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Influence of microclimate on crop growth, soil respiration and carbon sequestration under varied agronomic management in sali paddy in Assam

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Abstract

A field experiment was conducted in 2016 and 2017 in Golaghat district of Assam, India to find out the influence of varied crop microclimate imposed by two crop establishment techniques of rice viz. System of rice intensification (SRI) and conventional, transplanted on 26th June, 10th and 25th July at four different hill densities (20cm x 10cm, 20cm x 20cm, 25cm x 20cm & 25cm x 25cm) on crop performance as well as soil respiration, and carbon influx in the *kharif* paddy. Crops grown under SRI showed enhanced plant growth parameters such as plant height, tillers number per square meter in comparison to conventional establishment throughout the growing period. Regardless of crop establishment techniques and hill densities, early transplanted crops showed better growth parameters and grain yield. Similarly, with the increase in hill density, crop performance in terms of growth and yield was found to be inferior while the wider hill density recorded improved growth traits which resulted in increased yield. SRI establishment also owed significantly superior grain yield over the conventional one. Significantly greater emission of CO₂ measuring 455.28 mg CO₂ m⁻² d⁻¹ higher than that of conventional one was recorded under SRI establishment. SRI crops at wider hill density recorded appreciably higher soil organic carbon (SOC) build-up which was found gradually decreasing towards closer density, where as in conventional establishment it was significantly lower at wider spacing (25cm x 20cm and 25cm x 25cm). The study also indicates considerable impact of crop microclimate on optimal carbon farming in rice cultivation.

Keywords: Crop microclimate, crop establishment technique, SRI, conventional, soil respiration, soil organic carbon (SOC), carbon sequestration potential (CSP)

Introduction

Assam profoundly relies on rice (*Oryza sativa* L.) as its primary crop, cultivated across 2.5 m ha, yielding 5.2 mt with a productivity of 2.1 t ha⁻¹ (Economic Survey of India (2017-18). Despite being a rice surplus state presently, projections indicate a future demand of 13 mt by 2050 due to declining cultivable land and accelerated population growth (Anon., 2014) ^[1]. A targeted yield of 4.0 t ha⁻¹ is essential, to maintain self-sufficiency of the state, that necessitating a significant fillip from the existing productivity level (2.1 t ha⁻¹). Up-scaling of the productivity of *kharif* rice is decisive, as it holds the potential to play a crucial role in achieving this target. The effective use of land, water, nutrients, labour, capital, and other resources would result from maximum yield performance from a declining paddy field area, fostering sustainable agricultural methods. This move towards higher yield performance guarantees the preservation of essential resources for future generations while also promoting crop diversity (Kalita, 2020) ^[2]. When compared to traditional approaches, rice plants grown with the SRI methodology develop quickly, generate more tillers and leaves, and improve resource utilization, which results in better grain yields (Thakur *et al.*, 2010 and Kalita *et al.*, 2023) ^[3, 4]. The synergistic combination of timely and meticulously applied agronomic techniques that generate a favourable microclimate and enable the crop to fully express its genetic potential is responsible for the higher yield of rice under SRI. Many research findings highlighted that lower plant density in the SRI facilitates better air circulation, reducing humidity within the plant canopy and resulting

in decreased incidence of insect, pest and disease.

Consequently, this results in the growth of more robust and healthy rice plants.

Research conducted in North-east India opined modifications of plant spacing in SRI technique to optimize tiller production in this region of high rainfall. It stresses the urgent need for a more productive approach to *kharif* rice production that can address challenges related to food security, resource constraints, and changing climatic conditions (Das *et al.* 2014) [5]. This entail creating favorable microclimatic conditions to fully utilize the resources like light and water for better crop performance and yield sustainability (Kalita *et al.* 2023) [4]. The holistic manipulation in crop management practices in SRI techniques result in superior plant phenotypes and physiological processes, leading to increased resilience towards environmental stresses and ultimately greater crop yields (Visalakshmi *et al.*, 2014) [6]. Worldwide researches indicate that through the adoption of SRI practices yields can be improved by 20-50%, and sometimes even more (Gopalakrishnan *et al.*, 2013, Uphoff, 2015, Kalita, 2020 and Kalita *et al.*, 2023) [7, 8, 2, 4].

