Indian Journal of Agricultural Sciences **91** (10): 1482–6, October 2021/Article
https://doi.org/10.56093/ijas.v91i10.117512

Effect of grass-based cropping systems on carbon sequestration under changing climate scenario

B L KUMHAR[1], K K AGRAWAL[1], H K RAI[1], A AHIRWAL[1], H P MEENA[2], RAJENDRA KUMAR YADAV[2] and B D YADAV[3]

College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur 482 004, India

Received: 08 December 2020; Accepted: 30 March 2021

ABSTRACT

The present investigation was conducted during two consecutive years of 2018–19 and 2019–20 entitled "Effect of grass-based cropping systems on soil health improvement in terms of carbon sequestration under changing climate scenario". Pearl millet napier hybrid sole crop was exhibited significantly higher total dry biomass 52.20 t/ha, above ground carbon 18.45 Mg/ha, below ground carbon 5.54 Mg/ha, total above and below ground carbon 23.99 Mg/ha, above ground CO_2 sequestration 67.71 Mg/ha, below ground CO_2 sequestration 20.32 Mg/ha and total above and below ground CO_2 sequestration 88.02 Mg/ha during experimentation. PN hybrid in paired rows + rice bean - Egyptian clover noted higher soil organic carbon stock 14.75, 12.68 and 10.03 Mg/ha, soil CO_2 sequestration 54.17, 46.52 and 36.79 Mg/ha at 0-15, 15-30 and 30- 45 cm soil depth respectively, total carbon stock 57.96 Mg/ha, total CO_2 sequestration 212.70 Mg/ha, and carbon credit ₹ 49264 /ha/yr over guinea grass sole crop. Among the different grass based cropping systems maximum total carbon stock and total CO_2 sequestration under PN hybrid in paired rows + ricebean - Egyptian clover but pearl millet napier (PN) hybrid sole higher fodder carbon stock and fodder CO_2 sequestration over guinea grass sole crop for soil health improvement under present scenario of climate change.

Keywords: Carbon sequestration potential, Carbon stocks, Climate change, Cropping systems

In the recent decades Indian agriculture is confronting with sustainable increase in crop production and conservation of ever deteriorating natural resources, *i.e.* soil, water and biodiversity at the face of climate change. Climate change has been considered as the biggest global threat of 21st century (Kumar *et al.* 2018). Climate change, together with other megatrends like population growth, rapid urbanization, food insecurity and water scarcity increase the competition for resource and heightens tensions and instability (Anon. 2017a). Global climate change has already manifested itself through increase in global temperature by 0.6 to 0.8°C during the 20th century and increase in frequency of extreme events like very high intensity precipitation, frequent drought, heat waves etc (Singh *et al.* 2017). Carbon in the forms of methane (CH_4) and carbon dioxide (CO_2) is the major player in contributing to this global climatic shift. Carbon sequestration (CS) is the process of removal of carbon dioxide (CO_2) from atmosphere into green plants where it can be stored indefinitely. Soil carbon sequestration has numerous other benefits, viz. stabilization of soil aggregates, food for beneficial organisms, slow-release source of nutrients, increased water holding capacity, increase in nutrient holding capacity by improving cation exchange capacity, binding of toxic material build carbon, whereas grass-based cropping system minimal disturbance (Kane, 2015). There is opportunity to achieve a climate-friendly agriculture by both sequestering carbon and reducing emissions. Grass-based cropping system (GBCS) helps in increasing the fodder yields and resource-use efficiency through their vegetation cover, greater root production ability. It also helps in bind soil particles, soil conservation, adapting to mitigating global climate change, improving water quality, availability and ensuring food security (Soni *et al.* 2013, Biradar *et al.* 2019 and Kumhar *et al.* 2020a). Reduced soil disturbance and increased organic matter inputs in forage production systems may improve soil quality and crop production through their effects on soil organic matter (SOM) dynamics and nutrient cycling. GBCS are known to improve soil organic carbon (SOC) storage because of their ability to increase the quality, availability and diversity of soil microbial substrate, augmentation of root biomass carbon and nitrogen accumulation. Carbon sequestration in the biosphere has now become an important strategy to off-

Present address: [1]College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur; [2]Agricultural Research Station, Agriculture University, Kota; [3]Swami Keshwanand Rajasthan Agricultural University, *Bikaner*. *Corresponding author e-mail: prajapatiagro09@gmail.com.

set the effect of increasing atmospheric CO_2 concentration (Tanwar *et al.* 2019). Therefore, practices that sequester carbon in fodder crops also tend to enhance resilience in the face of climate variability. Thus likely to enhance longer-term adaptation to changing climates (Anon 2010 and Kumhar *et al.* 2020b). Maintenance of organic carbon in soil (SOC) is critically important for sustainable agricultural productivity and environmental quality. Enhancing soil carbon sequestration in agricultural land is a strategy of vital importance to decelerate the observed climate changes. The soil organic carbon and its fractions are good indicators of soil quality and environmental stability. Therefore, the present study was undertaken with the objective of grass-based cropping systems on soil health improvement in terms of carbon sequestration under changing climate scenario.

