www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(5): 1052-1057

www.thepharmajournal.com
Received: 01-02-2022
Accepted: 13-04-2022

G Sasthri
Department of Seed Science and Technology, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

D Kiruthiga
Department of Seed Science and Technology, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

R Jerlin
Department of Seed Science and Technology, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

K Natarajan
Krishi Vigyan Kendra, Tamil Nadu Agricultural University, Vridhachalam, Tamil Nadu, India

Corresponding Author:
G Sasthri
Department of Seed Science and Technology, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Utilization of biochar as a priming agent in blackgram seed management technique

G Sasthri, D Kiruthiga, R Jerlin and K Natarajan

Abstract
Biochar is hygroscopic in nature, and has the good water holding capacity. Due to this property many investigators have exploited the benefits of biochar as soil amendment. Very meagre evidences were traced on utilization of biochar for seed quality improvement through seed enhancement techniques like seed priming. Considering this in mind, the present investigation was initiated to exploit the benefits of biochar through seed priming. Studies were undertaken in the Department of Seed Science and Technology.

Tamil Nadu Agricultural University, Coimbatore, to evaluate the use of different types of biochars *viz*., redgram (stem), soapbush wattle (stem) and water hyacinth (whole plant) as priming agent for enhancing seed quality in blackgram. In order to extract the maximum nutrients for the preparation of biochar liquid which were used as seed priming agent, suitable soaking duration and concentration for each biochar were standardized. Irrespective of type of biochars evaluated, 24 hours of soaking duration was required to realize the full benefits of biochars. Whereas, the concentration of biochars required for priming was varied among the crops studied. Among the different biochars used as priming agent *viz*., redgram. soapbush wattle and water hyacinth, the biochar extract of soapbush wattle @ 5% enhanced the seed quality parameters *viz*., speed of germination, germination per cent, shoot length, root length, dry matter production and vigour index.

Keywords: Biochar - blackgram - seed priming - physiological seed quality parameters

Introduction
Priming of seeds is nothing but soaking the seeds in solution, but restricts radicle protrusion until the primed seeds are sown for germination (Pradhan *et al.*, 2017) [18]. Many researchers opined that seed priming can be used as seed management technique in many crops (Farooq *et al.*, 2006 in rice; Giri and Schillinger, 2003 in wheat; Rashid *et al.*, 2006 in barely; Pegah *et al.*, 2008 in maize; Moradi and Younesi, 2009 in sorghum) [4, 7, 19, 17, 14]. The influence of priming depends on the various factors like priming agent, concentration, soaking duration, seed to solution ratio, method of priming and the environment in which invigourative method was carried out. Though many research works were dealt with several organic and inorganic nutrients as priming agent but there is gap for effective utilization of biochar as priming agent. Biochar is one of the carbon rich produce which is obtained from plant biomass. It is a solid by product produced with a dry carbonization process i.e. pyrolysis. The effect of biochar may differ among the different pyrolytic temperatures and raw feedstock due to the variation of different biochar properties (Jindo *et al*., 2012) [10]. Depending on the biomass type from which biochar is produced, biochar may contain traces to high concentrations of nutrients that could influence seed germination Gaskin *et al*. (2008) [5]. The usage of a particular type of biochar is its intrinsic nutrient composition (rich or poor), which could produce varying results in the form of significant differences in plant growth (Deenik *et al*., 2016) [3]. Therefore, biochars obtained from three different type of feedstocks i.e. from agricultural crop (redgram), tree species (soapbush wattle) and weed species (water hyacinth) were used in these investigation to identify the most suitable biochar for seed management techniques in finger millet, blackgram and sesame.