According to IPCC, 2013 [9], the global emission of greenhouse gas (GHG) such as CO₂, CH₄ and N₂O is 76, 16 and 6 percent, respectively of which, CO₂ had increased from 280 ppm in the year 1850 to 395 ppm in the year 2014 that corresponding with global mean temperature rise of 0.85 °C in the time period of 1800 to 2012. The Paddy cultivation contributes 9 to 11% of the agricultural GHG emission, mainly CO₂, CH₄ and N₂O (IPCC, 2014) [10]. The rate of emissions of CO₂ can be mitigated by capturing it from the atmosphere, storing and maintaining in soil through “carbon sequestration”. Indian soil possesses a large sink capacity for atmospheric CO₂ sequestration as it has inferior level of SOC. Improved agronomic practices could mitigate the impact of climate change through both carbon sequestration and minimized emissions of GHGs. The exchange of CO₂ between terrestrial ecosystems and the atmosphere is one of the key processes that affect atmospheric CO₂ concentration. The conventional rice production system has been pressurizing the natural resource base indiscriminately to feed the expanding population and thereby deteriorating soil health and rice ecosystem balance by escalating more emission of CO₂, CH₄, and N₂O to the atmosphere (Ali *et al.*, 2019) [11]. Among different rice ecosystem, the SRI is a promising carbon farming practices as it imparts low carbon footprints (Krishnan *et al.*, 2017 and Kalita, 2020) [12, 2].

In view of this, a field experiment was taken up to study the crop growth, yield and also to have an insight on status of SOC, CO₂ efflux and carbon sequestration potential (CSP) of *kharif* rice grown under SRI and conventional techniques at varied transplanting dates and hill densities.

Materials and Methods

The study was carried out at Nepalikhuti village of Golaghat district of Assam, India continuously for two years (2016 and 2017). The region has a subtropical humid climate with high annual precipitation (>2000 mm), high relative humidity (>80%), and temperatures ranging from 50 to 37 °C. There were 1242.60 mm and 1618.80 mm of rainfall throughout the experimental period of June to November of 2016 and 2017, respectively. The highest reported rainfall of 342.10 and 449.9 mm was received in the month of July of both years which coincided with the tillering stage of the crop. The weekly mean bright sunlight hour was 4.67 hours in the first year and 3.24 hours (0.5 to 6.8 hours) in the second.

The soil of the experimental site is well drained sandy loam with acidic in reaction possessing medium level of soil organic

carbon and available nitrogen, and lower in phosphorus and potassium. The experiment was fitted in was factorial split plot design with two crop establishment methods viz. SRI (C₁) and conventional (C₂) transplanted in three different dates viz. 26th June (D₁), 10th July (D₂) and 25th July (D₃) as the main plot treatment, and at four levels of hill densities viz 20cm x 15cm (S₁), 20cm x 20cm (S₂), 25cm x 20cm (S₃) and 25cm x 25cm (S₄) as sub plot treatment. The test variety was “*Shraboni*” which is a medium duration high yielding variety with average yield of 5 t ha⁻¹. The age of the transplanted seedlings was 12 and 21 days old for SRI and conventional technique, respectively. The crop was nurtured with 10 t ha⁻¹ of FYM along with recommended integrated nutrient management package. At different stages of the crop such maximum tillering stage (MTS), flowering and physiological maturity (PM), growth parameters such as plant height, number of tillers m⁻² etc were found out following standard procedures.

The CO₂ flux per unit area per unit time was measured in-situ by alkali absorption method (Gupta and Singh, 1981) [13]. The CO₂ emission rate was calculated as follows:

$$\text{CO}_2\text{-C (mg)} = (\text{B} - \text{V}) \times \text{N} \times \text{E};$$

Where,

B: Volume of HCl needed to titrate NaOH solution from the control

V: Volume of HCl needed to titrate NaOH solution in the vial

N: 1.0 (Molarity of HCl)

E: Equivalent weight (6 for C; 22 for CO₂).

The emission was expressed as mg CO₂-C m⁻²d⁻¹.

Carbon sequestration potential was estimated in terms of increase in carbon stock in the soil. Here, CO₂ emission from the field was not taken in account. The SOC content was measured for both initial and final stage for all the treatments (Pathak *et al.* 2011 and Singh *et al.* 2014) [14, 15]. The mass of SOC in the particular thickness of soil layer was then calculated as follows:

$$\text{MSOC} = \text{SOC} \times \text{BD} \times \text{T}$$

Where,

MSOC: Mass of SOC (Mg ha⁻¹),

SOC: Organic C concentration in soil (%)

BD: Bulk density (g m⁻³) and

T: Thickness of surface layer (cm)

Carbon sequestration potential (CSP) of the treatment was calculated as

$$\text{CSP}_{\text{treatment}} = \text{MSOC}_{\text{treatment}} - \text{MSOC}_{\text{initial}}$$

Where,

CSP_{treatment}: Carbon sequestration potential of each treatment

MSOC_{treatment}: Final SOC (Mg ha⁻¹) of each treatment

MSOC_{initial}: Initial SOC (Mg ha⁻¹)

In this study, the data pertaining to each parameter were subjected to statistical analysis using the "Analysis of Variance" method as outlined by Cochran and Cox (1957). The significance of treatment effects was evaluated through the F-test, with the variance ratio (F) being considered significant. The critical difference (CD) was reported at a 5% significance level if the F-test gave significant results; otherwise, the standard error of the mean (S.E.m) was mentioned.

