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Impact of Microclimatic Regime on Growth, Yield and Requirement of Growing Degree Days of Kharif Rice (*Oryza sativa*L.) under System of Rice Intensification (SRI) in the Brahmaputra Valley, Assam

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ABSTRACT

A field experiment was carried out in 2016 and 2017 in the farmers' field in Assam, India to find out the effect of varied crop microclimate imposed by two crop establishment methods viz. System of Rice Intensification(SRI) and conventional, three different transplanting dates (26th June, 10th and 25th July) and four hill densities (20cm x 10cm, 20cm x 20cm, 25cm x 20cm & 25cm x 25cm). Throughout the growing period, crops grown under SRI system showed improved plant statures such as plant height, tillers number per unit area, leaf area and dry matter production per hill as compared to conventional one. SRI registered a significantly higher grain yield which was found to be 17 percent over the conventional system. However, accumulation of growing degree days (GDD) was found to be significantly lower in SRI establishment while the highest accumulation was registered in both early date of transplanting (26th June) and lower density (16 hills m-1), as well. Irrespective of methods of crop establishment and hill densities, early transplanted crops showed superior growth attributes and grain yield. Likewise, the lowest hill density recorded better crop growth traits and yield which got reduced with the increase in hill density.

Keywords: *microclimate, System of Rice Intensification, conventional, transplanting dates, GDD*

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INTRODUCTION

Rice (*Oryza sativa* L) is the principal crop in the state of Assam growing in 25.03 lakh ha area with a production of 51.93 lakh t and productivity of 2.1tha^{-1} [1]. In contemporary times the state is a rice surplus state, but it is estimated that by 2050 the state would require 130 lakh t of rice with the decline of cultivable land with rapid urbanization and growth of population to maintain self-sufficiency and fulfill demands [2]. A projected yield of 4.0 tha^{-1} has to be achieved from the present level of 2.1 tha^{-1} utilizing limited resources. Therefore, reconsideration of productivity enhancement of the crop, especially the winter rice is a must as it is capable of playing an extraordinary role. Production maximization from lesser rice area would prompt a tremendous fillip inefficient use of land, water, nutrient, labor, capital and other biotic and abiotic resources. Further, this would definitely open an avenue for crop diversification in one way or, it would ensure the conservation of these resources for our future generations in the other way.

SRI is a planting method based on the principles of using single, young transplants at wider spacing, the application of compost, mechanical weed control and intermittent irrigation. There is low trauma to the root system and, hence, the plants recover more quickly from the shock of transplanting which preserves the potential for much greater tillering, faster root growth and grain filling [3]. The rice plants in SRI system grow vigorously, and produce more tillers and leaves ensuring better resource utilization, and resulting in higher grain yield in comparison to other conventional systems [4]. The higher productivity of rice grown in SRI is the result of a synergistic effect of timely and judiciously followed agronomic manipulations that create a favourable microclimate to explore and exploit the ultimate genetic potentiality of the crop. Research revealed that the lower plant density in SRI ease the air circulation that create less humidity within the plant canopy resulting in lesser incidence of pest and disease attack, that leading to stronger and healthier rice plants [5, 6]. The combined changes in crop management owing to SRI practices results in improved plant phenotypes and physiological processes which eventually give rise to superior crop yields and more resilience to stresses. Rice yields are improved by 20-50%, and often by more [7]. The SRI plant-soil environment tremendously improved the above and below ground plant growth in combination with improved photosynthetic efficiency that ultimately enhanced the plant performance and productivity [8, 9, 10].

SRI is a combination of practices (a) that needs to be used with appropriate adaptation to local conditions, and (b) that have synergistic effects on one another [11]. SRI practices are used in various combinations by as many as 10 million farmers on about 4 million hectares in over 50 countries [12]. These practices can improve the expression of rice plants' genetic potential, thereby creating more productive and robust phenotypes. The SRI practices illustrate that by adapting various practices to specific and local farm conditions, farmers themselves can adapt in a way that leads to increased yields, while reducing necessary inputs such as seeds, water and chemicals, as well as on labour [13].The system should be understood as a suite of flexible principles to be adapted to particular agroecological and socio-economic settings [14]. According to the "SRI International Network and Resources Centre at Cornell University", SRI "is not a recipe of precise things to do". The flexibility in SRI's definition of practices renders SRI a challenge for evaluation and assessment of adoption. Further modifications and refinements to make adaptations to local conditions is regarded as intrinsic to this methodology.

