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Comparative quantification of carbon sequestration in sole crops and Bael based agri-hortisystem

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ABSTRACT

Carbon sequestration has been proposed as an important means for mitigating climate change, particularly in medium and longer range. Fossil fuels will remain the dominate source of energy well into the 21st century. Carbon sequestration is a potential solution for limiting the atmospheric release of carbon dioxide emissions that may contribute to global warming. A field study was conducted during rainy (*kharif*) season of 2018 at Agricultural Research Farm in Rajiv Gandhi South Campus, Banaras Hindu University, Barkachha, Mirzapur under two systems, *viz*., in open system and in bael based agri-horti system. Black gram, sesame, green gram, soybean, and pearl millet were sown solely in open system and also grown in interspaces between the rows of bael trees in 12 year-old agroforestry system. The result showed that in bael based agri-horti system, the bael+soybean variety 'JS-20229'observed significantly higher above ground biomass (4045.71 kg/m^2) and below ground biomass (1049.88 kg/m^2) over other treatments. Similar trend was observed in case of above ground carbon sequestration (1819.57 kg/m^2) and below ground carbon sequestration (472.34 kg/m^2). However, in the sole system, the highest above ground biomass (4.22 kg/m^2) and below ground biomass (1.10kg/m^2) was observed in pearl millet variety 'PHB-2168' which was at par with pearl millet variety 'Nandi-52. Similarly, in sole crop, maximum aboveg round carbon sequestration (1.90 kg/m^2) and below ground carbon sequestration (0.49 kg/m^2) was recorded in pearl millet variety 'PHB-2168'.

Key words: *Fossil fuel, Global warming, Carbon sequestration, Agroforestry system*

Introduction

Environmental issues have never attained so much global prominence in the history of human civilization as it does today. It is now widely accepted that current global climate change is the most serious environmental issue affecting human lives on a global scale. Global warming increases the atmospheric concentration of the greenhouse gases such as methane, nitrous oxide and carbon dioxide. It is changing climate in unpredictable ways, from floods and hurricanes to heat waves and droughts. To try and reduce the risk of global warming and extreme weather events, it is required to reduce the quantity of how much fossil fuel we are burning. One of the approaches for reducing CO_2 concentration in the atmosphere is carbon (C) sequestration. The Land Use, Land Use Change and Forestry (LULUCF), an approach that became popular in the context of the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) allows the use of carbon sequestration through afforestation and reforestation as a form of GHG-offset activities. Agro-forestry systems attracted attention as a Carbon sequestration strategy from both industrialized and developing countries (Takimoto *et al*., 2008). Carbon sequestration involves the net removal of CO_2 from the atmosphere and storage in long-lived C pools. Such pools include above-ground plant biomass; below-ground biomass such as roots, soil microorganisms. Most carbon enters the ecosystem through the photosynthesis in the leaves, and carbon accumulated is in aboveground biomass. More than half of the portioned carbon is eventually transported below ground through the root and root exudates and litter deposition. Carbon sequestration process can continue for longer periods and eventually gets stabilized, but changes in land use practices can bring SOC stocks to a new equilibrium, with more or less carbon sequestered. Now there are more emphasis in the role of tree to capture and store atmospheric CO_2 in vegetation, soils, and biomass products. Carbon sequestration refers to the establishment of long-term storage of carbon in the terrestrial biosphere, underground or the ocean so that the build-up of carbon dioxide concentration in the atmosphere will be reduced or slowed in order to improve environmental conditions and check the processes of environmental degradation. Agroforestry system maintained the soil fertility vital for global food security and environmental sustainability. In regions where the green revolution has not been able to make a dent due to lack of soil fertility; agro-forestry may hold promise. The carbon sequestration potential of agroforestry systems has been successfully established theoretically, however, field measurements to validate these concepts are limited. The present investigation was carried out with the objective to make a comparative quantification in the sole cropping system and crop grown in the interspaces of bael in the agro-horticultural systemin BHU Uttar Pradesh state of India.