Result and Discussion

Effect on crop growth

Data on plant height and number of tillers m^{-2} as influenced by imposition of microclimatic variation in terms of method crop establishment, date of transplanting and various level of plant density are presented in Fig. 1 & 2.

With respect to varied methods of crop establishment, the mean plant height under SRI was significantly taller than that of the crops under conventional system at flowering and physiological maturity. However, crop establishment methods failed to show any significant variation in MTS. Throughout the crop growing

stages, significantly higher number of tillers m^{-2} was recorded in SRI crops. Increased plant height and tiller numbers m^{-2} under SRI might be due to shallow planting of younger seedling in resulting in extensive root system that absorbing more nutrients from the soil consequently enhancing emergence of more tillers from the collar region compared to conventional method besides increasing plant height. The negligible disturbance of growing buds and the roots during transplanting of SRI seedling facilitated significant improvement in growth parameters of SRI crop (Thakur *et al.*, 2015 and Hosain *et al.*, 2018) ^[16, 17].

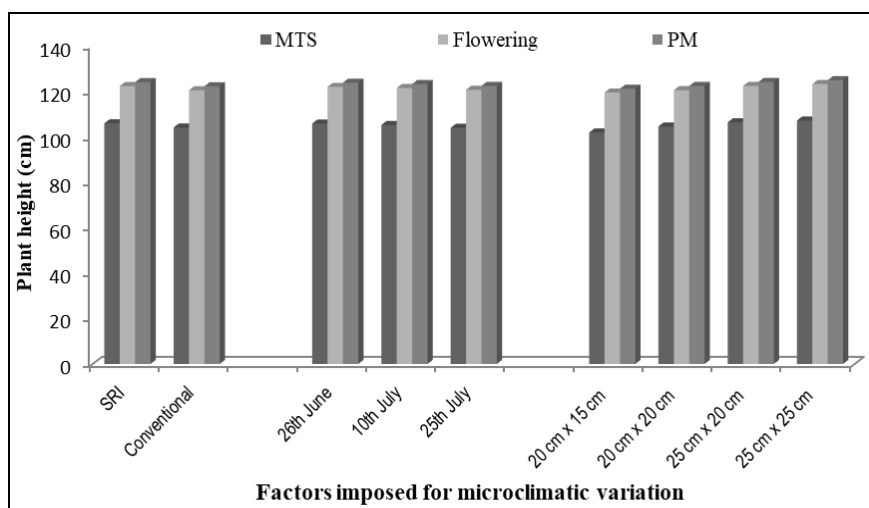


Fig 1: Plant height (cm) as influenced by manipulation of microclimate imposed by methods of crop establishment, transplanting date and hill density (Pooled data)

Plant height was found to be not affected by date of transplanting at any stages of crop growth; however, significant variation was noted with respect to number of tillers m^{-2} . Highest tiller number was registered under early transplanting (26th June) followed by intermediate (10th July) and late transplanting (25th July). In flowering and physiological maturity stage, 26th June planted crop registered the maximum tiller numbers m^{-2} , which was statistically at par with 10th July planted crop. Further, quantity of tillers recorded in 25th July planted crop was found to be comparable as that of 10th July. Such superiority of early transplanting dates with respect to number of tillers per plant was also reported by Sharma *et al.* (2011) ^[18] and Sharma *et al.* (2018) ^[19]. Interaction between crop establishment and date of planting was found to be non-

significant. In respect of hill density, wider spacing *i.e.* hill density of 16 hills m^{-2} registered the tallest plant which was at par with hill density of 20 and 25 hills m^{-2} . Significantly lowest height was observed in 20cm x 15cm spacing (33 hills m^{-2}). Similar trend was also noted with respect to tiller number m^{-2} , the lowest being recorded under hill density of 33 hills m^{-2} . The highest number of tillers was recorded in microclimatic variation imposed by 20 hills m^{-2} which was comparable with both 16 and 25 number of hill m^{-2} . The increased magnitude of plant height and tiller m^{-2} under lower hill density might be attributed to efficient utilization of growth resources in lower degree of intra-specific competition that triggered a substantial fillip in photosynthetic rate. Similar was reported by Singh *et al.* (2012) ^[20] and Chakraborty *et al.* (2014) ^[21].