Additional improvements in SRI will come from both researchers and farmers, with the latter considered as partners rather than simply adopters. This is consistent with SRI's representing a paradigm shift more than a fixed technology [15]. SRI practices have induced a tremendous impact on the perception and understanding of how to achieve sustainable and productive rice farming, stimulating farmers and scientists to design the SRI system to suit the local agroecological set up. Scientists opined for modification of planting geometry in SRI establishment for harnessing more number of effective tillers per unit area in high rainfall zone of northeast India [16]. Moreover, the agro-ecological situations featuring winter rice cultivation under the medium land situation with reasonable drainage capacity could provide a promising scope for production maximization of rice with some agronomic manipulation of SRI method despite of heavy rainfall in the state of Assam during the monsoon.

So, there is an important need to redesign a more productive approach for *kharif* rice production that iscapable of answering the challenges of fulfilling food security with limited resource, changing climate by creating favourablemicroclimatic regime to achieve better crop performance and yield in a sustained manner. In view of this, a field experiment was undertaken to study the crop growth, yield and requirement of growing degree days (GDDs) of *kharif* rice grown under SRI and conventional techniques at varied transplanting dates and hill densities.

MATERIALS AND METHOD

The field experiment was conducted in for two consecutive years *viz.* 2016 and 2017 in *Nepalikhuti* village (26°66′99″ N; 93°68′26″E) of Assam, India which belongs to Upper Brahmaputra valley zone. The zone is characterized by sub-tropical humid climate with high rainfall (>2000 mm per annum), high relative humidity (>80%) and temperature ranges from 5^0C to 37^0C. During the period of experimentation (June to November), 1242.60mm and 1618.80 mm of rainfall was received in 2016 and 2017, respectively. The maximum rainfall was recorded in the month of July in both the year (342.10 and 449.9 mm) that coinsided the tillering stage of the crop. In 1st and 2nd year the weekly mean bright sunshine hour (BSSH) was 3.24 hr (0.5 to 6.8. hr) and 4.67 hrs(1.1 to 8.8 hr),respectively. The soil is sandy loam, well drained, with acidic in reaction with medium soil organic carbon and available nitrogen , and low in and potassium. The design of the experiment was Factorial split plot design with two crop establishment methods *viz.* SRI (C_1) and conventional (C_2) transplanted in three different dates *viz.*26th June (D_1), 10th July (D_2) and 25thJuly (D_3) as the main plot treatment, and at four levels of hill densities *viz* 20cm x 15cm (S_1), 20cm x 20cm (S_2), 25cm x 20cm (S_3) and 25cm x 25cm (S_4) as sub plot treatment. A medium-duration high-yielding variety "*Shraboni*" with average yield of 5 t ha^{-1} was selected for this experiment. The seedling age for SRI was 12 days while under conventional system 21 days old seedlings were planted. For nutrition, the crop was nourished with recommended integrated nutrient management package along with 10 tha^{-1} of FYM.

Growth contributing parameters such as plant height, number of tillers m^2, dry matter accumulation hill^{-1} at maximum tillering stage (MTS), flowering and physiological maturity (PM) stage is found out following standard procedures. The leaf area was worked out as per the Length-Width method using the formula [17]:

LA = L x W x K x Number of leaves per hill

Where L = Maximum length of 3rd leaf blade from the top (cm)

W = Maximum width of the same leaf (cm)

K = Factor of 0.75 for Kharif rice

The heating unit growing degree days (GDD) was estimated as the deviation from the mean daily temperature above the minimum threshold or base temperature.

$$GDD = [(T_{Max} + T_{Min}) / 2] - T_{base}$$

Where,

T_{Max} = Daily maximum temperature

T_{Min} = Daily minimum temperature

T_{base} = Base temperature (considered 10^{o}C for rice)

Statistical analysis: The data related to each parameter were analysed statistically using the procedure of "Analysis of Variance" given by Cochran and Cox (1957). Significance of the variance due to the treatment effect was determined by F-test, whenever variance ratio i.e. F is significant. The critical difference (CD) was reported at 5% level, otherwise only S.Em was mentioned.

