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Effect of bagasse and mixed biochar on growth and productivity of *Glycine max* (L) Merril

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Abstract
Due to the dependence of major population of India on agriculture the rise in demands poses a pressure on agricultural sciences. Continuous cultivation of soil causes a steady decrease in the soil organic content and fertility. This steady decrease in fertility is compensated by addition of chemical fertilizers but decrease in organic content is a more serious problem. The application of chemical fertilizers may increase crop production but affect soil health and GHGs emission. To overcome this, a new approach biocharcoal (biochar) is introduced. Biochar is produced by the pyrolysis of biomass feedstock (plant/animal). Bagasse and mixed biochar was prepared at 500 ºC and applied to soil. The mixed biochar was prepared from three feedstocks i.e., pine needle, bagasse and chicken litter. The *Glycine max* (L.) Merril. was grown in biochar treated soil, and the growth and productivity were recorded during the life cycle. During life cycle of 120 days the plant biomass first increases and then decreases. The yield and Chlorophyll pigment was found high in biochar treated soil than control. The data was analyzed by applying Tukey HSD test of post hoc treatment in SPSS 16.00 software. Thus, the study indicates that biochar treatments were found to be best suited for *Glycine max.*

Keywords: Biochar, Bagasse, GHGs, SOC, C-sequestration, CEC, Pyrolysis, WHC

1. Introduction

Now-a-days the application of chemical fertilizers to soil has become a common practice in agriculture system that increases crop production but simultaneously affects the soil health and the GHGs emission from agricultural fields. Keeping in view the aim of increasing the agricultural production along the maintenance of soil health and safe environment a new approach i.e., biochar is introduced.Regular cultivation of soil causes a gradual decrease in soil organic content (SOC) and fertility. This gradual decrease in fertility is compensated by addition of fertilizers but the decrease in organic content is a more permanent problem. Incorporation of biochar can slow or reverse this trend. Biochar is an organic material produced by the pyrolysis of C-based feedstock (plant/animal material) and is best described as a soil conditioner (Verheijen *et al*., 2009) [37]. Pyrolysis is the heating of feedstock in an oxygen-deficient or low oxygen environment. The choice of feedstock varies from wood material, crop residue, switchgrass, organic waste, chicken litter to dairy manure, green waste and waste water sludge (Chan *et al*., 2008; Demirbas, 2004; Dias *et al*., 2010; Hossain *et al*., 2010; Ogawa and Okimori. 2010; Trompowsky *et al*., 2005; Yuan *et al*., 2011) [4, 7, 8, 11, 24, 35, 42]. Biochar is highly resistant to decomposition in soil; its residence time ranges from tens of years to millions (Preston and Schmidt, 2006; Verheijen *et al.*, 2010) [26, 38]. The persistent nature of biochar-C in soil shows that it will contribute to soil C-sequestration (Ennis *et al*., 2012; Lai *et al*., 2013; Malghani *et al*., 2013) [9, 16, 23]. and reduce GHGs emissions (Stewart *et al*., 2013). Biochar when applied to soil has been reported to boost soil fertility and improve soil quality. Soil benefits include increasing soil pH, water holding capacity (WHC), attracting more beneficial fungi, and microbes, improving CEC and retaining nutrients (Lehmann *et al*., 2006; Lehmann, 2007) [18, 19]. These benefits have been shown to increase yield in biomass and crops under variable conditions (Steiner *et al*., 2007; Rondon *et al*., 2007; Chan *et al*., 2007; Yamato *et al*., 2006; Lehmann *et al*., 2003) [32, 27, 3, 40, 17]. Biochar is widely used as a soil amendment to improve soil properties and enhance plant yield (Kramer *et al*., 2004; Liang *et al*., 2010; Ogawa and Okimori, 2010) [15, 21, 24]. When biochar is applied at higher rates physico-chemical properties such as pH, EC, porosity, CEC as well as soil aggregation are also modified (Gundale and DeLuca, 2006; Warnock*et al*, 2007; Amonette and Joseph, 2009) [10, 39, 1]. Positive yield effects from biochar addition were reported by Kimetu *et al*. (2008) [13]. Spokas *et al*. (2012) [31] concluded that while application of biochar can lead to positive results in agricultural production, there have been some reports of no crop yield benefits (Schnell *et al*., 2012) [29]. Or even negative yield responses (Lentz and Ippolito, 2012) [20]. Despite the great potential of soybean, Sanchez and Logan (1992) [28].Reported that soil fertility in high-rainfall, low-altitude regions of the tropics can be low due to rapid organic matter mineralization. Van Wambeke (1992) [36].Observed that the presence of highly weathered secondary minerals in the soil can result to poor growth and low yield. In the international world trade markets, soybean is ranked number one in world among the major oil crops (Chung and Singh, 2008) [5]. According to the US Food and Drug Administration Soy protein products can be good substitutes for animal products because, unlike some other beans, soy offers a 'complete' protein profile.

