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A Review

The potential of jute crop for mitigation of greenhouse gas emission in the changing climatic scenario

A.K. SINGH
Crop Production Division, ICAR-Central Research Institute for Jute and Allied Fibres, Barrackpore
KOLKATA (W.B.) INDIA

Abstract : Global warming is steadily increasing and impacting on highly vulnerable developing countries. Agriculture which is an essential sector for most of developing countries contributing to climate change with greenhouse gas emissions (GHG) and suffering from the effects of climate change. The challenge of feeding the population and reducing agricultural GHG emissions requires the successful transfer of climate-friendly agricultural and land use practices to farmers serving adaptation and mitigation needs. Jute crop have the potential to absorb and fix carbon dioxide from the atmosphere, save for the carbon released back through the application of agro-chemical inputs and use of fossil fuels in the management of jute production systems. The paper reviews the relationship between carbon sequestration, jute crop management systems and the effects on greenhouse gases. This may help in identifying the point to improve environmental efficiency and accessing opportunities for carbon trading, contribute to the development of sustainable technologies to manage GHG emissions and global warming.

Key Words : Jute, Carbon sequestration, Greenhouse gas, GHG mitigation, Climate

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Introduction

The effects of climate change have already been felt all over the world, in diverse forms ranging from shifting weather patterns, receding ice caps, crop losses, altered distribution of precipitation, increased frequency and intensities of floods and droughts and serious ecological imbalances. All of these effects also have resulted in significant economic losses (Stern, 2006). To prevent projected and unforeseen disasters, the atmospheric stock of greenhouse gases (GHGs) should be controlled especially in terms of CO_2.

The potential for mitigation of GHGs in agriculture is high and 74 per cent of this potential can be found in developing countries (Cole *et al.*, 1997). The intergovernmental panel on climate change (IPCC) estimates the global technical mitigation potential of agriculture to be 7.18 to 10.60 Gt CO_2^{-e} per year at carbon prices upto 100 USD per tonne of CO_2^{-e}. This makes mitigation in agriculture a cost effective when compared with non-agriculture sectors such as energy. Agriculture is a major source of GHG and contributing about 334.41 million tons of the total CO_2 equivalents emission from India (INCCA, 2010). The technical mitigation options available from agriculture could be through the adoption of improved cropland management practices, reducing emissions of methane and nitrous oxide through improved manure, efficient management of irrigation water and crop residue management.

In jute crop, daily potential biomass production of 49.7 g^{-2} day^{-1} has been reported (Palit, 1993). High biomass production is very important for total potential primary productivity and average carbon fixation. Jute production is primarily an agricultural activity that is used to generate income for producers through the production and sale of fibres. Hence, jute plant as potential carbon sequesters can play a role as a means of removing carbon from the atmosphere.

Greenhouse emission from agriculture :

The earth's atmosphere contains carbon dioxide (CO_2) and other greenhouse gases such as methane (CH_4), nitrous oxide (N_2O) that act as a heat insulation layer resulting in progressive heat conservation by the atmosphere. The concentration of these three most important GHGs in the atmosphere is increasing causing the temperature at the Earth's surface to rise (IPCC 2007). Approximately 8.7 Gt (1 giga ton = 1 billion tonnes) of carbon (C) are emitted to the atmosphere each year on a global scale by anthropogenic sources (Denman *et al.,* 2007). The agriculture sector is one of the largest contributors to carbon emissions behind energy production (Johnson *et al.,* 2007). There is scientific empirical evidence that agriculture contributes about 20 per cent of global emissions (Cole *et al.* 1997 and Marble *et al.,* 2011). Agricultural practices leading to increase in the global temperature by 0.6 ± 0.2°C at an average rate of increase of 0.17°C per decade since 1950 (Dubey and Lal, 2009). The increase in surface air temperature level is more directly linked to the increase in the concentration of CO_2 in the atmosphere. The risk is that increasing global temperatures could negatively affect biological systems (Lal, 2004). The emergence of extreme weather changes as a result of climate change is also expected to have great impact on plant development (IPCC, 2001) and agricultural dependent rural livelihoods (Bockel *et al.,* 2011). The emissions as well as sink capacity of the agriculture sector are still highly uncertain, and available estimates need to be refined through environmental study and management practices (Seip, 2011).