RESULT AND DISCUSSION

Biometric observation and growth studies

The data on the growth parameters *viz.*, plant height, number of tillers m^{-2}, leaf area (LA) and dry matter production at different crop growth stages as influenced by method of crop establishment, date of transplanting and hill density were recorded during both the year of investigation (2016 and 2017) and have been summarized and enumerated in table 1, 2 and 3.

Plant height and number of tillers m^{-2}

Data on plant height and the 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 table 1.

Effect of a method of crop establishment

A perusal of the data furnished in table 1 indicated that, the mean plant height under SRI was significantly taller than that of the crops under the conventional system at flowering and physiological maturity. However, crop establishment methods failed to show any significant variation in MTS. Throughout the crop growthstages, the 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 a younger seedling in resulting in the extensive root system that absorbsmore nutrients from the soil consequently enhancing emergence of more tillers from the collar region compared to the 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 [18, 19].

Effect of date of transplanting

Plant height was found to be not affected by date of transplanting at any stages of crop growth; however, significant variation was noted with

Table 1: Influence of method of crop establishment, date of transplanting and hill density on plant height (cm) and number of tillers m^{-2}

Treatment	MTS		Plant height (cm) Flowering		PM		MTS		Number of tillers m^{-2} Flowering		PM	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Crop establishment												
SRI	104.95	106.93	122.05	122.64	123.91	124.28	302.16	311.57	314.20	318.50	289.90	302.83
Conventional	103.37	104.83	120.19	120.84	122.07	122.47	229.00	237.88	244.24	249.18	219.62	279.48
S.Em±	*0.92*	*0.91*	*0.31*	*0.48*	*0.58*	*0.54*	*3.52*	*3.09*	*3.73*	*4.68*	*3.31*	*4.33*
CD (P=0.05)	*NS*	*NS*	*0.98*	*1.51*	*1.82*	*1.72*	*11.10*	*9.74*	*11.76*	*14.76*	*10.43*	*13.64*
Date of transplanting												
26th June	104.98	106.72	121.73	122.26	123.62	124.07	283.06	288.97	292.92	298.53	265.08	304.46
10th July	104.36	106.11	121.22	121.87	123.13	123.39	264.00	275.91	279.29	283.81	255.63	290.74
25th July	103.14	104.82	120.41	121.08	122.22	122.66	249.70	259.29	265.45	269.18	243.58	278.26
S.Em±	*1.13*	*1.11*	*0.38*	*0.59*	*0.71*	*0.67*	*4.31*	*3.78*	*4.57*	*5.73*	*4.05*	*5.30*
CD (P=0.05)	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*13.60*	*11.93*	*14.41*	*18.07*	*12.77*	*16.70*
Hill density												
20 cm x 15 cm	101.04	102.77	119.27	119.78	120.95	121.47	249.98	258.50	265.19	271.33	238.32	257.29
20 cm x 20 cm	103.73	105.44	120.21	120.88	122.28	122.51	263.40	272.69	277.78	281.96	255.10	301.88
20 cm x 25 cm	105.57	107.25	122.11	122.71	123.93	124.41	276.67	285.92	288.89	294.08	263.71	304.42
25 cm x 25 cm	106.29	108.07	122.89	123.58	124.79	125.11	272.29	281.78	285.02	287.99	261.93	301.03
S.Em±	*0.44*	*0.57*	*0.45*	*0.54*	*0.59*	*0.64*	*4.72*	*5.84*	*4.02*	*5.53*	*3.71*	*5.80*
CD (P=0.05)	*1.26*	*1.62*	*1.30*	*1.57*	*1.71*	*1.85*	*13.55*	*16.75*	*11.53*	*15.85*	*10.62*	*16.63*

Note:- MTS: maximum tillering stage; PM: Physiological maturity; NS: Non-significant; S.Em: Standard error of mean; CD: critical difference

respect to number of tillers m^{-2} due to microclimatic variation imposed by the date of planting. The 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, a 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 many [20, 21]. Interaction between crop establishment and date of planting was found to be non-significant.