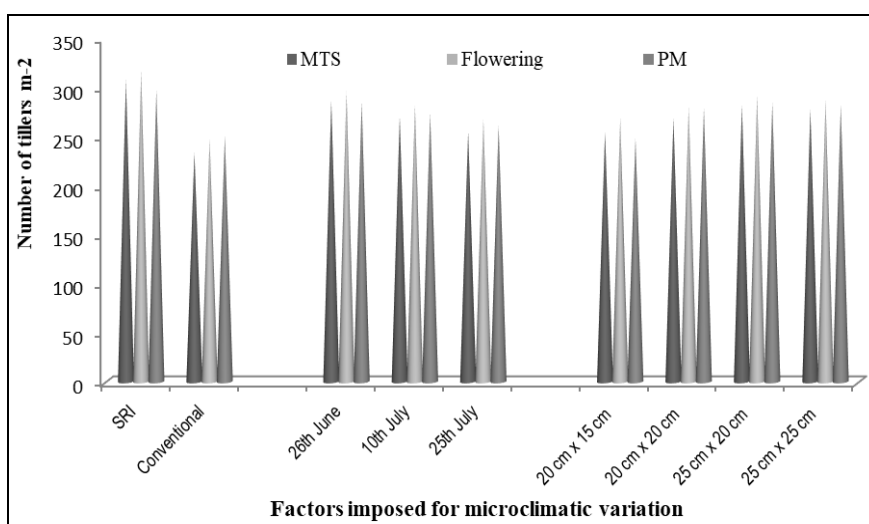


Fig 2: No. of tillers m^{-2} as influenced by manipulation of microclimate imposed by methods of crop establishment, transplanting date and hill density (Pooled data)

Effect on Grain Yield

The two years of yield data along with the pooled data presented in Fig. 3 revealed that the superiority of SRI technique in terms of grain yield which was on an average 1.17 times higher than that achieved from conventional one. Significantly greater yield of 57.13 q ha^{-1} was obtained owing to SRI technique of crop establishment while the conventional crop registered 48.83 q/ha of grain yield. The improved yield under the SRI method can be attributed to the practice of planting young, single seedlings per hill in an environment free from hypoxic conditions. This approach likely promoted enhanced growth and physiological characteristics, leading to more efficient utilization of light, nutrients, and water. Consequently, this facilitated an accelerated photosynthetic rate and effective translocation of assimilates to the sink. These findings align with earlier studies by Mitra *et al.* (2013) [22] and Thakur *et al.* (2015) [16] and Kalita, *et al.* 2023 [4].

The Fig 3 also indicates the significant differences in crop performance due to various transplanting dates. Specifically, the

early transplanting on 26th June resulted in the highest grain yield of 54.86 and 58.16 q ha^{-1} in 2016 and 2017, respectively which was followed by the 15-day delayed transplanting on 10th July and the 30-day delayed transplanting on 25th July. The substantial improvement in grain yield associated with the early transplanting date (26th June) was consistently observed in both years. Pooled analysis further confirmed the superiority of early planting which was 1.02 and 1.09 times significantly higher than that of the July plantings dates, viz. 10th and 25th July, respectively. The yield reduction under delayed transplanting conditions can be attributed to unfavorable weather parameters, leading to the development of a poorly developed canopy which eventually resulted in insufficient photosynthesis coupled with partial and ineffective translocation of assimilate from source to sink. Previous research studies, such as those conducted by Gautam *et al.* (2019) [23] and Kalita, (2020) [2] have also emphasized on the significant impact of meteorological conditions on growth, yield and overall production of paddy worldwide.