MATERIALS AND METHODS

Field experiment was conducted at Research Farm of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh during two consecutive years 2018–19 and 2019–20 with eight grass-based cropping systems, viz. pearl millet napier (PN) hybrid sole crop (T_1), guinea grass sole crop (T_2), PN hybrid in paired rows + rice bean (*Kharif*) - Egyptian clover (*Rabi*) (T_3), PN hybrid in paired rows + *Desmanthus* (T_4), PN hybrid in paired rows + *Sesbania grandiflora* (T_5), guinea grass in paired rows + rice bean (*Kharif*) - Egyptian clover (*Rabi*) (T_6), guinea grass in paired rows + *Desmanthus* (T_7) and guinea grass in paired rows + *Sesbania grandiflora* (T_8). The experiment was laid out in three replications under randomized block design (RBD). The various soil physco-chemical characteristics of experimental soil are loamy clay with *p*H 7.02, electrical conductivity (0.20 dS/m^2), medium organic carbon (0.65%), available nitrogen (190 kg/ha), available phosphorous (19.5 kg/ha) and available potassium 275.5 (available) were found in low range.

Recommended dose of 150 kg N, 80 kg P_2O_5 and 40 K_2O kg/ha was applied through urea, single super phosphate and muriate of potash. All the observations were recorded and recommended package of practices as adopted in Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, were followed to raise the crops. Data were analyzed using standarad statistical procedures. Other computations were made using following relationships:

Dry forage yield (above ground biomass)

$$\text{Dry matter yield (t/ha)} = \frac{\text{Green fodder yield (t/ha)} \times \text{Dry matter content (\%)}}{100}$$

Below ground crops biomass (t/ha)

Belowground biomass (t/ha) = Aboveground biomass (t/ha) × Root: shoot ratio

Total crop biomass (t/ha) = (above + below ground) crop biomass (t/ha)

Methodology for carbon determination: The carbon in plant biomass was determined by ash method. The oven dried sample of 5.0 g for each part of the crops was taken in pre weighed crucible. The crucibles were placed in the muffle furnace adjusted at 400^{0}C for 2.30 h. Percentage of organic carbon was calculated as formula given by Allen *et al.* (1986).

Fodder carbon stocks (Mg/ha): Carbon was sequestered by the plant photosynthesis and stored as biomass in different parts of the plant. To determine biomass carbon stock, dry biomass was converted into carbon by Ash method suggested by Ajit *et al.* (2017).

$$\text{Carbon stock (Mg/ha)} = \frac{\text{Total dry biomass (t/ha)} \times \text{Carbon content (\%)}}{100}$$

Soil carbon stock (Mg/ha): Soil organic carbon stocks were calculated by multiplying the organic carbon with weight of the soil (bulk density and depth) for a particular depth and expressed as ton per ha (Mg/ha) as the equation given by (Pearson *et al.* 2007).

SOC (Mg/ha) = Total SOC concentration (g/kg) × Soil bulk density (Mg/m^3) × Soil depth (m) × 10

Bulk density was determined by using core sampler method (Bodman 1942).

CO_2 sequestration potential (Mg/ha)

C sequestered = Carbon stock (Mg/ha) × 3.67

RESULTS AND DISCUSSION

Total dry biomass: Pearl millet napier (PN) hybrid sole cropping exhibited significantly higher total dry (above ground + below ground) biomass 52.20 t/ha followed by PN hybrid in paired rows + *Desmanthus* 45.5 t/ha at par with PN hybrid in paired rows + ricebean - Egyptian clover 44.2 t/ha and PN hybrid in paired rows + *Sesbania grandiflora* 40.4 t/ha over the guinea grass sole crop 29.6 t/ha (Table 1). Biomass production under different cropping systems depends on number of factors, viz. choice of crops, growth habit, site quality, soil type, age of crop, management practice applied, frequent intercultural operations, moisture conservation and their interaction with belowground crops have also contributed towards the increasing aboveground biomass production. Similar results were also obtained by Jain *et al.* (2018), Sarvade *et al.* (2019) and Kundu *et al.* (2019).