Effect of hill density

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}). A 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 a lower degree of intra-specific competition that triggered a substantial fillip in photosynthetic rate. A similar was reported by [22, 23].

Leaf area and dry matter production

The data pertaining to leaf area and dry matter production at different stages of growth in both the year of experimentation as imposed by different microclimatic variations *viz.* crop establishment methods, transplanting dates and hill densities has been furnished in table 2.

Effect of method of crop establishment

Appraisal of data on leaf area hill^{-1} at different growth stages revealed that initially at the tillering stage the conventional crops produced appreciably higher leaf area (1424.69 to 1551.84 cm^2 hill^{-1}); however, from MTS onwards, the SRI crops produced significantly more leaf area up to physiological maturity stage of the crop, the highest being recorded as 2994.64 and 3025.72 cm^{2}hill^{-1} in 2016 and 2017, respectively at the flowering stage (Table 2).

However, dry matter production hill^{-1} (Table 3) was recorded to be increasing with the growth of the crop, and attained its maximum (62.34 g hill^{-1}) at physiological maturity in 2017. On the other hand, hand, in the 2nd year of experimentation,the maximum production of dry matter per hill (57.40g hill^{-1}) was registered at the flowering stage in the 1st year of experimentation. In the case of dry matter production also lower accumulation of dry matter was observed in the tillering stage of SRI crop compared to conventional. The acceleration of dry matter production was noticed from MTS onwards. Lower value of leaf area and dry matter production per hill during the tillering stage in SRI establishment might be due to the interception of a lesser quantum of solar energy by the smaller canopy provided by lower number of tillers of SRI crops during that stage.

The observations on increased leaf area and dry matter accumulation in SRI are in corroborating with the findings of many researchers [8, 24].

Effect of date of transplanting

Both Leaf area and dry matter production hill^{-1} were found significantly influenced by the date of transplanting. The 26th June transplanted crops produced higher leaf area as well as dry matter than that of 10th and 25th July planted crops. In both the years of investigation, a significant reduction of leaf area and dry matter production hill^{-1} was seen due to the delaying of the transplanting date up to 25th July. This might be due to the shortening of the vegetative phase that was imposed by higher daily maximum temperature coupled with reduced rainfall in delayed transplanting. Weather parameters *esp*. daily maximum temperature and rainfall had a tremendous effect on the growth of rice crop [25].

Effect of hill density

Crops grown under wider hill density (16 hills m^{-2}) attained the maximum Leaf area of 4010.07 and 4047.57 cm^2 hill^{-1} at the flowering stage in 2016 and 2017, respectively (Table 2). In contrary to this, the highest dry matter production was observed at the physiological maturity stage in 2016; however, the highest value (65.15 g hill^{-1}) was registered at the flowering stage in 2017 (Table 3). A consistent increase in leaf area production was recorded with each reduction of hill density in 2016 and 2017 as well. The lowest hill density registered the highest production of leaf area followed significantly by 20, 25 and 33 hills m^{-2}, respectively. Throughout the crop growing stages, maximum value of dry matter production hill^{-1} was recorded in lowest hill density which was observed to be at par with its immediate higher plant density*i.e.* 20 hills m^{-2} from MTS onwards, however, plant density of 25 hills m^{-2}produced comparable dry matter in all except 33 hills m^{-2} in the tillering stage. At physiological maturity, dry matter production per hill ranged from as lower as 33.24-36.08 g under 33 hills m^{-2} to 61.07-73.00 g under hill density of 16 hills m^{-2}. The lower level of intra-specific competition in widely spaced crops might lead to the availability of more resources to the plants which enhanced the tillering, leaf area and eventually the dry matter. Similar opinion were observed in several research findings [22, 23].The interaction effect with respect to leaf area per hill and dry matter production per hill at various crop growth stages were found insignificant.