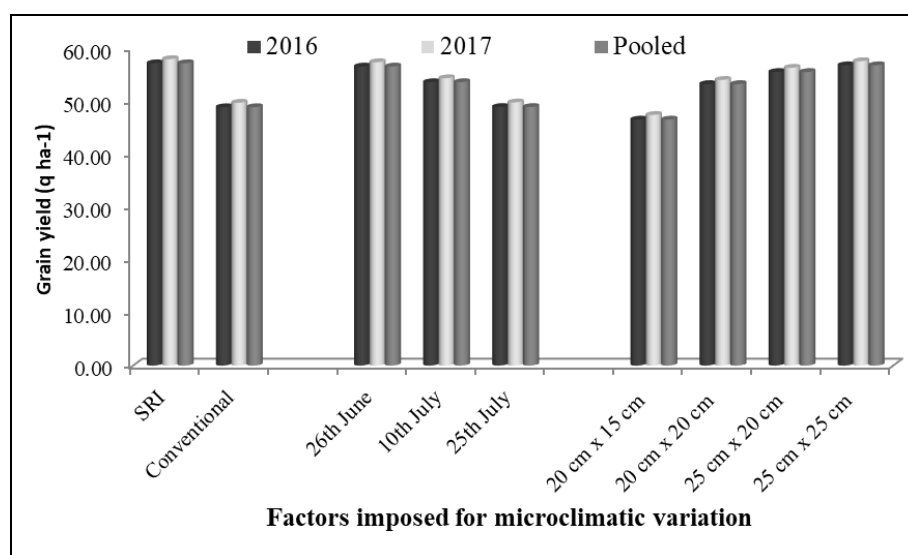


Fig 3: Effect of varied crop microclimatic condition on grain yield (q ha^{-1}) of rice

Irrespective of crop establishment methods and transplanting dates, the grain yield, influenced by varying hill densities, revealed a significant drop off with increasing density levels. The highest grain yield of 55.21 qha^{-1} and 58.29 qha^{-1} were recorded under the hill density of $25 \text{ cm} \times 25 \text{ cm}$ in 2016 and 2017, respectively which were statistically comparable to hill densities of 20 and 25 hills m^{-2} in both years. Pooled analysis further confirmed a 1.12 times increase in grain yield when adopting a hill density of 16 hills m^{-2} compared to the closest density of 33 hills m^{-2} . The superior yield under wider hill densities can be attributed to enhanced yield attributing parameters, resulting in a larger sink size and efficient translocation of photosynthates to the sink, particularly when the crop was cultivated under optimal planting patterns. These findings align with previous research by Das and Chandra (2012) [24], highlighting the importance of planting density in optimizing grain yield in rice cultivation.

Carbon sequestration study

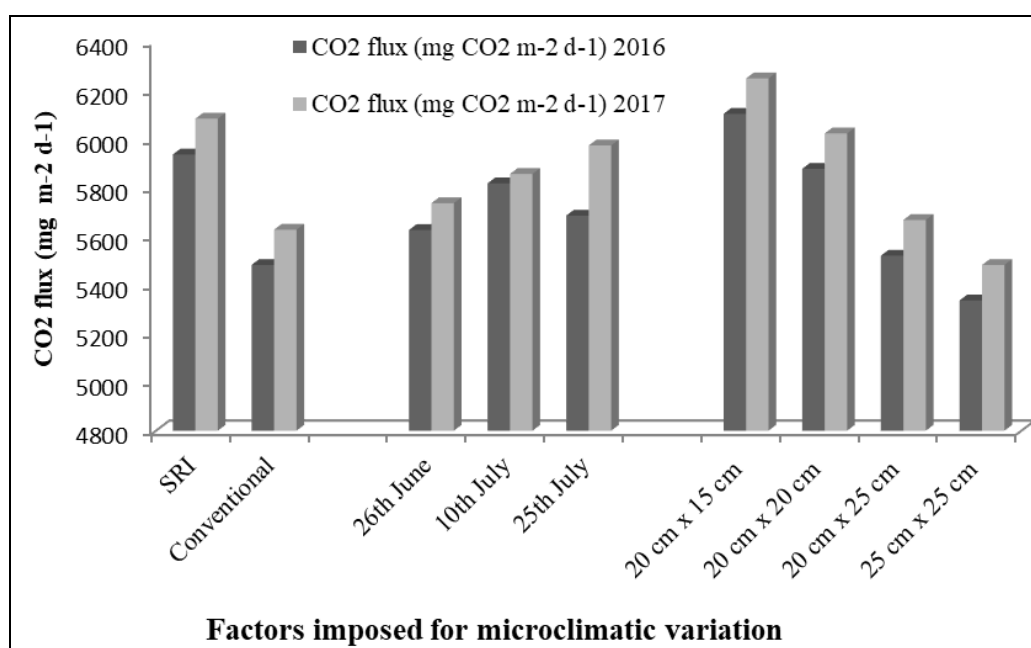
CO₂ flux: The CO₂ flux measured at maximum tillering stage are presented in Table 1 and Fig. 4 indicates significant influence of all the three factors viz. crop establishment methods, date of transplanting and various measures of hill density on emission of CO₂ from the soil. Significantly greater quantum of CO₂ efflux measuring to $5935.42 \text{ mg CO}_2 \text{ m}^{-2} \text{ d}^{-1}$ and $6082.47 \text{ mg CO}_2 \text{ m}^{-2} \text{ d}^{-1}$ was recorded under SRI establishment in 2016 and 2017; which were 454.11 and 456.44 unit higher than that of conventional one. The underlying reason of higher emission of CO₂ in SRI might be due to increased rate of respiration resulted from the luxuriant and vigorous vegetative growth specially the root system. This got more intensified as a result of the absence of the barrier i.e. standing water due to its unique water management practice in SRI resulting in accelerated decomposition of organic matter. These findings corroborate with those reported by Liu *et al.* (2013) [25] and Krishnan *et al.* (2017) [12].