Carbon stocks in crops: Pearl millet napier (PN) hybrid sole crop exhibit significantly higher above ground carbon stock 18.45 Mg/ha, below ground carbon stock 5.54 Mg/ha, total above and below ground carbon stock 23.99 Mg/ha as compared to other grass-based combinations (Table 1). Below ground biomass of fodder crops in the form of roots comprise about 1/5th to 1/4th of the total living biomass and there is constant addition of organic matter to the soil through decaying dead roots, which leads to improvements in the carbon status of the soil. It might be due to its high below ground biomass carbon concentration. The higher below ground biomass carbon concentration of PN hybrid was attributed to its deep penetrating roots unlike the other grass species, PN hybrid which has a deep penetrating and bulky root structure. This observation is in agreement with

Table 1 Total fodder dry biomass, carbon stocks and CO_2 sequestration as influenced by different grass based cropping systems

Cropping System	Total dry biomass (t/ha)	Carbon stocks (Mg/ha)			CO_2 sequestration (Mg/ha)		
		Above ground	Below ground	Total	Above ground	Below ground	Total
T_1	52.2	18.45	5.54	23.99	67.71	20.32	88.02
T_2	29.6	10.78	3.02	13.80	39.56	11.08	50.64
T_3	44.2	16.10	4.40	20.50	59.51	16.14	75.23
T_4	45.5	16.20	4.81	21.00	59.62	17.64	77.08
T_5	40.4	14.47	4.27	18.74	53.53	15.66	68.76
T_6	35.3	13.15	3.36	16.51	48.42	12.33	60.59
T_7	36.1	13.13	3.73	16.85	48.19	13.67	61.84
T_8	32.9	12.03	3.37	15.39	44.30	12.35	56.48
SEm ±	1.36	0.22	0.072	0.28	0.81	0.23	1.05
CD (P=0.05)	4.03	0.66	0.188	0.84	2.42	0.68	3.11

the findings of Tanwar *et al.* (2019) and Bhardwaj *et al.* (2019). The variation in total carbon stock under different fodder crops depends primarily upon the ash content and the ash content depends upon the number of structural components of respective crops. Increasing soil organic carbon, and as such could represent a win–win scenario. Moreover, perennial crops ensure vegetation cover and thus photosynthesis all year around which increases the biomass that is produced and left on the site to become soil organic carbon. Thus, there is greater potential to maintain or sequester soil organic carbon relative to annual crops. Along with potential benefits for soils and GHG emission reduction, perennial crops store biomass. Similar finding had been reported by Sathiya and Babu (2016), Tanwar *et al.* (2019) and Ledo *et al.* (2020).

Soil organic carbon stocks: The significantly highest soil organic carbon stock was found under PN hybrid in paired rows + ricebean - Egyptian clover 14.75, 12.68 and 10.03 Mg/ha at various depth, i.e. 0-15, 15-30 and 30-45 cm respectively. Grass-based cropping systems provided better soil physical environment, or in other words enhanced protection for soil organic matter (SOM). PN hybrid in paired rows + ricebean - Egyptian clover exhibit significantly higher total soil organic carbon stock 57.96 Mg/ha. The sequestered carbon in soil helps in reducing CO_2 present in the atmosphere, while enhances soil quality and a sustained productivity. Soil carbon sequestration can be accomplished by management practices that add high amounts of biomass to the soil, cause minimal soil disturbance, conserve soil and water, improve soil structure, and enhance soil faunal activity. Similar findings were also reported by Bhardwaj *et al.* (2019), Mondal *et al.* (2019), Chatterjee *et al.* (2019) and Fornara *et al.* (2020).

CO_2 sequestration potential: In the present study pearl millet napier hybrid sole crop exhibit significantly higher above ground CO_2 sequestration 67.71 Mg/ha, below ground CO_2 sequestration 20.32 Mg/ha and total above and below ground CO_2 sequestration 88.02 Mg/ha (Table 2). There are many studies available in published literature on CO_2 sequestration potential of crops and cropping systems. However, the choice of crop species, cropping system, timing of fallowing and quality and quantity of residue returned to the soil have considerable impact on soil organic carbon stocks. Inclusion of annual legume potentially increase soil

Table 2 Carbon stocks, CO_2 sequestration and carbon credit as influenced by different grass based cropping systems