Accumulated growing degree days (AGDD)

The data on AGDD at MTS, flowering and physiological maturity in 2016 and 2017 enumerated in Table 4 and Fig.1 and Fig.2 show that the crop responded differently owing to the varied types of crop establishment, transplanting time and varying levels of hill densities.

Effect of method of crop establishment

The perusal of data on AGDD with respect to crop

Table 2. Influence of method of crop establishment, date of transplanting and hill density on leaf area (cm^2 hill $^{-1}$) at different growth stages

Treatment	Tillering		MTS		Flowering		PM	
	2016	2017	2016	2017	2016	2017	2016	2017
Crop establishment								
SRI	560.8	571.0	2948.0	2944.9	2994.6	3025.7	1011.1	1044.9
Conventional	1424.6	1551.8	2587.8	2631.1	2681.7	2709.8	630.4	651.8
S.Em±	*19.9*	*14.8*	*18.6*	*29.6*	*23.4*	*24.9*	*15.4*	*12.5*
CD (P=0.05)	*62.8*	*46.7*	*58.7*	*93.4*	*73.8*	*78.4*	*48.7*	*39.5*
Date of transplanting								
26th June	1045.9	1117.2	2878.2	2871.1	2931.0	2955.9	887.6	917.5
10th July	1009.3	1064.2	2777.2	2797.0	2854.9	2866.0	829.8	857.5
25th July	923.0	1002.7	2648.3	2696.0	2718.5	2781.3	744.8	770.0
S.Em±	*24.4*	*18.1*	*33.0*	*29.2*	*31.5*	*30.5*	*18.9*	*19.6*
CD (P=0.05)	*76.9*	*57.2*	*104.2*	*92.1*	*99.3*	*96.1*	*59.6*	*61.7*
Hill density								
20cm x 15cm	671.1	708.3	1707.5	1738.5	1778.1	1782.6	434.1	448.6
20cm x 20cm	900.8	944.2	2374.8	2370.2	2422.2	2450.8	648.8	673.7
20cm x 25cm	1136.1	1158.0	3085.5	3098.3	3142.2	3190.0	941.3	978.0
25cm x 25cm	1263.0	1435.1	3903.8	3945.1	4010.0	4047.5	1258.6	1293.0
S.Em±	*35.4*	*20.2*	*44.9*	*27.0*	*34.4*	*32.3*	*19.4*	*19.1*
CD (P=0.05)	*101.6*	*58.2*	*128.8*	*77.5*	*98.8*	*92.8*	*55.9*	*55.0*

Note: MTS: maximum tillering stage; PM: physiological maturity; NS: Non-significant; S.Em: Standard error of mean; CD: critical difference

Table 3. Influence of method of crop establishment, date of transplanting and hill density on dry matter production (g hill $^{-1}$)at different growth stages

Treatment	Tillering		MTS		Flowering		PM	
	2016	2017	2016	2017	2016	2017	2016	2017
Crop establishment								
SRI	13.0	14.6	50.8	53.8	57.4	59.7	53.0	62.3
Conven-tional	21.6	24.2	45.8	48.9	50.9	54.2	45.5	54.1
S.Em±	*0.48*	*0.52*	*0.72*	*0.71*	*0.68*	*0.71*	*0.66*	*0.71*
CD (P=0.05)	*1.52*	*1.62*	*2.27*	*2.25*	*2.13*	*2.24*	*2.10*	*2.23*
Date of transplanting								
26th June	19.3	21.1	50.6	53.5	56.3	59.0	51.6	60.9
10th July	17.4	19.4	48.9	52.1	54.3	57.4	49.7	58.4
25th July	15.2	17.6	45.5	48.6	51.8	54.4	46.4	55.1
S.Em±	*0.63*	*0.57*	*0.88*	*0.88*	*0.83*	*0.87*	*0.81*	*0.87*
CD (P=0.05)	*1.98*	*1.80*	*2.78*	*2.76*	*2.61*	*2.74*	*2.57*	*2.73*
Hill density								
20 cm x15 cm	15.1	17.4	30.8	34.5	35.7	37.1	33.2	36.0
20 cm x 20 cm	17.3	19.2	45.9	47.5	49.6	53.2	44.2	53.8