2. Methodology

2.1 Biochar Preparation

In this study two types of biochar were prepared - bagasse and mixed biochar. The mixed biochar was prepared from the combination of three feedstocks in equal proportion i.e., pine needles, chicken manure and sugarcane derived bagasse. The feedstocks were grinded using a grinder. Later the samples were dried at 105 ºC in an oven for 24 hrs to remove surface moisture. The feedstock was then pyrolysed at 500 ºC under the recommendation of Lehmann *et al.* (2003) [17].in a muffle furnace. After pyrolysis the sample was cooled, crushed and sieved with 2mm mesh.

2.2 Soil Sampling

The soil used for experimental study was collected from Botanical Garden of Government Post Graduate College Rishikesh. The soil was collected 10-20cm below the top soil layer. The soil was air-dried for 24 hrs and then sieved through a 2 mm mesh to remove plant debris, stones and other unwanted matter prior to potting. 10% (w/w) biochar was applied according to big biochar experiment of IBI.

2.3 Experimental Plot

The study was a two-year study in consecutive years 2014 and 2015 to confirm the results. Pot trials were conducted for the comparative study of two biochars. The study was conducted under natural conditions at Botanical Garden of Government Post Graduate College Rishikesh from June 2014 to October 2014 and June 2015 to October 2015. In each pot 4 seeds were sown. Upon germination healthy seedlings were kept and others were discarded. The seeds were sown in plastic bags that had many holes at their base so that excess water could drain out and for aeration. The experiment plot was covered with transparent polythene sheet from above to prevent them from excessive rainfall and so that sunlight can pass through it. The study was a randomised block design of treatments with three replicates each. There were total 3 treatments:

T1 - Control
T2 - Bagasse biochar treatment
T3 - Mixed biochar treatment

2.4 Recording Data and Statistical Analysis

The parameters fresh weight of root, shoot, plant, dry weight of root, shoot, height of plant and leaf area were recorded after every 30 days i.e., at the 30, 60, 90 and 120 day of lifecycle representing 1, 2, 3 and 4 crop age respectively. The dry weight was recorded after drying the plant material in an oven at 70 ºC for 24 hrs. The pigment composition was determined according to the formula of Koski and Smith (1948). After harvesting the yield and productivity parameters i.e., number of pods per plant, number of seeds per pod, length of pod and seed dry weight were recorded. For analysing the data obtained through experiment ANOVA was applied. For comparison of means in order to assess their performance regarding growth and productivity Tukey HSD test was applied at p=0.05 using SPSS 16.00 Software package.

3. Results and discussion

3.1 Effect on Root biomass, Shoot biomass and total plant Biomass

The fresh weight of root, shoot, plant, dry weight of root shoot and plant have been given in the Tables-1 to 12 for the years 2014 and 2015 (Tables-1 to 6 represent the results for 2014 and Tables-7 to 12 represent the results for 2015).

