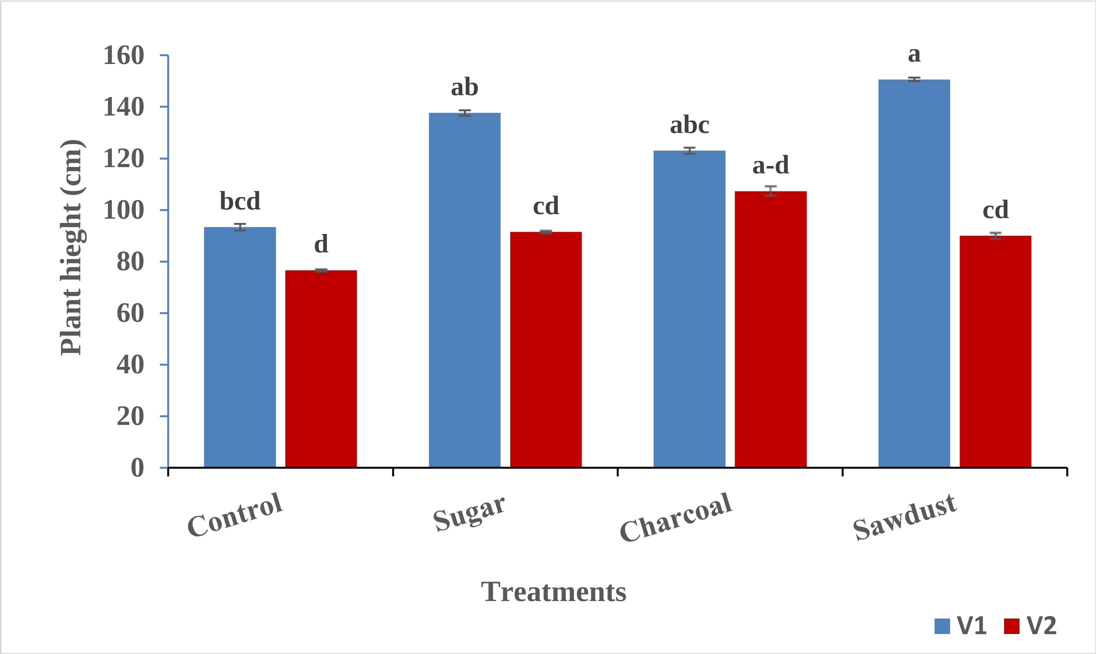

Fig. 3. Interaction effects of different carbon resources verses variety on the plant height (cm) of both *Sorghum bicolor*'s variety. Vertical bars represent ± standard error of the mean. Means that do not share a letter are significantly different.

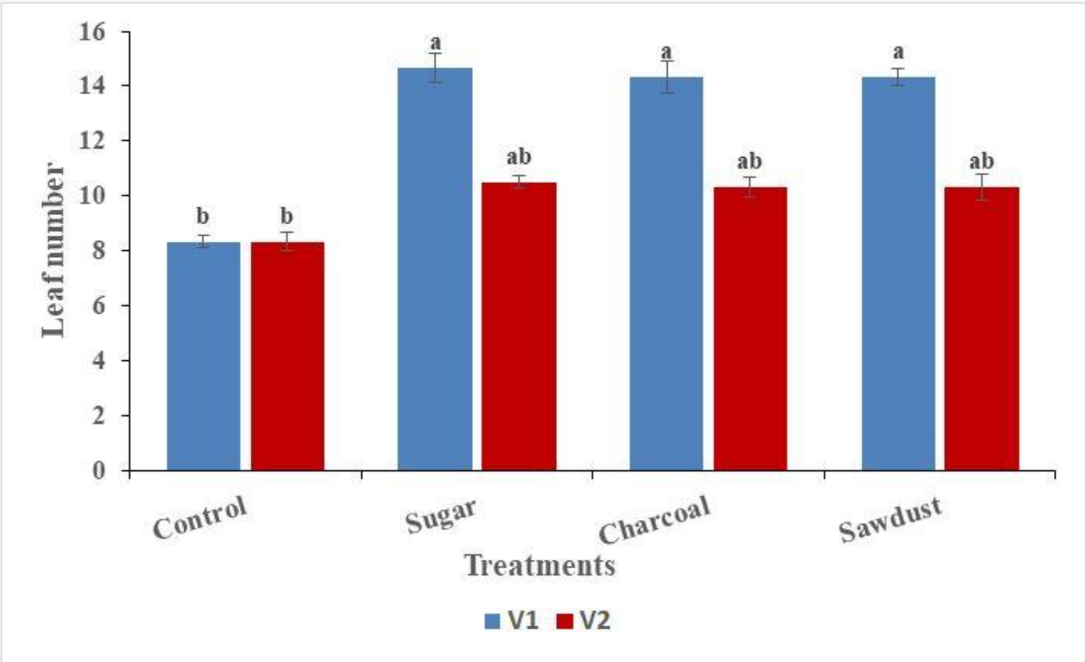

Fig. 4. Interaction effects of different carbon resources verses variety on leaf number per plant for both *Sorghum bicolor*'s variety. Vertical bars represent ± standard error of the mean. Means that do not share a letter are significantly different.