20 cm x 25 cm	18.4	20.4	57.2	60.8	64.5	67.4	58.5	70.0
25 cm x 25 cm	18.4	20.5	59.4	62.7	66.8	70.1	61.0	73.0
S.Em±	*0.64*	*0.64*	*1.18*	*1.23*	*1.13*	*1.23*	*1.19*	*1.12*
CD (P=0.05)	*1.82*	*1.84*	*3.39*	*3.53*	*3.24*	*3.52*	*3.40*	*3.22*

establishment reveals that the conventional crop took 1400.08 and 1469.50 °d to attain the MTS in 2016 and 2017, respectively; whereas the SRI crops took significantly less AGDD *viz.* 1319.85 and 1315.13 °d. Conventional crops required 2049.66 to 2077.92 °d for flowering and 2553.96 to 2562.81 °d for physiological maturity. In comparison to the conventional method, SRI needed significantly lesser AGDD for the attainment of various phenophases mentioned earlier. This might be due to the faster rate of tiller production up to MTS which shortened the phyllochron of crops under SRI management resulting in reduced crop duration, and thereby, the lower magnitude of AGDD compared to conventional crops. A number of findings were found in conformity with this result [26].

Effect of date of transplanting

The statistically lower magnitude of AGDD was recorded in the case of delayed *i.e.* 25th July planting throughout the crop growthstages under study. In MTS, however, the AGDD of 26th June and 10th July were found insignificant. On the other hand, the 26th June planting registered significantly higher AGDD as compared to remaining late planting at flowering as well as at physiological maturity in both the year. Consistent reduction of AGDD values with each 15 days delay in planting was observed in both the phenophase. A total of 2554.10 and 2570.66 °d were required by the early transplanted crop to reach physiological maturity which was 61.60 and 100.30 °days more than that of 10th July in 2016 and 2017, respectively. The AGDD difference between the 26th June and the 25th July planting was noted as 205.10 and 213.50 °d in both 2016 and 2017. This might attributable to the fact that the environmental factors in early transplanted crop favored simultaneous growth and development of crops within the required time frame while delayed transplanted crop encountered with less favorable environmental situations that compelleddevelopment to advance while stopping the growth. The increased value of AGDD in early planted crop was revealed in several findings [27, 28]. Besides, many researchers reported the favored contribution of crop microclimate due to the proper time of transplanting [11, 29, 30].

Effect of hill density

The significant effect brought out by different levels of hill density showed increased AGDD value under widest hill density under study; which was followed by 20, 25 and lastly by 33 hills m^{-2}, respectively in all the growing stages and both the investigating years as well. For the attainment of the flowering stage, the crop took 1999.50 to 2017.88 ^{0}days under the lowest hill density; which was gradually followed by its immediate next level of hill density *i.e.* 20 hills m^{-2}; then by 25 and finally by 33 hills m^{-2}. The crop under widest density (16 hills m^{-2}) took 2496.69 and 2477.67 ^{0}days in 2016 and 2017, respectively to attain physiological maturity, which were 57.50 and 46.6 ^{0}days more than that of the closest density under study (33 hills m^{-2}). The widely spaced crop took comparatively more days to complete various phenophases which might eventually result in an increased value of AGDD besides offering a favorable microclimate for simultaneous growth and development process.

The data pertaining to grain yield for both 2016 and 2017 along with their pooled data are enumerated in Table 5. Appraisal of data reveals appreciably significant differences owing to different crop establishment methods, dates of transplanting and varied levels of hill densities.

