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Effect of Lantana Biochar on Yield and Economics of Organic Chickpea (*Cicer arietinum* L.)

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Abstract
A field experiment was carried out during Rabi 2021-2022 at Organic Farming Unit of Rajasthan College of Agriculture, MPUAT, Udaipur. The experiment was laid out in factorial randomized block design with three replications and assigning sixteen treatment combinations consisting of two factors and both were at four levels first factor was different doses of *Lantana camara* biochar *i.e.* control and different levels of *Lantana camara* biochar (1.5 t ha^{-1}, 2.5 t ha^{-1}, 3.5 t ha^{-1}) and second factor was different time of application of *lantana camara* biochar (at sowing, at branching, at pod formation, 50% at sowing + 50% at branching). Results revealed that application of 3.5 t ha^{-1} *Lantana camara* biochar gave higher seed yield (1436 kg ha^{-1}), haulm yield (3523 kg ha^{-1}) and biological yield (4959 kg ha^{-1}) as compared to control, 1.5 t ha^{-1}, and application of 3.5 t ha^{-1} *Lantana camara* biochar and application of 2.5 t ha^{-1} *Lantana camara* biochar perceived to be par with each other. Application of *Lantana camara* biochar in two split does i.e. 50% at sowing + 50% at branching resulted in higher seed yield (1386), haulm yield (3334 kg ha^{-1}) and biological yield (4720 kg ha^{-1}) as compared to application of *Lantana camara* biochar at time of sowing, at branching and pod formation stage, respectively.

Keywords: Lantana camara, biochar, split application

Introduction
Organic agriculture combines tradition, innovation, and science to benefit the shared environment and promote fair relationships and good quality of life for all involved. Organic farming is being practiced in 190 countries of the world. The harmful effects of chemicals used in agriculture are changing the mindset of consumers of different countries who are now buying organic produce with high premium for health. Policy makers are also promoting organic farming for restoration of soil health and generation of rural economy apart from making efforts for creating better environment. The global area under organic agriculture is about 74.9 million hectare and world organic market is now 120.6 billion US$ (FiBL, 2021) [5]. In India, about 4.33 million ha area is under organic cultivation and total production of certified organic products is 3.49 MMT (APEDA, 2021) [2]. In India, about 4.34 million ha area is under organic cultivation and total production of certified organic products is 3.49 million tonn (APEDA, 2021) [2]. Chickpea (*Cicer arietinum* L.) is an important pulse crop grown and consumed all over the world. Globally, it was grown on 149.66 lakh ha area, with a total production of 162.25 lakh t and average productivity of 1252 kg ha^{-1} (FAOSTAT, 2020) [4]. In India, chickpea had a lion's share of 49.3% in the total pulses production during 2020. It contributes highest area and production *i.e.* 10.17 m ha and 11.35 mt, respectively among pulses with a productivity of 1116 kg ha^{-1} at national level. More than 90 percent production in the country has been cultivated at Madhya Pradesh, Maharashtra, Rajasthan, Uttar Pradesh, Karnataka, Andhra Pradesh, Gujarat, Jharkhand, Tamil Nadu and Telangana. In Rajasthan, chickpea is cultivated in 2.46 m ha area with a production of 2.66 mt (Agricultural Statistics, 2020) [1]. Biochar is a carbonaceous product of the pyrolysis of solid biomass formed after heating at the temperature of 300-600 °C in the absence of oxygen. It is a dark colored powdery product with several unique properties like high porosity, high cation exchange site which provides favorable conditions for living microbiota in the soil and increase the soil carbon pool. It is predominantly known to optimize the bulk density of the soil. Biochar produced at a lower pyrolysis temperature have better properties to deliver nutrients than the biochar prepared at higher temperature. On an average, crop residue biochar contained 1.23% nitrogen, 0.32% phosphorus, 0.56% sulphur, 2.73% potassium and 50-70% carbon but the nutrient content may vary according to the type of biomass to be pyrolyzed and prevailing

conditions during the process (Li *et al.*, 2019) [8]. So, biochar application improves the overall properties of soil and act as a soil amendment to enhance soil fertility.