Currently, the pre-sowing treatment like seed priming / hardening with 0.5% calcium chloride, 100 ppm zinc sulphate and 0.5% manganese sulphate for finger millet, blackgram and sesame respectively are in practice as per the recommendation of Crop Production Guide (2012) [12], Department of Agriculture, Government of Tamil Nadu. Eventhough these treatments augmented the seed quality parameters, for effective utilization of crop residues and also in line with organic seed treatment, biochar was selected as seed priming material in seed management techniques as eco friendly product. All the three crops selected are cultivated mainly as rainfed crops which need drought tolerant mechanisms that is possible through priming with biochar due to its hygroscopic nature.

Materials and Methods

Standardisation of soaking duration and concentration of biochar as priming agent for seed priming

The different type of biochars *viz.,* redgram (from stem) and soapbush wattle (*Acacia holosericiae*) (from stem) were obtained from Dry land Agricultural Research Station, TNAU, Chettinad and water hyacinth (whole plant) from Department of Environmental Sciences, Tamil Nadu Agricultural University, Coimbatore. Then these biochars were ground and sieved to get the fine powder. The biochar extracts were prepared by immersing the biochars in water/ethanol at the concentrations of 1, 2, 3, 4 and 5 per cent based on its solubility for different durations *viz.,* 6, 12 and 24 hours of soaking duration. The redgram and water hyacinth biochars are soluble in water and soapbush wattle is soluble in ethanol not in water. After the soaking duration, clear solutions were obtained by filtering through whatman number filter paper which gave the different per cent solutions of 1, 2, 3, 4 and 5% concentrations of biochar extracts (Plate 1). Then the blackgram seed was primed by adopting the following seed to solution ratio of 1: 0.3 and seed soaking duration of 3 hrs (Standardized as per Crop Production Guide (2012) [12], Department of Agriculture, Government of Tamil Nadu). Then dried back to their original moisture content and evaluated for the following seed quality characters. The laboratory studies were carried out at Department of Seed Science and Technology, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India during the year 2019.

The experimental design followed is Factorial Completely Randomized Design with three replications.

The observations like Germination (%) was arrived by conducting the germination test as per ISTA (2013) in roll towel method. The speed of germination was calculated using the formula suggested by Maguire, (1962). Root length and shoot length were measured from randomly selected ten normal seedlings. Dry matter production of seedlings was weighed as per ISTA, (2013). Vigour index values were computed using the following formula (Abdul-Baki and Anderson, 1973).

Vigour index = Germination% x Seedling length in cm (Root length + Shoot length)

Assessment of nutrient content of biochar

For the analysis, 0.5 g of sample was transferred into 100 ml conical flask and aquaregia (sulphuric acid+ nitric acid) was added to the sample which was kept under sand bath for digestion and it was indicated by colour changes (i.e. black colour changed into colourless). After the digestion, extract was prepared by adding water to the conical flask in order to cool down the acid digested material and filtered using filter paper and volume made upto 100 ml in the volumetric flask. From the prepared extract, the macro nutrients *viz*. total nitrogen (Micro Kjeldhal method), total phosphorus (Colorimetric method), total potassium (Flame photometry), calcium (Versenate method) and micronutrients (Atomic absorption spectrophotometer) were analysed.

Statistical analysis

The data obtained were analysed for the F test of significance adopting the procedure described by (Panse and Sukhatme, 1985). Wherever necessary, the per cent values were transformed to angular values using arc sine transformation before analysis. The critical difference (CD) was calculated at 5 per cent (P=0.05) probability level and wherever F value is non significant it was denoted by NS.

Results and Discussion

a. Standardisation of soaking duration of biochar for seed priming

Blackgram seed was subjected for priming with different types of biochar extracts *viz*., redgram, soapbush wattle and water hyacinth. Based on their solubility, biochars were dissolved in water/ ethanol at the concentrations of 1, 2, 3, 4 and 5 per cent for different soaking durations of 6, 12 and 24 hours in order to derive maximum nutrients from biochar into extracts and The experiment carried out to find out the optimum soaking duration revealed that irrespective of concentration and type of biochar, the biochar extract obtained from 24 hours soaking duration was found superior to the extracts received from other durations. The superiority of soaking duration of biochar was evaluated through assessment of the physiological parameters by conducting germination test. More pronounced effect was registered from 24 hours soaking duration than other durations. This might be due to more time available to solubilize the biochars thereby more nutrients might have transferred from biochar to extract. Thus, this study revealed that irrespective of type of biochar, that could be soaked for 24 hours to get maximum benefits of biochars.