*C.*Effects of varieties and treatments on some forage and growth characters

Data in Table 1, illustrate the effects of different organic carbon resources on some growth and forage characters of two varieties of *sorghum bicolor* L. in regarding the comparison between both varieties in response different carbon resources, results indicated there is no significantly differences between both varieties for all above growth characteristics. However, variety one showed better outcomes from fresh leaf weight (17.08 g). While variety one, showed better results from other remain growth parameters as shown in Table 1. In relevant of effectiveness of different carbon resources on growth characteristics, the outcomes were differing, for example, the effects of all treatments were non-significant for characters' fresh leaf weight and dry leaf weight compare to control treatment. Although, the highest results were recorded in sawdust treatment (18.83 g) and the lowest response for fresh leaf weight belong to control treatment (10.83 g). In contrast, fresh shoot weight and dry shoot weight were significantly higher in sawdust treatment (56.50 g and 15.66 g, respectively) than those in control treatment were only (16.0 g and 3.30 g, respectively).

Table 1. Effects of different carbon recourses and varieties on some growth and forage characters (fresh leaf weight, fresh shoot weight, dry leaf weight, and dry shoot weight) for both varieties of *Sorghum bicolor* L.

Treatments	Fresh Leaf weight (g)	Fresh shoot weight (g)	Dry leaf weight (g)	Dry shoot weight (g)
Control	10.83 a	16.00 b	2.41 a	3.30 b
Sugar	21.50 a	33.66 ab	4.87 a	8.66 ab
Charcoal	14.66 a	38.00 ab	5.00 a	7.08 b
Sawdust	18.83 a	56.50 a	5.83 a	15.66 a
P value	*0.092*	*0.006*	*0.136*	*0.002*
Varieties				
V1	15.83 a	36.25 a	4.66 a	8.94 a
V2	17.08 a	35.83 a	4.39 a	8.41 a
P value	*0.676*	*0.952*	*0.792*	*0.779*

Means have the same letters in columns are not significantly different by Tukes test at $p \leq 0.05$.

D. Effects of varieties and treatments on some yield characters

Table 2 investigated the responses of both varieties of *Sorghum bicolor* L. in some yield characters under different organic carbon resources. In general, results indicated there is no significant differences between both varieties in regarding yield characteristics, but variety one, showed a little better results in dry yield and total dry yield (13.60 g; 2.17 ton/h, respectively) compare to variety two (2.81 g; 2.05 ton/h, respectively). While variety two gave higher results in fresh yield and total fresh yield than variety one.

In the relevant of the impacts of different carbon resources on yield characteristics, data showed in Table 2, that the sawdust treatment had significant influence on fresh yield, dry yield, total fresh yield, and total dry yield of both studied varieties compare to control or other treatments. Mean fresh yield and mean dry yield under sawdust treatment were (75.33 g and 21.50 g, respectively) while results of same characters were only (26.83 g and 5.71 g, respectively) under control treatments. White sugar and charcoal treatments were not significantly differences to increase yield characteristics as shown in Table 2.

Table 2. Effects of varieties and different carbon resources on means of some yield characters (fresh yield, dry yield, total fresh yield and total dry yield) for both varieties of *Sorghum bicolor* L.

Treatments	Fresh yield (g)	Dry yield (g)	Total fresh yield (Ton /h)	Total dry yield (Ton /h)
Control	26.83 b	5.71 b	4.29 b	0.91 b
Sugar	52.66 ab	13.54 ab	8.82 ab	2.16 ab
Charcoal	55.16 ab	12.08 b	8.42 ab	1.93 b
Sawdust	75.33 a	21.50 a	12.05 a	3.44 a
P value	*0.007*	*0.001*	*0.007*	*0.001*
Varieties				
V1	52.08 a	13.60 a	8.33 a	2.17 a
V2	52.91 a	2.81 a	8.46 a	2.05 a
P value	*0.921*	*0.709*	*0.921*	*0.709*

Means have the same letters in columns are not significantly different by Tukey s at p ≤ 0.05 .