Table 1: Influence of method of crop establishment, date of transplanting and hill density on CO₂ flux (mg CO₂ m⁻² d⁻¹) at maximum tillering stage

Treatment	CO ₂ flux (mg CO ₂ m ⁻² d ⁻¹)	
	2016	2017
Crop establishment		
SRI	5935.42	6082.47
Conventional	5481.31	5626.03
SEm±	38.64	37.33
CD (P=0.05)	121.76	117.62
Date of transplanting		
26 th June	5624.63	5735.17
10 th July	5816.50	5855.33
25 th July	5683.96	5972.25
SEm±	47.33	45.71
CD (P=0.05)	149.13	144.06
Hill density		
20 cm x 15 cm	6102.28	6247.78
20 cm x 20 cm	5876.33	6021.83
25 cm x 20 cm	5519.39	5666.22
25 cm x 25 cm	5335.44	5481.17
SEm±	82.05	82.52
CD (P=0.05)	235.33	236.67

The CO₂ flux was found to be significantly influenced by the date of transplanting. In 2016, maximum efflux was recorded in 10th July planting, which was at par with the late planting (25th July) and significantly superior to the early one *i.e.* 26th June planting. In the 2nd year, maximum emission was registered in late planting which was followed by 10th July and lastly by 26th June planting. However, the quantum of emission in 25th July

planting was at par with its 15 days earlier planting. The tendency of more emission with delaying of transplanting date might attributable to increased mean daily temperature which led to increase in soil temperature and thereby, soil respiration. Increased emission of soil CO₂ owing to increased temperature was reported by many researchers (Sugihara *et al.*, 2012 and Dilekoglu and Sakin, 2017) [26, 27].

**Fig 4:** CO₂ flux as influenced by methods of crop establishment, transplanting date and hill density in 2016 & 17

With the increase of hill density, emission of CO₂ was found to be increasing significantly in both the year. The maximum quantum of release was measured at highest density under study *i.e.* 33 hills m⁻² which was comparable to its immediate lower one (25 hills m⁻²). This might attribute to increased root respiration per unit area per unit time under closer plant density.

Carbon sequestration at harvest

The appraisal of data presented in Table 2 reveals that the method of crop establishment could not bring any significant impact on organic-C and CSP of both 0-15 and 15-30 cm layer

of soil at harvest though the SRI method, showed a marginal improvement in soil organic-C and CSP as compared to conventional one. However, a significant interaction effect of crop establishment methods and planting geometry on SOC was observed in the 2nd year of investigation (Table 3). SRI crops raised at lower hill density showed significantly higher SOC build-up in comparison to conventional crop grown in 25cm x 20cm and 25cm x 25cm as well. The tendency of building-up of soil organic-C under SRI might attribute to the typical microclimate created specially as a result of conoweeding and water management practice that enhancing the performance of

the rhizospheric microbes on decomposition of the large root system of the SRI crops. This is in agreement with the findings

of Dumas-Johansen (2009) [28] and Rajkishore *et al.* (2015) [29].

Table 2: Influence of crop establishment method, date of transplanting and hill density on organic carbon (%) and carbon sequestration potential (Mg ha⁻¹) of soil