b. Stanandardization of concentration of biochars as priming agent for priming

The biochar extracts obtained from different feedstocks *viz*., redgram stalk, soapbush wattle stalk and whole plant of water hyacinth plant by soaking in water/ethanol for 24 hours were tested as priming agent for priming blackgram seeds.

Seeds primed with 1% concentration of redgram biochar revealed the highest improvement in speed of emergence, germination per cent, root length, shoot length dry matter production and vigour index for 20, 14, 28 and 38 per cent respectively, higher than control. Beyond 1% concentration, utilization of biochar @ 2 to 5% gradually decreased all the quality parameters, however it was not lower than control (Table 1). While seeds primed with soapbush wattle biochar at 5% concentration recorded the maximum speed of emergence, germination per cent, seedling length, dry matter production and vigour index which showed 17, 23, 21, 26 and 27 per cent respectively, increase over control (Table 2 & Plate 2). Seeds primed with water hyacinth biochar at 3% concentration recorded the highest percentage of increase over control in speed of emergence, germination per cent, seedling length, dry matter production and vigour index of 13, 23, 14, 26 and 22 per cent respectively. Above 3% concentration, there was a decline in all the quality parameters, but not lower than control (Table 3).

Increased germination and seedling vigour through the biochar priming was due to the presence of nutrients and nature of biochar that was primed with seeds which was responsible for lesser inhibitory growth for seed germination and more space available in biochar primed seeds. This was in line with Major (2009) [12] in lettuce, radish and clover who used biochar as a soil amendment. Biochar contains macro and micronutrients *viz*., N, P, K, Ca, Mg, Cu, Fe, Mn and Zn. The major and micro nutrients present in redgram, soapbush wattle and water hyacinth biochar which were used for this study were analysed and presented in the table 4 & 5. Among the nutrients of biochar, calcium acted as enzyme cofactor in the process of germination which lead to increase in protein synthesis as reported by Christansen and Foy (1979). The variation in physiological parameters obtained at different concentrations was due to biphasic nature of biochar i.e. at low concentration it promotes the plant growth and *vice versa* at higher concentration. Decreased seed germination and vigour at higher concentration was reported by Shanmugasundaram and Kannaiyan (1989) [20] in bajra. Solaiman *et al.* (2012) [22] had also proved that all the plant attributes were decreased at higher concentration of biochar application in subterranean clover and for mungbean, root growth was affected to a greater extent than germination. In the soilless petri dish bioassay, inhibition of seed germination and or root growth observed at the highest rate of biochar application that might be due to trace levels of compounds that occur only above economic agronomic rates of application (Thies and Rillig, 2009) [24].

The growth parameters like root length and shoot length were increased in seeds primed with biochar because of the fertilizing effect of biochar resulted in nutrient release from damaged or decayed tissue of storage organ by hydrolysis as reported in sorghum (Shehzad *et al*., 2012) [21]. The addition of biochar improved the shoot length of lettuce plant (Méndez *et al.*, 2017). Root biomass was increased by 20% due to application of biochar in wheat as revealed by Gebremedhin *et al.* (2015). Whereas the root length was increased under drought condition to absorb water from deep soil Nahar and Gretzmacher (2011) [15], Hafeez *et al.* (2017) which was observed in soybean seedlings under drought stress. The increase in dry weight was due to early vigour and high germination per cent because of which seedling reached the autotrophic stage in advance than in control (Srimathi *et al*., 2007) [23] which produced relatively higher amount of dry matter as reported in greengram. Yue *et al.* (2017) [25] observed that application of sludge derived biochar to the soil which significantly stimulated the growth and weight of turf grass by mineral nutrition enhancement in plant. In another study, Khan *et al.* (2013) revealed that growth parameters of rice were increased due to application of nutrient rich sewage sludge biochar. The increase in vigour index was due to induction of growth promoting substances and translocation of secondary metabolites to the seedling growth.