Table 1: effect of bagasse and mixed biochar on fresh weight of root (2014)

Treatment	Crop age				Mean
	1	2	3	4	
T1	0.32	0.99	1.25	1.22	0.95^{a}
T2	0.77	1.29	1.38	1.35	1.20^{c}
T3	0.76	1.28	1.36	1.34	1.19^{b}
	0.62^{a}	1.19^{b}	1.33^{d}	1.31^{c}	

* Figures with same alphabets are statistically at par.

Table 2: effect of bagasse and mixed biochar on dry weight of root (2014)

Treatment	Crop age				Mean
	1	2	3	4	
T1	0.13	0.32	0.34	0.31	0.29^{a}
T2	0.36	0.38	0.51	0.48	0.43^{c}
T3	0.33	0.41	0.46	0.42	0.41^{b}
	0.27^{a}	0.37^{b}	0.45^{d}	0.40^{c}	

* Figures with same alphabets are statistically at par.

Table3: effect of bagasse and mixed biochar on fresh weight of shoot (2014)

Treatment	Crop age				Mean
	1	2	3	4	
T1	0.53	1.17	1.51	1.40	1.15^{a}
T2	1.41	1.75	2.17	1.98	1.98^{c}
T3	1.42	1.73	1.94	1.77	1.72^{b}
	1.12^{a}	1.55^{b}	1.87^{d}	1.72^{c}	

* Figures with same alphabets are statistically at par.

Table 4: effect of bagasse and mixed biochar on dry weight of shoot (2014)

Treatment	Crop age				Mean
	1	2	3	4	
T1	0.13	0.34	0.49	0.35	0.33^{a}
T2	0.42	0.53	0.57	0.54	0.52^{c}
T3	0.42	0.47	0.58	0.56	0.51^{b}
	0.32^{a}	0.45^{b}	0.55^{d}	0.48^{c}	

* Figures with same alphabets are statistically at par.

Table 5: effect of bagasse and mixed biochar on fresh weight of plant (2014)

Treatment	Crop age				Mean
	1	2	3	4	
T1	0.85	2.16	2.76	2.64	2.10a
T2	2.17	3.04	3.55	3.34	3.02c
T3	2.18	3.02	3.31	3.11	2.90b
	1.74a	2.74b	3.21d	3.03c	

* Figures with same alphabets are statistically at par.

Table 6: effect of bagasse and mixed biochar on dry weight of plant (2014)

Treatment	Crop age				Mean
	1	2	3	4	
T1	0.26	0.66	0.87	0.67	0.62a
T2	0.78	0.91	1.09	1.02	0.95c
T3	0.76	0.88	1.04	0.98	0.91b
	0.60a	0.82b	1.00d	0.89c	

* Figures with same alphabets are statistically at par.

Table 7: effect of bagasse and mixed biochar on fresh weight of root (2015)

Treatment	Crop age				Mean
	1	2	3	4	
T1	0.32	0.99	1.26	1.22	0.95a
T2	0.76	1.29	1.38	1.35	1.20b
T3	0.77	1.29	1.37	1.34	1.19b
	0.62a	1.19b	1.34d	1.30c	

* Figures with same alphabets are statistically at par.

Table 8: effect of bagasse and mixed biochar on dry weight of root (2015)

Treatment	Crop age				Mean
	1	2	3	4	
T1	0.13	0.32	0.34	0.31	0.28a
T2	0.36	0.38	0.51	0.48	0.43c
T3	0.35	0.41	0.46	0.41	0.41b
	0.28a	0.37b	0.44d	0.40c	

* Figures with same alphabets are statistically at par.

Table 9: effect of bagasse and mixed biochar on fresh weight of shoot (2015)

Treatment	Crop age				Mean
	1	2	3	4	
T1	0.53	1.27	1.51	1.40	1.18a
T2	1.41	1.75	2.17	1.98	1.83c
T3	1.42	1.74	1.94	1.77	1.72b
	1.12a	1.59b	1.88d	1.72c	

* Figures with same alphabets are statistically at par.