Treatment	Soil depth (0-15 cm)				Soil depth (15-30 cm)			
	OC (%)		CSP (Mg ha ⁻¹)		OC (%)		CSP (Mg ha ⁻¹)	
	2016	2017	2016	2017	2016	2017	2016	2017
Crop establishment methods								
SRI	0.687	0.688	1.931	1.948	0.668	0.664	1.162	1.646
Conventional	0.678	0.682	1.622	1.910	0.660	0.651	1.042	1.556
SEm±	0.006	0.003	0.132	0.114	0.004	0.004	0.091	0.133
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Date of transplanting								
26 th June	0.690	0.689	1.892	1.909	0.670	0.664	1.073	1.654
10 th July	0.681	0.686	1.827	1.977	0.663	0.659	1.054	1.630
25 th July	0.676	0.680	1.611	1.900	0.660	0.650	1.180	1.518
SEm±	0.008	0.003	0.161	0.139	0.006	0.005	0.110	0.163
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Hill density								
20 cm x 15 cm	0.680	0.686	1.752	1.994	0.663	0.655	1.210	1.711
20 cm x 20 cm	0.682	0.684	1.757	1.952	0.663	0.658	1.213	1.689
25 cm x 20 cm	0.683	0.685	1.828	1.926	0.666	0.659	1.011	1.558
25 cm x 25 cm	0.684	0.685	1.770	1.844	0.666	0.658	0.975	1.446
SEm±	0.005	0.005	0.135	0.123	0.008	0.004	0.163	0.123
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
NB: For 0-15 cm : Initial bulk density (g cc ⁻¹): 1.304 g cc ⁻¹ ; Initial OC (%): 0.588 For 15-30 cm : Initial bulk density (g cc ⁻¹): 1.354 g cc ⁻¹ ; Initial OC (%): 0.594								

Table 3: Interaction effect of method of crop establishment and planting geometry on SOC in 2017

C x H	20 cm x 15 cm	20 cm x 20 cm	25 cm x 20 cm	25 cm x 25 cm	MEAN
SRI (C)	0.680	0.682	0.691	0.698	0.688
Conventional (H)	0.691	0.687	0.679	0.672	0.682
MEAN	0.686	0.684	0.685	0.685	0.685
S.E.m±: 0.006; CD (P=0.05): 0.018					

Conclusion

In nut-shell, it may be concluded that early planting of *kharif* paddy on 26th June at 25cm x 25cm apart following SRI method could be a promising crop management option to access the complimentary crop microclimatic condition to perform the best. Besides, crop performance, the study draws attention to consideration of microclimatic factors to optimize carbon farming for better sequestration in *kharif* paddy field in long run.

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References

- Anonymous. Vision 2050, Agriculture in Assam. Jorhat: Assam Agricultural University; c2014. p. 43.
- Kalita R. Resource Use Efficiency in Winter Rice (*Oryza sativa* L.) grown under System of Rice Intensification (SRI) Concept as influenced by Microclimate. Ph.D. Thesis. Jorhat: Assam Agricultural University; c2020.
- Thakur AK, Uphoff N, Anthony E. An assessment of physiological effects of system of rice intensification practices compared with recommended rice cultivation practices in India. *Experimental Agriculture*. 2010;46(1):77-98.
- Kalita R, Thakuria RK, Medhi B, Saikia M. Production maximization of rainy season rice (*Oryza sativa*) through effective use of water and solar radiation under modified system of rice intensification in Assam. *Indian Journal of Agronomy*. 2023;68(1):1-8. DOI: 10.59797/ija.v68i1.194.
- Das A, Patel DP, Munda GC, Ramkrushna GI, Kumar M, Ngachan SV, *et al.* Improving productivity, water and energy use efficiency in lowland rice (*Oryza sativa*) through appropriate establishment methods and nutrient management practices in the mid-altitude of north-east India. *Experimental Agriculture*. 2014;50(3):353-375.
- Visalakshmi V, Rama Mohana Rao P, Hari Satyanarayana H. Impact of paddy cultivation systems on insect pest incidence. *Journal of Crop and Weed*. 2014;10:139-142.
- Gopalakrishnan S, Kumar RM, Humayun P, Srinivas V, Kumari BR, Vijayabharathi R, *et al.* Assessment of different methods of rice (*Oryza sativa* L.) cultivation affecting growth parameters, soil chemical, biological, and microbiological properties, water saving, and grain yield in rice-rice system. *Paddy and Water Environment*. 2013;12:79-87.
- Uphoff N, Fasoula V, Iswandi A, Kassam A, Thakur K. Improving the phenotypic expression of rice genotypes: Rethinking intensification for production systems and selection practices for rice breeding. *The Crop Journal*. 2015;3:174-189.
- Stocker TF, Qin D, Plattner G-K, Tignor M, Allen SK, Boschung J, *et al.*, editors. *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University