The optimum concentration of biochars being recommended for blackgram seed priming are 1 per cent for redgram biochar, 5 and 3 per cent for soapbush wattle and water hyacinth biochars respectively.

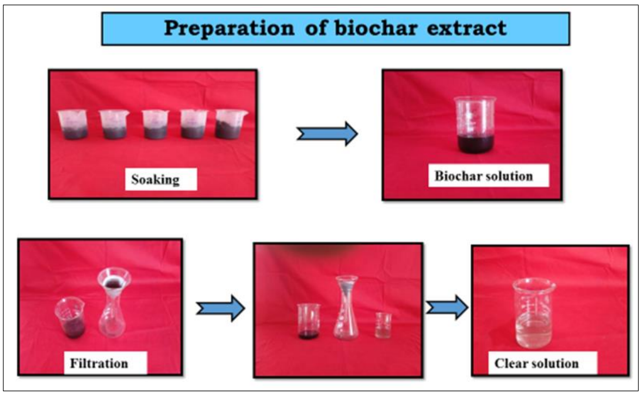

Plate 1: Steps in preparation of biochar extract

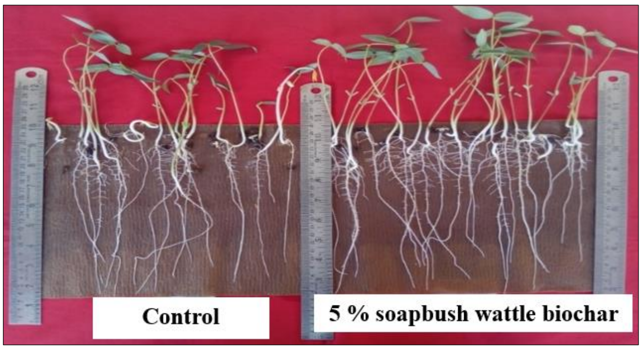

Plate 2: Seedling vigour of blackgram seeds primed with 5% soapbush wattle biochar

Table 1: Standardization of redgram biochar soaking duration and concentration for seed priming on physiological seed quality parameters in blackgram cv. CO 6

Conc.	Speed of germination			Mean	Germination (%)			Mean
	6 h	12 h	24 h		6 h	12 h	24 h	
Control	4.26	4.26	4.26	4.26	78 (62.02)	78 (62.02)	78 (62.02)	78 (62.02)
BC 1%	4.28	4.46	5.15	4.63	79 (62.72)	84 (66.42)	89 (70.63)	82 (64.89)
BC 2%	4.27	4.33	5.13	4.58	79 (62.72)	84 (66.42)	87 (68.86)	83 (65.64)
BC 3%	4.23	4.27	5.01	4.50	81 (64.15)	83 (65.64)	85 (67.21)	83 (65.64)
BC 4%	4.21	4.26	5.12	4.53	80 (63.43)	82 (64.89)	84 (66.42)	82 (64.89)
BC 5%	4.19	4.25	4.95	4.46	80 (63.43)	81 (64.15)	83 (65.64)	81 (64.15)
MEAN	4.24	4.30	4.93	4.49	79 (62.72)	82 (64.89)	82 (64.89)	82 (64.89)
	T	D	T x D		T	D	T x D	
S.Ed.	0.054	0.038	0.094		0.769	0.544	1.333	
CD (P=0.05)	0.111	0.078	0.192		1.561	1.104	2.704	
Conc.	Root length (cm)			Mean	Shoot length (cm)			Mean
	6 h	12 h	24 h		6 h	12 h	24 h	
Control	14.4	14.4	14.4	14.4	14.7	14.7	14.7	14.7
BC 1%	14.5	16.2	18.0	16.2	14.6	15.5	17.2	15.7
BC 2%	14.5	15.7	17.3	15.8	14.4	15.5	16.3	15.4
BC 3%	14.4	15.6	17.3	15.7	14.3	15.4	16.7	15.4
BC 4%	14.3	15.4	17.2	15.6	14.3	15.3	16.2	15.2