Table 10: effect of bagasse and mixed biochar on dry weight of shoot (2015)

Treatment	Crop age				Mean
	1	2	3	4	
T1	0.12	0.35	0.49	0.34	0.33a
T2	0.42	0.53	0.57	0.54	0.51c
T3	0.42	0.47	0.58	0.56	0.51b
	0.32a	0.45b	0.55d	0.48c	

* Figures with same alphabets are statistically at par.

Table 11: effect of bagasse and mixed biochar on fresh weight of plant (2015)

Treatment	Crop age				Mean
	1	2	3	4	
T1	0.85	2.27	2.76	2.64	2.13a
T2	2.17	3.04	3.55	3.34	3.03c
T3	2.20	3.02	3.31	3.11	2.91b
	1.74a	2.78b	3.21d	3.03c	

* Figures with same alphabets are statistically at par.

Table 12: effect of bagasse and mixed biochar on dry weight of plant (2015)

Treatment	Crop age				Mean
	1	2	3	4	
T1	0.25	0.67	0.83	0.66	0.60a
T2	0.78	0.91	1.09	1.02	0.95c
T3	0.77	0.88	1.05	0.97	0.92b
	0.60a	0.82b	0.99d	0.88c	

* Figures with same alphabets are statistically at par.

From the perusal of Tables-1 to 12 for two years, it is concluded that biochar treatments differ significantly from the control. The bagasse biochar treatment was found statistically superior. The fresh weight of root dry weight of root, fresh weight of shoot, dry weight of shoot, fresh weight of plantand dry weight of plant was found higher in biochar-amended soils and fresh weight and dry weight first increases up to 3rd crop age (upto 90 days) and decreases at the end of life cycle. The results were in consistent with the finding of Baruah and Baruah (2015) [2]. The research of Seremesic *et al*. (2015) [30].Also reveal that shoot biomass was significantly affected by soil type and biochar level and shows better response of soybean to biochar application. Sun *et al*. (2012) [34].Suggested that biochar incorporation to brown soil might bring potential benefit to soybean production from N-retention in soil and enhanced microbial turnover that resulted with P and K feedback.

3.2 Effect on Height of plant and leaf area

The height of plant and leaf area were measured for the years of study 2014 (Tables 13 and 14) and 2015 (Tables 15 and 16).

Table 13: effect of bagasse and mixed biochar on height of plant (2014)

Treatment	Crop age				Mean
	1	2	3	4	
T1	38.67	65.00	95.00	108.00	76.67a
T2	58.67	89.33	123.33	135.67	101.75b
T3	58.33	86.67	122.00	131.33	99.58b
	51.89a	80.33b	113.44c	125.00d	

* Figures with same alphabets are statistically at par.

Table 14: effect of bagasse and mixed biochar on leaf area (2014)

Treatment	Crop age				Mean
	1	2	3	4	
T1	3.80	6.82	9.34	10.70	7.66a
T2	11.67	19.62	26.08	41.72	24.77c
T3	6.82	11.72	19.62	21.67	14.96b
	7.43a	12.72b	18.35c	24.69d	

* Figures with same alphabets are statistically at par.

Table 15: effect of bagasse and mixed biochar on height of plant (2015)

Treatment	Crop age				Mean
	1	2	3	4	
T1	40.00	65.33	98.00	109.33	78.17a
T2	60.33	91.67	124.33	135.33	102.91c
T3	58.33	86.67	125.00	132.33	100.58b
	52.89a	81.22b	115.78c	125.67d	

* Figures with same alphabets are statistically at par.

Table 16: effect of bagasse and mixed biochar on leaf area (2015)

Treatment	Crop age				Mean
	1	2	3	4	
T1	3.800	6.79	8.78	10.72	7.52a
T2	11.48	19.48	29.48	49.45	27.47c
T3	6.76	11.66	18.78	21.45	14.66b
	7.35a	12.64b	19.02c	27.20d	

* Figures with same alphabets are statistically at par.