The major source of GHGs emission in agriculture is use of agrochemical inputs, farm machinery and equipment. This includes the use of inorganic fertilizers and pesticides, fossil fuels for running of tractors, electricity for running of water pumps and the emission due to the manufacture, packaging, transportation, etc (Fig. 1). There is currently no standard procedure on how to account for temporary removals of GHGs from or release to the atmosphere in life cycle assessment (LCA) accounting (Brandao *et al.,* 2013). A number of studies have been conducted that aimed at modelling energy and material flows in crop production systems (Ozkan *et al.,* 2003; West and Marland, 2002; Lal, 2004 and Namdari *et al.,* 2011). Studies conducted using the LCA approach include that of Wood and Cowie (2004) which gave the emission factors associated with the production of chemical fertilizers-N, P_2O_5 and K_2O. GHG emissions due to application of agro-chemical inputs and the energy use are assessed using carbon footprints based on LCA methods. Carbon footprint is a measure of the total emission of greenhouse gases in carbon equivalents (methane and nitrous oxide) from a product across its life cycle from the production of raw material used in its manufacture, to disposal of the finished product (Carbon, 2007). In the last few years, there has been an increase in number of case studies of carbon foot printing of cultivation systems. Even though it is remarked that GHG emissions from soil are highly sensitive to environmental conditions and management practices, none of the carbon foot printing studies was based on actual measurements. LCA approach was used to calculate carbon footprints of sugar cane in Zambia (Plassmann *et al.,* 2010). CH_4 emissions were considered only for rice cultivation, and for the rest, only N_2O emissions were studied (Gan *et al.,* 2011 and 2012).

Reduction of greenhouse emission from agriculture :

The magnitude of decline or enhancement of carbon

Stages	Process	Equipment	Input	GHG
	Tillage	Tractor/Power tiller	Diesel	CO_2
		Bullock	-	CH_4
	Sowing	Seed drill	Diesel	CO_2
		Manual	-	-
	Transplanting	Manual	-	-
Production	Irrigation	Pump	Diesel/electricity	CO_2
	Fertilizer production	Factory	Electricity	CO_2
	Fertilizer application	Fertilizer drill	Diesel	CO_2
		Manual	-	-
	Biocide production	Factory	Electricity	CO_2
	Biocide application	Sprayer	-	-
	Soil microbial processes	-	-	$CH_4/N_2O/CO_2$
	Harvesting	Combine	Diesel	CO_2
		Manual	-	-

Fig. 1 : Greenhouse gas emission at different life cycle of crop production (Source: Pathak *et al.,* 2013)

due to continuous cultivation depends on the balance between the loss of carbon by oxidative forces and the quantity and quality of crop residues. The loss of carbon is likely to be enormous in tropical and subtropical regions because of high atmospheric temperature (Jenny and Raychaudhuri, 1960). A lot of studies have been focused on reducing the emissions from agriculture (Cole *et al.*, 1997; Lal *et al.*,1998 and Lal, 2004). Scientific evidence suggests that 50 to 66 per cent of the cumulative historic carbon loss from soil can be recovered if managed intelligently (Lal, 2004). There is little information available in Indian agro-ecosystem, although there is possibly a greater potential for sequestrating carbon with crop rotations in this region (Velayutham *et al.*, 2000 and Lal, 2004). Carbon emission and sequestration inventories have been reviewed sector-wise for all states in India to identify the sectors and regions responsible for carbon imbalances. The carbon status, which is the ratio of annual carbon storage against carbon emission, for each Indian state is computed. This shows that small states like Arunachal Pradesh, Mizoram and Andaman and Nicobar Islands, where carbon sequestration is higher due to good vegetation cover. The analysis also shows that Maharashtra emits higher CO_2, followed by Andhra Pradesh, Uttar Pradesh, Gujarat, Tamil Nadu and West Bengal (Ramachandra and Shwetmala, 2012).