4.DISCUSSION

Our findings agree with those of several recent research that demonstrated a beneficial impact of carbon resources on both soil characteristics and plant growth (Glaser et al., 2002; Lehmann et al., 2003; Steiner et al., 2007, Chan et al., 2007;). For instance, these results in agreement with Ni et al., (2016) who stated that sawdust enhanced plant growth by raising root activity, soluble sugar, and chlorophyll content as well as by supplying the root zone with the right amount of moisture and nutrients as improve the morphologic and yield components Furthermore, the current study is consistent with other research involving the addition of other carbon resources (white sugar plus sawdust) to soil, which has been found to boost microbial populations and CO_2 production while also reducing soil nitrogen (Echen et al., 2007; Shakir, 2019). However, it is less known how charcoal affects soil characteristics and plant growth. Dibenzofurans, polychlorinated dibenzo-p-dioxins, and polynuclear aromatic hydrocarbons are just a few of the toxic compounds that can be produced during the combustion of woody materials (Kim et al., 2003). We discovered that the addition of sawdust and charcoal had a beneficial effect on seed germination and yields of sorghum respectively, which agree with the findings of the study of Salih et al, (2019) which showed that, charcoal was caused to significantly improve some growth and yield parameters such as plant height, technical stem length, total fresh yield, and dry stem yield. The effects of adding charcoal to plant biomass were always beneficial and were usually tied to specific characteristics of the charcoal, supporting our initial hypothesis.

Our finding overwhelmingly imply that different wood species have inherent differences in their charcoals, which could have a significant impact on ecological processes. This is due to the fact that wood from different species can have drastically different physical and chemical characteristics, and even though the pyrolysis process may change these characteristics to some extent (Downie et al., 2009).

In addition, Nottingham et al., (2009) shown that increasing microbial activity in the soil by adding sugar at different rate, led to release of carbon from the soil as CO_2. The addition of molasses (carbon) to compacted soil decreased the germination of seeds from a variety of grass and weed species, as demonstrated by McLaren et al (2012), they proposed that this was caused by the anaerobic bacteria growing in the seed bank, which deprived the seeds of oxygen and had direct harmful effects on the seeds. The addition of sugar has been shown to reduce germination of Chilean needle grass in a grassland seed inundation trial (Faithfull, 2010).

Conclusion

It could be concluded that mulching with sawdust treatment creates a healthy environment and had positive effects on the plant growth characteristics and yield performance of the two varieties of

Sorghum bicolor. Germination rate, plant height, and leaf number were significantly higher after mulching with sawdust. Therefore, considering the effect of sawdust on soil properties and plant growth and physiology, are a better choice than other resources of carbon additions. Further studies are required to determine the effects of mulch quality and mulch-layer thickness on crop yield and biomass characteristics.

ACKNOWLEDGMENT

Special thanks are extended to the Salahaddin University- Collage of Agriculture engineering sciences for the provision of financial support. We acknowledge our department for providing laboratory equipment. We also thank our network friends for supplying their advice.

REFERENCES

Afzal, M., Ahmad, A. and Ahmad, A.H., 2012. Effect of nitrogen on growth and yield of sorghum forage (Sorghum bicolor (L.) Moench cv.) under three cuttings system. *Cercetări Agronomice în Moldova*, *45*(4), pp.57-64.

Blumenthal, D.M., Jordan, N.R. and Russelle, M.P., 2003. Soil carbon addition controls weeds and facilitates prairie restoration. *Ecological applications*, *13*(3), pp.605-615.

Chan, K.Y., Van Zwieten, L., Meszaros, I., Downie, A. and Joseph, S., 2007. Agronomic values of green waste biochar as a soil amendment. *Soil Research*, *45*(8), pp.629-634.

Cooper, A.J., 1973. Root temperatures and plant growth. *Res. Rev. 4, Commonwealth Bureau of Horticulture and Plantation Crops*.

Cothren, J.T., Matocha, J.E. and Clark, L.E., 2000. Integrated crop management for sorghum. *Sorghum: Origin, history, technology, and production*, pp.409-441.

Dalenberg, J.W. and Jager, G., 1981. Priming effect of small glucose additions to 14C-labelled soil. *Soil Biology and Biochemistry*, *13*(3), pp.219-223.

Eschen, R., Müller-Schärer, H.E.I.N.Z. and Schaffner, U., 2006. Soil carbon addition affects plant growth in a species-specific way. *Journal of Applied Ecology*, *43*(1), pp.35-42.

Faithful, I.G., Hocking, C. and McLaren, D.A., 2010, September. Chilean needle grass (*Nassella neesiana*) in the native grasslands of south-eastern Australia: biodiversity effects, invasion drivers and impact mechanisms. In *Papers and Proceedings 17th Australasian Weeds Conference* (pp. 431-434).

Ghani, A., Saeed, M., Hussain, D., Arshad, M., Shafique, M.M. and Shah, S.A.S., 2015. Evaluation of different sorghum (*Sorghum bicolor* L. moench) varieties for grain yield and related characteristics. *Science. Letters*, *3*, pp.72-74.