Effect of method of crop establishment

In 2016 and 2017, grain yield under SRI system was recorded to be 1.18 and 1.16 times higher than that of the conventional method of establishment, respectively. This enhancement of grain yield was found as statistically significant. The pooled analysis revealed the same trend of result with an

Table 4. Influence of method of crop establishment, date of transplanting and hill density on accumulated growing degree days (°d)

Treatment	MTS		Flowering		Physical maturity	
	2016	2017	2016	2017	2016	2017
Crop establishment						
SRI	1319.8	1315.1	1878.9	1882.1	2376.4	2369.3
Conventional	1400.0	1469.5	2049.6	2077.9	2553.9	2562.8
S.Em±	*8.80*	*5.25*	*4.55*	*3.39*	*4.70*	*3.96*
CD (P=0.05)	*27.72*	*16.53*	*14.33*	*10.70*	*14.80*	*12.47*
Date of transplanting						
26th June	1386.5	1406.8	2023.1	2018.1	2554.1	2570.6
10th July	1420.3	1401.3	1987.0	1974.2	2492.5	2470.3
25th July	1272.9	1368.7	1882.8	1947.8	2348.9	2357.2
S.Em±	*10.7*	*6.4*	*5.5*	*4.1*	*5.7*	*4.8*
CD (P=0.05)	*33.9*	*20.2*	*17.5*	*13.1*	*18.1*	*15.2*
Hill density						
20 cm x 15cm	1292.3	1348.1	1933.4	1947.8	2439.2	2443.0
20cm x 20cm	1284.7	1373.4	1942.3	1956.0	2445.0	2454.0
20 cm x 25cm	1418.6	1413.5	1982.3	1998.5	2479.8	2477.6
25 cm x 25cm	1444.11	1434.08	1999.15	2017.88	2496.69	2489.58
S.Em±	*7.2*	*6.5*	*3.8*	*4.7*	*2.9*	*3.2*
CD (P=0.05)	*20.8*	*18.9*	*11.0*	*13.6*	*8.3*	*9.2*

Note:- MTS: maximum tillering stage; PM: physiological maturity; NS: Non-significant; S.Em: Standard error of mean; CD: critical difference

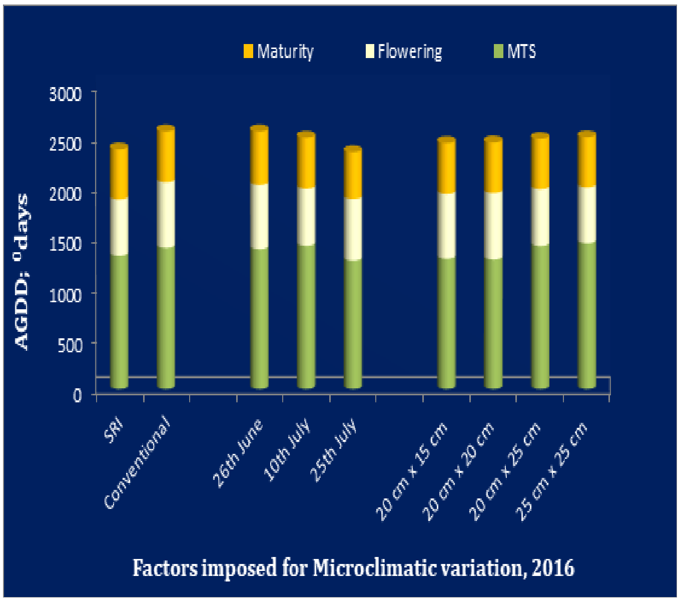

Fig1. AGDD as influenced by manipulation of microclimate imposed by methods of crop establishment, transplanting date and hill density in 2016

Grain Yield

increased yield of 57.13qha^{-1} amounting to 1.17 times more compared to the conventional method which was registered as 48.83 q ha^{-1}.

The increased yield under SRI method might be due to the planting of young and single seedlings per hill in absence of hypoxic conditions. This may enhance the growth and physiological features facilitating the efficient utilization of light, nutrient and water that ultimately, resulted in accelerated photosynthetic rate as well as effectual translocation of assimilates to the sink [15, 31].