Cropping systems	Soil carbon stocks (Mg/kg)			Soil CO_2 sequestration (Mg/kg)			Total carbon stock (Mg/ha)	Total CO_2 sequestration (Mg/ha)	Carbon credit (₹/ha/yr)
	0-15 cm	15-30 cm	30-45 cm	0-15 cm	15-30 cm	30-45 cm			
T_1	13.57	11.20	9.18	49.80	41.07	33.68	57.92	212.57	49233
T_2	13.51	11.05	8.93	49.55	40.55	32.76	47.27	173.48	40179
T_3	14.75	12.68	10.03	54.17	46.52	36.79	57.96	212.70	49264
T_4	14.63	12.52	9.73	53.68	45.92	35.71	57.87	212.38	49190
T_5	14.33	12.50	9.46	52.59	45.86	34.70	55.01	201.89	46760
T_6	14.63	12.62	9.97	53.67	46.32	36.58	53.71	197.14	45659
T_7	14.36	12.51	9.47	52.68	45.92	34.72	53.17	195.15	45197
T_8	14.26	12.33	9.41	52.32	45.25	34.51	51.37	188.54	43668
SEm ±	0.20	0.15	0.15	0.77	0.57	0.49	0.38	1.27	317.47
CD (P=0.05)	0.63	0.45	0.45	2.29	1.70	1.48	1.12	3.68	952.3

carbon under grass-based cropping system through increased root mass inputs and rooting depth one of the causes of the soil organic matter increase observed in grass-based cropping system. Similar results found by Dabin *et al.* (2019), and Nishanth *et al.* (2013). PN hybrid in paired rows + ricebean - Egyptian clover higher soil CO_2 sequestration (54.17, 46.52 and 36.79 Mg/ha) at 0-15, 15-30 and 30- 45 cm soil depth respectively, total CO_2 sequestration (212.70 Mg/ha) over guinea-grass sole crop. This considering only the top 45 cm may favour practices and crops which concentrate SOC in the top 15 cm rather than sequester carbon across a more relevant profile. Overall, perennial crops accumulate SOC through time and perennial crops with legume inclusion will lead to a SOC increased during study. The SOC build-up in soils of the control plot might be because of continuous addition of root biomass and root exudates from grass legumes intercropping. Intercropping of legume species is a key cause of greater carbon build-up in soil. Additionally, while some management practices such as reduced or no tillage may reduce SOC losses, additional agricultural practices may be required so the full life cycle needs to be considered.

Cabon credit: Mean maximum carbon credit was under PN hybrid in paired rows + ricebean - Egyptian clover ₹ 49264/ha/yr over the rest of treatments (Table 2). The second-best cropping system was pearl millet napier hybrid sole crop ₹ 49233 /ha/yr at par with PN hybrid in paired rows + *Desmanthus* ₹ 49190 /ha/yr over guinea-grass sole crop.

On the basis of present study, it can be concluded that among the different grass-based cropping systems maximum total carbon stock and total CO_2 sequestration under PN hybrid in paired rows + ricebean - Egyptian clover but pearl millet napier hybrid sole higher fodder carbon stock and fodder CO_2 sequestration over guinea-grass sole crop for soil health improvement under present scenario of climate change.

ACKNOWLEDGEMENTS

Frist author greatly acknowledges, JNKVV Jabalpur, to provide all necessary facilities for conduction of research trial and EPCO, Bhopal for financial support as Chief Minister Fellowship on climate change.

REFERENCES

Ajit, Dhyani, S K, Handa A K, Newaj R, Chavan S B, Alam B, Prasad R, Ram A, Rizvi R H, Jain A K, Uma, Tripathi D, Shakhela R R, Patel A G, Dalvi V V, Saxena A K, Parihar, A K S, Backiyavathy M R, Sudhagar R J, Bandeswaran C and Gunasekaran S. 2017. Estimating carbon sequestration potential of existing agroforestry systems in India. *Agroforest System* **91**: 1101–18.

Allen S E, Grimshaw H M and Rowland A P. 1986. *Chemical Analysis*. *Method in Plant Ecology,* pp 285–344. P D Moore and Chapman (Eds), America: Blackwell Scientific Publications.

Bhardwaj A K, Rajwar D, Mandal U K, Ahamad S, Kaphaliya B, Minhas P S, Prabhakar M, Banyal R, Singh R, Chaudhari S K and Sharma P C. 2019. Impact of carbon inputs on soil carbon fractionation, sequestration and biological responses under major nutrient management practices for rice-wheat cropping systems. *Scientific Reports* **9**: 91–114.