The height and leaf area of soybean plant was found high in biochar treated soil. Similar trend was observed Baruah and Baruah (2015) [2]. Some researches reveal that bagasse ash can be considered as a good source of micronutrients (Fe, Zn, Mn and Cu) and due to this it can be a good soil additive. Jamail*et al*. (2004) [12].Found maximum straw yield in wheat at 10% bagasse ash treatment.

3.3 Effect on yield and pigment composition

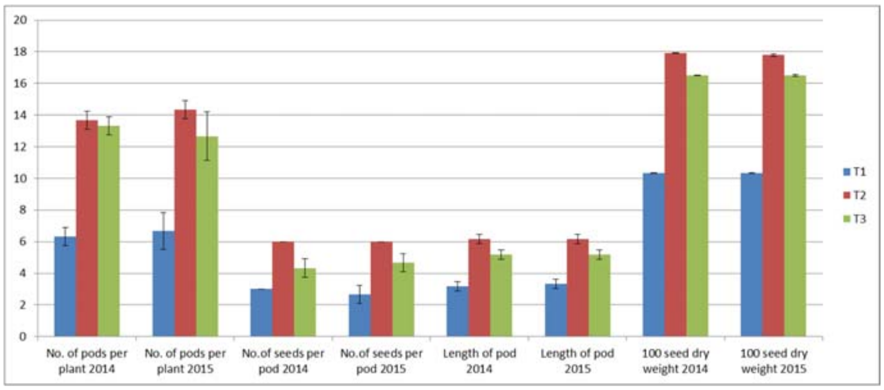

Fig 1: Graph showing effect of biochar on yield

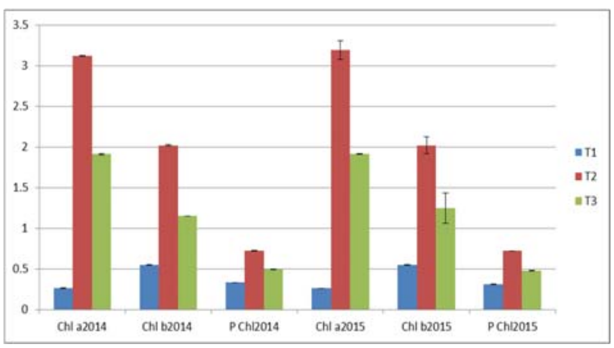

Fig 2: Graph showing effect of biochar on chlorophyll composition

From the perusal of Figure1 it is crystal clear that biochar amended soil increases yield in terms of number of pods per plant, number of seeds per pod, length of pod and seed dry weight. The higher grain yield may be attributed due to higher nutrient availability caused by high immobilization of soil. From Figure 2 it is concluded that the chlorophyll composition was also found high in plants grown in biochar treated soil. Study of Danish *et al*. (2014) [6] also concluded that chlorophyll pigment synthesis was also improved in those plants which are cultivated in biochar amended soils. Similar result of yield was found by Yooyen*et al*. (2015) [41]. The increase in seed dry weight may be correlated with increase in number of seeds/pod, sustained nutrient supply, increased photosynthetic activity (Pakhale*et al*., 2009) [25]. Recent study of Yooyen*et al*. (2015) [41].Concluded that the influence of biochar on dry weight and soybean seed weight is due to its properties in soil enrichment enabling the plant to accumulate its dry weight and seed weight better.

4. Conclusion

From the present study it can be concluded that adding biochar during soybean plantation is a substitute to improve soil fertility, enhance its growth and yield. The growth, pigment and productivity increased significantly in bagasse biochar treatment followed by mixed biochar treatment. The results obtained may be attributed to highly porous nature of bagasse biochar that ultimately increases WHC. Previous studies by other authors also suggested that the increase in yield was due to biochar application that not only improves the availability of nutrients but also promotes vegetative growth by improving the photosynthetic pigments production. This study aimed at evaluating the biochar application to soybean provides a solution for bio-waste management along with C- sequestration and soil health maintenance.

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