Material and Methods

The experiment was laid out at Organic Farming Unit (Agronomy), Rajasthan College of Agriculture, Udaipur which is located in Southern Eastern part of Rajasthan at an altitude of 581.16 metres above mean sea level with 24° 35' N latitude, 72° 42' E longitude. The region comes under the agro-climatic zone IVa (Sub-Humid Southern Plain and Aravali Hills) of Rajasthan. The climate of this zone is typical sub-tropical conditions defined by mild winter and moderate summers accompanied with high relative humidity especially during the months of June to September. The mean weekly meteorological parameters recorded at Agro-meteorological Observatory, Rajasthan College of Agriculture, Udaipur during the *rabi* season, 2021-2022. Total rainfall received during the rabi season of 2021-22 was 637 mm with a range between 373-1140 mm, most of which is contributed by South-West monsoon from July to October. The minimum and maximum temperatures ranged between 3.3 °C to 12.5 °C and 20.9 °C to 36.3 °C, respectively. The minimum and maximum relative humidity ranges between 17.1 percent to 70.6 percent and 59.3 percent to 96.0 percent, respectively during experimentation. In the present experimental field, *Lantana* biochar was used through slow pyrolysis in biochar production system (Pratap Kiln) which was prepared in the CTAE, Udaipur. Stalks of *Lantana camara* plant were fed to the pyrolysis reactor in oxygen limiting condition where the temperature goes up to 450 °C for the period of four minutes. This process occurs in three stages, first where the moisture content of the biomass was reduced to <10 percent at the temperature of 180 °C, second where the biochar production starts with the breakdown of hemicellulose and cellulose at the temperature range of 180-360 °C and last stage where lignin breaks down at the temperature of 450 °C.

The experiment was laid out in factorial randomized block design with three replications and assigning sixteen treatment combinations consisting of two factors and both were at four levels first factor was different doses of *Lantana camara* biochar *i.e.* control and different levels of *Lantana camara* biochar (1.5 t ha^{-1}, 2.5 t ha^{-1}, 3.5 t ha^{-1}) and second factor was different time of application of *lantana camara* biochar (at sowing, at branching, at pod formation, 50% at sowing + 50% at branching). The lantana biochar was incorporated into the soil as per the treatments with help of the spade in 15 cm top soil layer.

Table 1: Effect of application of Lantana biochar on yield and harvest index of chickpea

Treatments	**Yield (Kg ha^{-1})**			**Harvest index (%)**
	Seed	**Haulm**	**Biological**	
Doses of Lantana biochar (t ha^{-1})				
D_1- Control	1067	2348	3416	31.33
D_2- 1.5	1216	2897	4113	29.64
D_3- 2.5	1365	3382	4747	28.85
D_4- 3.5	1436	3523	4959	28.98
S.Em±	25.816	72.037	74.254	0.810
C.D. at 0.05	74.562	208.057	214.461	NS
Stages of application				
S_1- At sowing	1161	2762	3922	29.80
S_2- At branching	1279	3057	4337	29.63
S_3- At pod formation	1258	2997	4255	29.83
S_4- 50% at sowing + 50% at branching	1386	3334	4720	29.54
S.Em±	25.816	72.037	74.254	0.810
C.D. at 0.05	74.562	208.057	214.461	NS

Results and Discussion

Doses of lantana biochar: In the present investigation, application of 3.5 t ha^{-1} lantana biochar recorded significantly higher seed yield (1436 kg ha^{-1}) with an increase of 34.51% over control (1067 kg ha^{-1}). Similarly, significantly higher haulm yield (3523 kg ha^{-1}) was also recorded with 3.5 t ha^{-1} lantana biochar application with an increase of 50.02% over control (2348 kg ha^{-1}) and maximum biological yield (4959 kg ha^{-1}) was obtained when applied 3.5 t ha^{-1} lantana biochar, while minimum biological yield (3416 kg ha^{-1}) was found in control (Table 1). This might be due to the vigorous vegetative growth resulting in higher photosynthate production and translocation from source to the sink which is apparent on reproductive growth *viz.* number of pods plant^{-1}, and 100 seed weight which were the important yield attributes having significant positive effect on seed yield. Rondon *et al.* (2007) [9] got the similar results where bean yield was increased by 46% and biological yield by 39% over the control. A recent meta-analysis by Ye *et al.* (2020) [10] also observed that biochar application along with organic and inorganic fertilizers led to higher crop yields. In a similar study there was significant increase in yield of maize in biochar amended plots (Arif *et al.* 2021) [3].

Stages of application: Application of lantana biochar at different crop growth stages registered significant improvement in seed yield (1386 kg ha^{-1}), haulm yield (3334 kg ha^{-1}) and biological yield (4720 kg ha^{-1}) over application of lantana biochar at the time of sowing. This might be due to greater nutrient availability to the crop throughout the growing period because lantana biochar was given in split doses, this increases the period of nutrient availability to the crop and also improves the water holding capacity of the soil due to porous structure of lantana biochar which improves the growth of crop which leads to increase in more number of pods per plant. This results in significant increase in seed yield, haulm yield and biological yield of chickpea. These results were close to the findings of Husk *et al.* (2010)[7] stated that crop biomass was increased 17-20% for soybean and 17-99% for forage were observed, with an estimated biochar application rate of 3.9 t ha^{-1}. In the same line research work also done by Gebremendhin *et al.* (2015) [6] showed in their experiment that use of biochar of weed *Prosipis juliflora* application rate of 4 t ha^{-1}increased the seed yield 16.5% of wheat crop.

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