Materials and Methods

A study was carried out on Comparative quantification of carbon sequestration in sole crops and bael based agri-horti system in the Agriculture Research Farm in Rajiv Gandhi South Campus, Banaras Hindu University, Barkachha, Mirzapur during rainy (*kharif*) season of 2018. It spreads between $25^{0}10'$ latitude, $82^{0}37'$ longitude and 147 meters above mean sea level. The climate of the area is sub-humid with dry hot summers. The soil of experimental fields was alluvium, having pH of 6.8. The crop studied was black gram, sesame, green gram, soybean and pearl millet in Randomized Complete Block Design (RBD) with ten treatment replicated thrice under two systems, *viz.*, open and bael based agri-horti system. The size of each plot was 3 m × 3m and spacing of black gram, sesame, green gram and soybean is 30 cm × 10 cm each, pearl millet is 45 cm × 15 cm and bael was spaced at 7m × 7m which was 12-year-old orchard. Nitrogen, phosphorus and potassium were applied in the form of urea, single super phosphate and muriate of potash, according to recommendation of crops. All the crop plants occurring within the borders of the quadrant were cut at ground level and collected (fresh weight) and oven dried for 24-48 hours at 65 to 70 ^{o}C till a constant weight (dry weight).

Further calculation as follows:

$$\text{Standing biomass} = \frac{\text{Dry weight (of above ground tissues) (kg)}}{\text{Plot area (m}^2\text{)}}$$

Below ground biomass of roots is calculated by multiplying the above ground biomass by a factor of 0.26 (Cairns *et al*., 1997).

Belowground biomass = Total above ground biomass × 0.26.

Total crop biomass = Above ground crop biomass+ Below ground biomass

Total carbon in crop:

The crop biomass is converted into carbon amount by multiplication with a factor of 0.45 (Woomer, 1998).

Total carbon in crop= Total biomass of crop × 0.45

Above ground biomass of trees:

Above ground biomass was determined by non-destructive method, equation developed by Sandra Brown (1997) given as following:

$Y= \exp [-2.134+ (2.530\ ln D)]$

Where, Y = Above ground biomass in kg,

D = Diameter in cm and

ln= Natural log

Below ground biomass of trees:

Below ground biomass of tree roots is calculated by multiplying the above ground biomass by a factor of 0.26 (Cairns *et al*., 1997).

Below ground biomass of trees = Above ground biomass of trees × 0.26

Total carbon in trees:

Total carbon in tree = Total tree biomass multiplied by a factor of 0.45 due to the fact that around 45% carbon is found in the total biomass of trees (Woomer, 1998).

Total carbon in trees = Total biomass × 0.45

Rate of carbon sequestration:

Rate of carbon sequestration was calculated by as per total carbon sequestration and divided by age of plantation.

$$\text{Rate of carbon sequestration} = \frac{\text{Total carbon}}{\text{Age of plantation}}$$

CO_2 was estimated as per the formula suggested by Pearson *et al.* (2007).

CO_2 sequestered = Biomass carbon stock × 3.67

Results and Discussion

Data indicated that significantly higher above ground (4.22 kg/m^2) and below ground biomass (1.10 kg/m^2) was recorded in pearl millet variety 'PHB-2168' which was statistically similar to pearl milletvariety 'Nandi-52' in comparison to other treatments and the minimum value of aboveground and below ground biomass was recorded in soybean variety 'JS-335' in the sole cropping system (Table 1). However in the bael based agri-horti system, bael+soybean variety'JS-2029' was recorded statistically maximum above (4045.71 kg/m^2) and below ground biomass (1049.88 kg/m^2) over all the treatments which was followed by bael + soybean variety 'JS-335' and bael + black gram variety 'Shekhar-2' was recorded lowest value of above and below ground biomass (Table 2).

Further analysis of data in Table 1 revealed that

Table 1. Effect of sole crops on above and below ground biomass accumulation and carbon sequestration.