- Press; c2013.
10. IPCC. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the 5th Assessment Report of the Intergovernmental Panel on Climate Change. Geneva: IPCC; c2014.
 11. Ali MA, Inubushi K, Kim PJ, Amin S. Management of Paddy Soil towards Low Greenhouse Gas Emissions and Sustainable Rice Production in the Changing Climatic Conditions; c2019. Available from: <http://dx.doi.org/10.5772/intechopen.83548>
 12. Krishnan RK, Lakshmanan A, Ajith K, Shajeeshjan P. Sobering Rice Production from Conventional to Climate Smart. International Journal of Current Microbiology and Applied Sciences. 2017;6(9):2804-2813.
 13. Gupta SR, Singh JS. Soil respiration in tropical grassland. Soil Biology and Biochemistry. 1981;13:261-268.
 14. Pathak H, Byjesh K, Chakrabarti B, Aggarwal PK. Potential and cost of carbon sequestration in Indian agriculture: Estimates from long-term field experiments. Field Crops Research. 2011;120:102-111.
 15. Singh A, Kumar S, Singh YV, Bhatia A. Carbon sequestration and yield of rice (*Oryza sativa*)-wheat (*Triticum aestivum*) soils amended with different organic manures and tillage practices. Indian Journal of Agronomy. 2014;59(2):215-220.
 16. Thakur AK, Mohanty RK, Singh R, Patil DU. Enhancing water and cropping productivity through Integrated System of Rice Intensification (ISRI) with aquaculture and horticulture under rainfed conditions. Agricultural Water Management. 2015;161:65-76.
 17. Hosain T, Hossain E, Nizam R, Fazle Bari ASM, Chakraborty R. Response of Physiological Characteristics and Productivity of Hybrid Rice Varieties under System of Rice Intensification (SRI) over the Traditional Cultivation. International Journal of Plant Biology and Research. 2018;6(2):1085.
 18. Sharma A, Dhaliwal LK, Sandhu SK, Singh S. Effect of plant spacing and transplanting time on phenology, tiller production and yield of rice (*Oryza sativa* L.). International Journal of Agricultural Sciences. 2011;7:249-253.
 19. Sharma N, Murty NS, Mall P, Bhardwaj SB. An analysis on the yield and yield contributing characters of rice in tarai region of Uttarakhand. International Journal of Chemical Studies. 2018;6(3):42-47.
 20. Singh YV, Singh KK, Sharma SK. Influence of Crop Nutrition and Rice Varieties under Two Systems of Cultivation on Grain Quality, Yield and Water Use. Rice Science. 2012;19(4):129-138.
 21. Chakraborty S, Biswas PK, Roy TS, Mahmud MAA, Mehraj H, Jamal Uddin FM, *et al.* Growth and Yield of Boro Rice (BRRI Dhan 50) as Affected by Planting Geometry under System of Rice Intensification. Journal of Bioscience and Agriculture Research. 2014;2(1):36-43.
 22. Mitra B, Mookharjee S, Biswas S, Mukhopadhyay P. Potential water saving through System of Rice Intensification (SRI) in Tarai region of West Bengal, India. International Journal of Bio-resource and Stress Management. 2013;4(3):449-451.
 23. Gautam P, Lal B, Nayak AK, Raja R, Panda BB, Tripathi R, *et al.* Inter-relationship between intercepted radiation and rice yield influenced by transplanting time, method, and variety. International Journal of Biometeorology. 2019;63(3):337-349.
 24. Dass A, Chandra S. Effect of different components of SRI on yield, quality, nutrient accumulation and economics of rice (*Oryza sativa*) in Tarai belt of northern India. Indian Journal of Agronomy. 2012;57(3):250-254.
 25. Liu Y, Wan K, Tao Y, Li Z, Zheng G, Li S, *et al.* Carbon Dioxide Flux from Rice Paddy Soils in Central China: Effects of Intermittent Flooding and Draining Cycles. PLoS ONE, 2013, 8(2). DOI: 10.1371/journal.pone.0056562.
 26. Sugihara S, Funakawa S, Kulasara M, Kosaki T. Effects of land management on CO₂ flux and soil C stock in two Tanzanian croplands with contrasting soil texture. Soil Biology and Biochemistry. 2012;46:1-9.
 27. Dilekoglu MF, Sakin E. Effect of Temperature and Humidity in Soil Carbon dioxide Emission. The Journal of Animal and Plant Sciences. 2017;27(5):1596-1603.
 28. Dumas-Johanse MK. Effect of the system of rice intensification (SRI) on livelihood strategies for Cambodian farmers and possible carbon storage and mitigation possibilities for greenhouse gas emissions. M.Sc. Thesis. University of Copenhagen; c2009.
 29. Rajkishore SK, Natarajan SK, Manikandan A, Vignesh NS, Balusamy A. Carbon Sequestration in Rice Soils: A Review. The Ecoscan. 2015;9(1, 2):427-433.