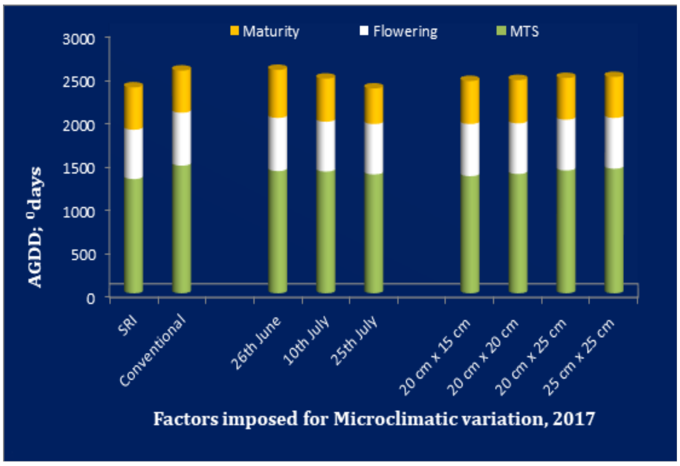

Fig 2: AGDD as influenced by manipulation of microclimate imposed by methods of crop establishment, transplanting date and hill density in 2017

Table 5: Influence of method of crop establishment, date of transplanting and hill density on grain yield (q ha^{-1})

Treatment	2016	2017	Pooled
Crop establishment			
SRI	55.57	58.69	57.13
Conventional	47.14	50.51	48.83
S.Em±	*0.66*	*0.67*	*0.57*
CD (P=0.05)	*2.07*	*2.11*	*1.80*
Date of transplanting			
26th June	54.86	58.16	56.51
10th July	52.06	55.05	53.56
25th July	47.15	50.59	48.87
S.Em±	*0.81*	*0.82*	*0.70*
CD (P=0.05)	*2.54*	*2.59*	*2.20*
Hill density			
20 cm x 15 cm	44.73	48.25	46.49
20 cm x 20 cm	51.61	54.79	53.20
20 cm x 25 cm	53.89	57.08	55.48
25 cm x 25 cm	55.21	58.29	56.75
S.Em±	*1.49*	*1.33*	*1.24*
CD (P=0.05)	*4.27*	*3.81*	*3.57*

Note:- NS: Non-significant; S.Em: Standard error of mean; CD: critical difference

Effect of date of transplanting

Appraisal of grain yield data furnished on Table 5 indicates that all the date of transplanting differed significantly among them. The early one *i.e.* 26th June transplanting registered the highest grain yield of 54.86 and 58.16 q ha^{-1} in 2016 and 2017, respectively, which was followed by 15 days and lastly by 30 days delayed planting *i.e.* 10th July and 25th July. This enhancement of grain yield due to early date of transplanting (26th June) was significantly high in both year. The pooled analysis also showed that the grain yield of the early transplanted crop was significantly high with a magnitude of 1.02 and 1.09 times more than that of 10th and 25th July planting.

The reduction of yield under delayed transplanting might attribute to the occurrence of unfavorable weather parameters resulting in poorly developed canopy that eventually led to insufficient photosynthesis and ineffectual translocation of assimilates from source to sink. Investigations done by many researchers [32] worldwide revealed large impact of weather parameters on growth and yield attributes, and eventually on the yield of rice.

Effect of hill density

Data pertaining to grain yield as influenced by four different levels of density of hill portrayed that with the increase in density, grain yield was found to be decreased significantly, the highest being observed to be 55.21 and 58.29 qha^{-1} under 25cm x 25cm in 2016 and 2017, respectively. However, the highest value was found to be statistically at par with hill density of 20 and 25 hills m^{-2} in both year. The pooled analysis also depicts asimilar result with 1.12 times enhancement of grain yield owing to the adoption of 16 hills m^{-2} over the closest density *i.e.* 33 hills m^{-2}.

Improvement of yield under wider hill density is attributed to enhanced stature of yield attributes, forming larger sink size coupled with the efficient translocation of photosynthates to the sink, when the crop was raised under optimum planting pattern. Similar findings were also documented by many workers [33].

CONCLUSION

In view of the above, it may be concluded that despite a lesser accumulation of GDD in SRI crop, early transplantation in close proximity to 26th June at 16 hills m^{-2} could be an effective strategy to derive the benefit of a favorable microclimatic regime for securing superior grain yield resulted from improved plant statures *esp.*profuse tillering and, increased leaf area and dry matter accumulation

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