BC 5%	14.2	15.4	17.1	15.5	14.2	15.2	16.1	15.1
MEAN	14.3	15.4	16.8	15.5	14.4	15.2	16.2	15.2
	T	D	T x D		T	D	T x D	
S.Ed.	0.194	0.137	0.337		0.206	0.146	0.357	
CD (P=0.05)	0.395	0.279	0.684		0.419	0.296	0.725	
Conc.	**Dry matter production (g/10 seedlings)**			**Mean**	**Vigour index**			**Mean**
	6 h	**12 h**	**24 h**		**6 h**	**12 h**	**24 h**	
Control	0.210	0.210	0.210	0.210	2270	2270	2270	2269
BC 1%	0.214	0.262	0.272	0.249	2299	2663	3133	2698
BC 2%	0.213	0.254	0.263	0.243	2283	2621	2923	2609
BC 3%	0.212	0.246	0.252	0.236	2325	2573	2890	2595
BC 4%	0.212	0.238	0.244	0.231	2288	2517	2806	2537
BC 5%	0.211	0.224	0.238	0.224	2272	2479	2756	2502
MEAN	0.212	0.239	0.246	0.232	2289	2520	2796	2502
	T	D	T x D		T	D	T x D	
S.Ed	0.0027	0.0019	0.0047		44.162	31.227	76.491	
CD (P=0.05)	0.0055	0.0039	0.0096		89.575	63.339	155.149	

(Figures in parenthesis indicate arcsine values)
Conc.- Concentration, BC- Biochar

Table 2: Standardization of soapbush wattle biochar soaking duration and concentration for seed priming on physiological seed quality parameters in blackgram cv. CO 6

Conc.	**Speed of germination**			**Mean**	**Germination (%)**			**Mean**
	6 h	**12 h**	**24 h**		**6 h**	**12 h**	**24 h**	
Control	4.24	4.24	4.24	4.24	78 (62.02)	78 (62.02)	78 (62.02)	78 (62.02)
BC 1%	4.25	4.64	4.71	4.53	78 (62.02)	80 (63.43)	89 (70.63)	82 (64.89)
BC 2%	4.26	4.68	4.79	4.58	79 (62.72)	82 (64.89)	91 (72.54)	84 (66.42)
BC 3%	4.28	4.73	4.91	4.64	80 (63.43)	83 (65.64)	93 (74.65)	85 (67.21)
BC 4%	4.28	4.74	4.92	4.65	80 (63.43)	84 (66.42)	95 (77.07)	86 (68.02)
BC 5%	4.31	4.80	4.99	4.70	82 (64.89)	88 (69.73)	96 (78.46)	89 (70.63)
MEAN	4.27	4.63	4.76	4.56	79 (62.72)	82 (64.89)	90 (71.56)	84 (66.42)
	T	D	T x D		T	D	T x D	
S.Ed	0.054	0.038	0.094		0.975	0.689	1.689	
CD (P=0.05)	0.110	0.077	0.190		1.978	1.399	3.427	
Conc.	**Root length (cm)**			**Mean**	**Shoot length (cm)**			**Mean**
	6 h	**12 h**	**24 h**		**6 h**	**12 h**	**24 h**	
Control	15.3	15.3	15.3	15.3	14.7	14.7	14.7	14.7
BC 1%	15.5	16.2	18.1	16.6	14.8	15.0	15.3	15.0
BC 2%	15.5	16.4	18.4	16.7	14.8	15.7	16.3	15.6
BC 3%	15.8	16.8	18.8	17.1	14.9	15.8	16.6	15.7
BC 4%	15.8	16.9	18.9	17.2	14.9	15.8	17.0	15.9
BC 5%	15.9	17.2	19.4	17.5	15.0	15.9	17.1	16.0
MEAN	15.6	16.4	18.1	16.7	14.8	15.4	16.1	15.5
	T	D	T x D		T	D	T x D	
S.Ed	0.182	0.128	0.315		0.210	0.148	0.364	
CD (P=0.05)	0.369	0.261	0.639		0.426	0.301	0.739	
Conc.	**Dry matter production (g/10 seedlings)**			**Mean**	**Vigour index**			**Mean**
	6 h	**12 h**	**24 h**		**6 h**	**12 h**	**24 h**	
Control	0.219	0.219	0.219	0.219	2340	2340	2340	2340
BC 1%	0.220	0.229	0.236	0.228	2363	2496	2973	2610
BC 2%	0.222	0.237	0.241	0.233	2394	2632	3158	2727
BC 3%	0.224	0.244	0.254	0.240	2456	2706	3292	2818
BC 4%	0.225	0.254	0.269	0.249	2456	2747	3411	2871
BC 5%	0.228	0.266	0.278	0.257	2534	2913	3504	2983
MEAN	0.219	0.241	0.249	0.238	2423	2638	3112	2725
	T	D	T x D		T	D	T x D	
S.Ed	0.0029	0.0021	0.0051		35.728	25.264	61.884	
CD (P=0.05)	0.0060	0.0042	0.0104		72.469	51.243	125.520	