Mitigation of greenhouse emission through jute based cropping system :

Jute (*Corchorus capsularis* and *Corchorus olitorius*), is lignocellulosic, bast fibre plant next to cotton in importance. It is grown under wide variation of climatic conditions mainly in developing countries like India, Bangladesh, Myanmar, Nepal, Taiwan, Thailand, Vietnam, Cambodia, Brazil and some other countries. Bangladesh, India and Thailand account for over 90 per cent of world production. Depending on demand, price and agro-climate, the annual production of jute and allied fibres in the world is around 3.5 million tons.Natural fibres are eco-compatible by nature from cradle-to-grave. Diversified uses of jute as natural fibre composites (NFC) are enormous. Approximately 4.88 tons of carbon dioxide gets sequestered per ton of raw jute fibre production which is much higher than many tree species (Rajgopal and Sanyal, 2012). The carbon dioxide emission from jute is carbon-neutral in nature since the product is from plant-source and can be considered as a bio-mass. Life cycle assessment (LCA) study on jute and its products by Price Waterhouse Coopers Ltd. by National Jute Board (NJB) of India reveals that the most significant impact is carbon sequestration by green jute plants during the growth stage. It was estimated that, on an average, as much as 1.8–2.0 Mg ha^{-1} of the left over aboveground biomass of jute (leaves, tops and branches) is added annually to the soils under jute cultivation. The carbon build-up rate was 0.11 to 0.25 Mg C $ha^{-1}yr^{-1}$ under jute-rice-wheat cropping system (Mandal *et al.*, 2007). The root of jute plant can penetrate upto 60 cm soil depth or more with lateral roots may act as potential carbon sequesters and restorer of soil fertility. Pathak *et al.* (2011) reported carbon sequestration potential (CSP) of field crops including jute under various cropping system (Table 1). As per report of International Jute Study Group (IJSG, 2013), one hectare of jute plants consumes about 15 MT CO_2 and liberates 11 MT of O_2 in only 120 days. In carbon sequestration, biomass is measured as dry weight and carbon is taken to account for 50 per cent of dry weight (Losi *et al.*, 2003; IPCC, 2005; Timothy *et al.*, 2005 and Juwarkar *et al.*, 2011). Through jute cultivation in 0.80 million hectare area, India may reduce about 12 million tonnes of carbon dioxide from atmosphere every year which can be valued at 1080 crores INR (CRIJAF, 2013). The CER revenue per hectare out of jute cultivation can go to the jute growers or may be shared proportionately with jute industries and farmers.

Conclusion :

The GHGs emission from Indian agriculture

Table 1 : Potential of carbon sequestration of field crops under various cropping system

Cropping system	C sequestration potential (Mg C ha^{-1})	Reference
Jute-rice-wheat	1.45 – 3.33	Manna *et al*. (2007)
Maize-soybean-wheat	0.43 – 3.82	Hati *et al.* (2006)
Rice-wheat	0.41 – 1.87	Yadav *et al.* (2000)
Soybean-wheat	0.40 – 1.67	Behera *et al.* (2007)

primarily emanates from five principal activities, *viz.*, enteric fermentation from livestock, rice cultivation, manure management, agricultural soils and burning of crop residues which eventually results in increased temperatures. Hence, crop production practices which leads to less carbon emission are more desirable for sustainability and environmental safety from any production system. The transition to low-carbon agriculture requires identification of appropriate systems and management practices based on the resource endowments and the resource requirements. Jute production system with a low carbon foot-print can be a double win in the form of enhanced adaptation, increased mitigation and stability in the jute based farming system and sustainability in the country.

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