Treatment	Above ground biomass (kg/m^2)	Below ground biomass (kg/m^2)	Above ground carbon sequestration (kg/m^2)	Below ground carbon sequestration (kg/m^2)
Black gram (Shekhar 1)	0.86	0.22	0.38	0.10
Black gram (Shekhar 2)	1.04	0.27	0.47	0.12
Sesame (T 12)	1.30	0.34	0.58	0.15
Sesame (T 78)	1.23	0.32	0.55	0.14
Green gram (SML668)	0.92	0.24	0.41	0.10
Green gram (PDM 139)	0.82	0.21	0.37	0.09
Soybean (JS 335)	0.68	0.17	0.30	0.07
Soybean (JS 2029)	0.71	0.18	0.32	0.09
Pearl millet (Nandi-52)	4.16	1.07	1.86	0.48
Pearl millet (PHB2168)	4.22	1.10	1.90	0.49
SEm+	0.05	0.01	0.02	0.006
CD (P=0.05)	0.16	0.04	0.07	0.01

Table 2. Effect of Bael based agro-forestry system on above and below ground biomass accumulation and carbon sequestration

Treatment	Above ground biomass (kg/m^2)	Below ground biomass (kg/m^2)	Above ground carbon sequestration (kg/m^2)	Below ground carbon sequestration (kg/m^2)
Bael+ Black gram (Shekhar 1)	883.83	231.35	400.42	104.11
Bael+ Black gram (Shekhar 2)	618.10	158.70	276.14	70.32
Bael+ Sesame (T 12)	1305.27	340.37	556.37	152.72
Bael+ Sesame (T 78)	1007.47	261.46	452.26	116.11
Bael+ Green gram (SML668)	1233.14	319.88	554.36	143.39
Bael+ Green gram (PDM 139)	1057.16	274.86	474.72	122.68
Bael+ Soybean (JS 335)	3639.15	945.18	1636.61	423.78
Bael+ Soybean (JS 2029)	4045.71	1049.88	1819.57	472.34
Bael+ Pearl millet (Nandi-52)	1614.24	405.43	710.12	185.08
Bael+ Pearl millet (PHB2168)	1662.21	425.43	747.44	194.59
SEm+	99.21	23.76	40.01	11.40
CD (P=0.05)	297.05	71.15	122.79	34.60

significantly maximum above (1.90 kg/m^2) and below ground carbon sequestration (0.49 kg/m^2) was recorded in pearl millet variety 'PHB-2168' which was at par with pearl millet variety 'Nandi-52' whereas, the lowest above and below ground carbon sequestration was found in soybean variety 'JS-335' over all the treatments in sole crop. The execution of Table 2 shows that inbael based agri-horti system above (1819.57 kg/m^2) and below ground carbon sequestration (472.34 kg/m^2) was highest in bael+soybean variety 'JS-2029' followed by bael + soybean variety 'JS-335'. The lowest value of above and below ground carbon sequestration was recorded in bael + black gram variety 'Shekhar 2' among the different treatments. Among sole crops, the highest total dry matter accumulation and cumulative carbon sequestration was observed in pearl millet variety 'PHB-2168'. However in bael based farming practices, it was highest inbael + soybean variety 'JS-2029' over the other treatments.In agroforestry system, soybean performed well due to their shed loving habit. It was also observed that higher density will result in higher above ground biomass and aboveground carbon sequestration (Oelbermann *et al*., 2004). The higher above and below ground biomass might be the reason of higher carbon sequestration in sole as well as bael based agri-horti system of the present investigation. The earliest studies of potential carbon sequestration in agroforestry systems and alternative land use systems for India had estimated 68-228 Mg C/ha (Prasad, 2003), 25 t C/ha over 96 M ha of land (Sathaye and Ravindranath, 1998). However, the magnitude of carbon sequestration from forestry activities would depend on the scale of operation and the final use of economic produce.

Conclusion

Carbon sequestration is a broad and important topic. It is essential to circumvent the effects of climate change. Carbon capture and storage is one of the most effective and discussed methods of solving this issue. To reverse the effects of climate change, carbon capture and storage must be coupled with forward thinking method of generating clean energy so that no more carbon is released into the atmosphere.it might be concluded that in sole cropping, pearl millet variety 'PHB-2168' was better in accumulation and sequestration of biomass and carbon, respectively. However, in agri-horti system, bael + soybean variety 'JS-2029' was superior in the accumulation and sequestration of biomass and carbon in the system.

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