(Figures in parenthesis indicate arcsine values)
Conc.- Concentration, BC- Biochar

Table 3: Standardization of water hyacinth biochar soaking duration and concentration for seed priming on physiological seed quality parameters in blackgram cv. CO 6

Conc.	Speed of germination			Mean	Germination (%)			Mean
	6 h	12 h	24 h		6 h	12 h	24 h	
Control	4.24	4.24	4.24	4.24	80 (63.43)	80 (63.43)	80 (63.43)	80 (63.43)
BC 1%	4.26	4.27	4.71	4.41	80 (63.43)	84 (66.42)	90 (71.56)	84 (66.42)
BC 2%	4.27	4.29	4.75	4.44	80 (63.43)	84 (66.42)	90 (71.56)	84 (66.42)
BC 3%	4.28	4.31	4.95	4.51	84 (66.42)	88 (69.73)	96 (78.46)	89 (70.63)
BC 4%	4.28	4.28	4.81	4.46	84 (66.42)	88 (69.73)	92 (73.57)	88 (69.73)
BC 5%	4.27	4.27	4.80	4.45	82 (64.89)	84 (66.42)	90 (71.56)	85 (67.21)
MEAN	4.26	4.27	4.71	4.42	81 (64.15)	81 (64.15)	91(72.54)	85 (67.21)
	T	D	T x D		T	D	T x D	
S.Ed	0.045	0.031	0.078		0.743	0.526	1.288	
CD (P=0.05)	0.091	0.064	0.158		1.508	1.066	2.613	
Conc.	Root length (cm)			Mean	Shoot length (cm)			Mean
	6 h	12 h	24 h		6 h	12 h	24 h	
Control	13.6	13.6	13.6	13.6	14.2	14.2	14.2	14.2
BC 1%	13.7	13.8	17.1	14.8	14.2	15.7	16.5	15.4
BC 2%	13.5	14.1	17.7	15.1	14.3	15.8	17.4	15.8
BC 3%	14.0	14.0	18.8	15.6	15.1	15.9	17.6	16.2
BC 4%	13.3	13.9	18.2	15.1	14.8	15.7	17.4	15.9
BC 5%	13.1	13.8	17.2	14.7	14.6	15.6	17.3	15.8
MEAN	13.8	13.4	17.0	14.8	14.5	15.8	17.0	15.5
	T	D	T x D		T	D	T x D	
S.Ed	0.783	0.553	1.356		0.190	0.134	0.329	
CD (P=0.05)	NS	1.123	NS		0.386	0.272	0.668	
Conc.	Dry matter production (g/10 seedlings)			Mean	Vigour index			Mean
	6 h	12 h	24 h		6 h	12 h	24 h	
Control	0.212	0.212	0.212	0.212	2224	2225	2224	2224
BC 1%	0.209	0.219	0.216	0.215	2232	2479	3025	2578
BC 2%	0.211	0.218	0.242	0.224	2224	2511	3159	2631
BC 3%	0.220	0.221	0.257	0.233	2444	2631	3494	2856
BC 4%	0.216	0220	0.246	0.227	2361	2604	3275	2746
BC 5%	0.214	0.218	0.243	0.225	2272	2470	3105	2615
MEAN	0.218	0.212	0.237	0.223	2293	2487	3047	2569
	T	D	T x D		T	D	T x D	
S.Ed	0.012	0.009	0.022		70.117	49.580	121.447	
CD (P=0.05)	NS	0.018	NS		142.221	100.565	NS	