Glaser, B., Lehmann, J. and Zech, W., 2002. Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal–a review. *Biology and fertility of soils*, *35*(4), pp.219-230.

Habyarimana, E., Laureti, D., De Ninno, M. and Lorenzoni, C., 2004. Performances of biomass sorghum [*Sorghum bicolor* (L.) Moench] under different water regimes in Mediterranean region. *Industrial Crops and Products*, *20*(1), pp.23-28.

Huang, R.D., 2018. Research progress on plant tolerance to soil salinity and alkalinity in sorghum. *Journal of Integrative Agriculture*, *17*(4), pp.739-746.

Ismail, O.M. and Kardoush, M., 2011. The impact of some nutrients substances on germination and growth seedling of *Pistacia vera* L. *Australian Journal of Basic and Applied Sciences*, *5*(5), pp.115-120.

Karthika, N. and Kalpana, R., 2017. HCN content and forage yield of multi-cut forage sorghum under different organic manures and nitrogen levels. *Chemical Science Review and Letter*. *6*(23), pp.1659-1663.

Kim, E.J., Oh, J.E. and Chang, Y.S., 2003. Effects of forest fire on the level and distribution of PCDD/Fs and PAHs in soil. *Science of the Total Environment*, *311*(1-3), pp.177-189.

Lehmann, J., Pereira da Silva, J., Steiner, C., Nehls, T., Zech, W. and Glaser, B., 2003. Nutrient availability and leaching in an archaeological Anthrosol and a Ferralsol of the Central Amazon basin: fertilizer, manure and charcoal amendments. *Plant and soil*, *249*(2), pp.343-357.

Magill, A.H. and Aber, J.D., 2000. Variation in soil net mineralization rates with dissolved organic carbon additions. *Soil biology and biochemistry*, *32*(5), pp.597-601.

Mahmood, A.H., Florentine, S., Graz, F.P., Turville, C., Palmer, G., Sillitoe, J. and McLaren, D., 2018. Comparison of techniques to control the aggressive environmental invasive species *Galenia pubescens* in a degraded grassland reserve, Victoria, Australia. *Plos one*, 13(11), p.e0203653.

McLaren, D.A., Fridman, M. and Bonilla, J., 2012. Effects of pine oil, sugar and covers on germination of serrated tussock (*Nassella trichotoma)* and kangaroo grass (*Themeda triandra*) in a Pot Trial. *Perspectives*, *114*, pp.1803-1806.

Minitab, I. (2014). MINITAB release 19: statistical software for windows. *Minitab Inc, USA*.

Ni, X., Song, W., Zhang, H., Yang, X. and Wang, L., 2016. Effects of mulching on soil properties and growth of tea olive (*Osmanthus fragrans*). *Plos one*, *11*(8), p.e0158228.

Nottingham, A.T., Griffiths, H., Chamberlain, P.M., Stott, A.W. and Tanner, E.V., 2009. Soil priming by sugar and leaf-litter substrates: a link to microbial groups. *Applied soil ecology*, *42*(3), pp.183-190.

Prober, S.M., Lunt, I.D. and Morgan, J.W., 2009. Rapid internal plant-soil feedbacks lead to alternative stable states in temperate Australian grassy woodlands. *New models for ecosystem dynamics and restoration*, pp.156-168.

Prober, S.M., Thiele, K.R., Lunt, I.D. and Koen, T.B., 2005. Restoring ecological function in temperate grassy woodlands: manipulating soil nutrients, exotic annuals and native perennial grasses through carbon supplements and spring burns. *Journal of Applied Ecology*, *42*(6), pp.1073-1085.

Rathinasabapathi, B., Ferguson, J. and Gal, M., 2005. Evaluation of allelopathic potential of wood chips for weed suppression in horticultural production systems. *HortScience*, *40*(3), pp.711-713.

Salih, R.F., Osman, G.A. and Aziz, L.H., 2019. Growth and yield response of flax (linum usitatissimum l.) to different rates of charcoal and potassium fertilizer in erbil, kurdistan region-iraq. *Journal of Duhok University*, *22*(2), pp.71-80.

Shakir, S.B., 2019. *Investigating factors affecting restoration of native grassland in ex-cropland* (Doctoral dissertation, Federation University Australia).

Singh, P. and Sumeriya, H.K., 2012. Effect of nitrogen on yield, economics and quality of fodder sorghum genotypes. *Annals of plant and soil Research*, *14*(2), pp.133-5.

Steiner, C., Teixeira, W.G., Lehmann, J., Nehls, T., de Macêdo, J.L.V., Blum, W.E. and Zech, W., 2007. Long term effects of manure, charcoal and mineral fertilization on crop production and fertility on a highly weathered Central Amazonian upland soil. *Plant and soil*, *291*(1), pp.275-290.