Chatterjee D, Kuotsu R, Merasenla A, Saha S, Ray S K and Ngachan S V. 2019. Does rise in temperature adversely affect soil fertility, carbon fractions, microbial biomass and enzyme activities under different land uses. *Current Science* **116**(25): 2044–54.

Dabin Z, Pengwei Y, Na Z, Weidong C, Suiqi Z, Yangyang L, Donglin H, Bingnian Z, Zhaohui W and Yajun G. 2019. Building up the oil carbon pool via the cultivation of green manure crops in the Loess Plateau of China. *Geoderma* **337**: 425–33.

Fornara D, Olave R and Higgins A. 2020. Evidence of low response of soil carbon stocks to grassland intensification. *Agriculture, Ecosystems and Environment* **287**: 106705.

Jain N K, Meena H N, Yadav R S and Jat R S. 2018. Biomass production, carbon sequestration potential and productivity of different peanut (*Arachis hypogaea*) based cropping systems and their effect on soil carbon dynamics. *Indian Journal of Agricultural Sciences* **88**(7): 1044–53.

Kane D. 2015. Carbon sequestration potential on agricultural lands a review of current science and available practices. National Sustainable Agriculture Coalition, p 35.

Kumar B T N and Babalad H B. 2018. Soil organic carbon, carbon sequestration, soil microbial biomass carbon and nitrogen, and soil enzymatic activity as influenced by conservation agriculture in pigeonpea (*Cajanus cajan* L.) + soybean (*Glycine max* L.) intercropping system. *Indian Journal of Agricultural Sciences* **88**(4): 553–58.

Kumhar B L, Agrawal K K, Jha A K and Rai H K. 2020a. Variability of soil infiltration rate in different grass based cropping system in Central India. *Indian Journal of Pure and Applied Biosciences* **8** (4): 109-14.

Kumhar B L, Agrawal K K and Jha A K. 2020b. Weed screening in grass based cropping system in Central India. *Journal of Biotechnology and Crop Science* **9**(14): 94–99.

Kundu C K, Das H and Ghosh P K. 2019. Soil organic carbon sequestration potential and economic profitability of perennial forage crops under different mulching environments. *Range Management & Agroforestry* **40**(1): 83–88.

Lal R. 2004. Soil carbon sequestration to mitigate climate change. *Geoderma* **123**: 1–22.

Ledo A, Smith P, Zerihun A, Whitaker J, Vicente J L V, Qin Z, McNamara N P, Zinn Y L, Llorente M, Liebig M, Kuhnert M, Dondini M, Don A, Pines E D, Datta A, Bakka H, Eduardo A and Jon H. 2020. Changes in soil organic carbon under perennial crops. *Global Change Biology* : 1–11.

Mondal M, Das T K, Thomas P, Mishra A K, Bandyopadhyay K K, Aggarwal P and Chakraborty D. 2019. Effect of conservation agriculture on soil hydro-physical properties, total and particulate organic carbon and root morphology in wheat (*Triticum aestivum*) under rice (*Oryza sativa*) - wheat system. *Indian Journal of Agricultural Sciences* **89**(1): 46–55.

Nishanth B, Rajkumar J S I, Meenakshi S S, Sivakumar T, Sankaran V M and Thanga T V. 2013. Sequestration of atmospheric carbon through forage crops cultivated in Ramayanpatti, Tirunelveli District, Tamilnadu, India. *Research Journal of Agriculture and Forestry Sciences* **1**(3): 11–14.

Pearson T R, Brown S L and Birdsey R A. 2007. Measurement guidelines for the sequestration of forest carbon, general technical report, USAID forest service, pp 1-47.

Sarvade S, Upadhyay V B and Agrawal S B. 2019. Quality fodder production through silvo-pastoral system: a review. *Agroforestry* *for Climate Resilience and Rural Livelihood*: 345–59.

Sathiya B K and Babu C. 2016. Perennial forages as a tool for sequestering atmospheric carbon by best management practices for better soil quality and environmental safety. *Forage Research* **42** (3): 149–57.

Soni M L, Yadava N D, Beniwal R K, Singh J P, Kumar S and Birbal. 2013. Grass based strip cropping systems for controlling soil erosion and enhancing system productivity under drought situations of hot arid western Rajasthan. *International Journal of Agricultural and Statistics Sciences* **9**(2): 685–92.

Tanwar S P S, Kumar P, Verma A, Bhatt R K, Singh A, Lal K, Patidar M and Mathur B K. 2019. Carbon sequestration potential of agroforestry systems in the Indian arid zone. *Current Science* **117**(12): 2014–22.