(Figures in parenthesis indicate arcsine values)
Conc.- Concentration, BC- Biochar

Table 4: Major nutrients present in different type of biochars

Type of biochar	N (%)	P (%)	K (%)	Ca (ppm)
Redgram	0.56	0.15	0.84	212
Soapbush wattle	0.22	0.10	0.41	76
Water hyacinth	0.16	0.03	0.34	142

Table 5: Micro nutrients present in different type of biochars

Type of biochar	Fe (mg/Kg)	Mn (mg/Kg)	Zn (mg/Kg)	Cu (mg/Kg)
Redgram	194	74.9	34.3	20.8
Soapbush wattle	202	59	49.4	34.6
Water hyacinth	161.2	42.1	30.8	24.2

Conclusion

The results of this study suggested that, irrespective of type of biochar, it would be appropriate to soak the biochars for 24 hours to get solution with maximum benefits of biochars which was used as priming agent for priming the seeds of blackgram for increment in speed of germination, germination per cent and seedling vigour parameters.

The study concluded that among the different type of biochars *viz*., redgram, soapbush wattle and water hyacinth biochars evaluated, the biochar extracts of sopabush wattle @ 5% is suitable for utilization of biochar extract as priming agent in blackgram seeds. However, all three types of biochars at all the concentrations improved the physiological parameters higher than control. Therefore, biochar could be used not only as a valuable soil amendment to increase soil health and crop growth, but also can be used in seed management technique to enhance the physiological seed quality parameters.

References

1. Abdul-Baki AA, Anderson JD. Vigor determination in soybean seed by multiple criteria 1. Crop science 1973;13(6):630-633.
2. Christansen MN, Foy CD. Fate and function of calcium in tissue. Communication in Soil Science and Plant Analysis. 1979;10:427-442.
3. Deenik, Jonathan, Michael Cooney. The potential benefits and limitations of corn cob and sewage sludge biochars in an infertile oxisol. Sustainability. 2016;8(2):131.
4. Farooq M, Shahzad Barsa MA, Abdul W. Priming of field-sown rice seed enhances germination, seedling establishment, allometry and yield. Plant growth regulation. 2006;49(2-3):285-294.
5. Gaskin, Julia W, Christoph Steiner, Keith Harris, Das KC, Brian Bibens. "Effect of low-temperature pyrolysis conditions on biochar for agricultural use. Transactions

of the ASABE 2008;51(6):2061-2069.
6. Gebremedhin GH, Bereket H, Daniel B, Tesfaye B. Effect of biochar on yield and yield components of wheat and post-harvest soil properties in Tigray, Ethiopia. Journal of Fertilizers & Pesticides. 2015;6(2):2-5.
7. Giri Ghana S, Schillinger WF. Seed priming winter wheat for germination, emergence, and yield. Crop Science. 2003;43(6):2135-2141.
8. Hafeez Y, Sumera I., Khajista J, Sobia S, Summera J, Fahd R. Effect of biochar application on seed germination and seedling growth of *Glycine max* (l.) Merr. Under drought stress. Pakistan Journal of Botany. 2017;49:7-13.
9. ISTA. International rules for seed testing. Seed Science Technology, Supplement Rules, 2013, 27-57.
10. Jindo K, Mizumoto H, Sawada Y, Joseph S, Lehmann J. Characterization of biochars to evaluate recalcitrance and agronomic performances. Biogeosciences. 2012;11:6613-6621.
11. Khan S, Chao C, Waqas M, Arp HPH, Zhu YG. Sewage sludge biochar influence upon rice (*Oryza sativa* L.) yield, metal bioaccumulation and greenhouse gas emissions from acidic paddy soil. Environmental Science and Technology. 2013;47:8624-32.
12. Major J. A guide to conducting biochar trials - International Biochar Initiative, 2009, 1-30.
13. Mendez A, Cárdenas-Aguiar E, Paz-Ferreiro J, Plaza C, Gascó G. The effect of sewage sludge biochar on peat-based growing media. Biological Agriculture & Horticulture. 2017;33(1):40-51.
14. Moradi A, Younesi O. Effects of osmo-and hydro-priming on seed parameters of grain sorghum (*Sorghum bicolor* L.). Australian Journal of Basic and Applied Sciences. 2009;3(3):1696-1700.
15. Nahar K, Gretzmacher R. Response of shoot and root development of seven tomato cultivars in hydrophonic system under water stress. Acad. J Plant Sciences. 2011;4(2):57-63.
16. Panse VG, Sukhatme PV. Statistical methods for Agricultural workers, ICAR Publication, New Delhi, 1985.
17. Pegah MD, Zadeh FS, Janmohammadi M. Influence of priming techniques on seed germination behaviour of maize inbred lines (*Zea mays*). ARPN Journal of Agriculture and Biological Sciences. 2008;3(3):22-25.
18. Pradhan V, Prashant Kumar Rai, Bineeta Bara M, Srivastava DK. Influence of halopriming and organic priming on germination and seed vigour in blackgram (*Vigna mungo* L.) seeds. Journal of Pharmacogn Phytochem. 2017;6(4):537-540.
19. Rashid A, Hollington PA, Harris D, Khan P. On-farm seed priming for barley on normal, saline and saline–sodic soils in North West Frontier Province, Pakistan. European Journal of Agronomy. 2006;24(3):276-281.
20. Shanmugasundaram VS, Kannaiyan M. Effect of concentration of seed hardening chemicals on physiological characters of pearl millet (*Pennisetum typhoides* Stapf and Hubb). Journal of Agronomy and Crop Science. 1989;163(3):174-176.
21. Shehzad MMA, Ahmad AUH, Yaseen M. Influence of priming techniques on emergence and seedling growth of forage sorghum (*Sorghum bicolor* L.). J Anim Plant Science. 2012;22(1):154-158.
22. Solaiman ZM, Daniel VM, Lynette KA. Biochars influence seed germination and early growth of seedlings. Plant and soil. 2012;353(1-2):273-287.
23. Srimathi P, Kavitha S, Renugadevi J. Influence of seed hardening and pelleting on seed yield and quality in greengram (*Vigna radiata* L.) cv. CO 6. Indian Journal of Agricultural Research. 2007;41(2):122-126.
24. Thies JE, Rillig MC. Characteristics of biochar: biological properties. Biochar for environmental management. Science and technology. 2009, 85-105.
25. Yue Y, Cui L, Lin Q, Li G, Zhao X. Efficiency of sewage sludge biochar in improving urban soil properties and promoting grass growth. Chemosphere. 2017;173:551.