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Research Article

EFFECT OF PLANTING METHODS ON GROWTH AND AGROMETEOROLOGICAL INDICES OF RICE

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Abstract- A field experimental trail was carried out in the *kharif* season 2011 year at Regional Research Station (RRS), CCS Haryana Agricultural University, Kaul, India to evaluation the comparative performance of scented/basmati rice variety (CSR 30) under five different methods of planting *viz.,* machine transplanting under pudlled (M_1) and unpuddled conditions (M_2), direct seeding under *vattar* conditions (M_3), direct seeding under zero tillage(with residue) (M_4), conventional practice (nursery raising) (M_5) in a randomised block design with three replications. Among different method of planting the growth indices like the leaf area index, relative growth rate, leaf area duration, , leaf weight ratio, specific leaf area, unit leaf area, leaf relative growth rate, relative leaf growth rate, relative leaf area growth were significantly higher in M_1 planting method and relative leaf area expansion rate, and net assimilation rate, leaf area ratio, leaf area portioning factor were higher in M_3 planting method. Agrometeorological indices like accumulated growing degree days, accumulated helio-thermal units, accumulated photo thermal units were obtained highest in M_3, M_2 and M_5 planting method and highest radiation use efficiency were obtained in M_5 as well as highest radiation use efficiency were obtained in M_1 planting method.

Keywords- Basmati rice, Planting method, Growth indices, Agrometeorological indices

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Introduction

Rice cultivation in India extends from 8 to 35^{0}N latitude and from sea level to as 3000 meter. Rice crops need a hot and humid climate; it's best suited to regions which have high humidity, prolonged sunshine and as assured supply of water [1]. Fifty per cent of the human population on earth, especially of the East use rice as the stable diet and as such vast cultivations of rice are common throughout the world. In India, rice is grown on an area of 42.75 million hectares with total production of 105.24 million tonnes and productivity of 2.62 t/ha [2]. The major contribution in the national food basket comes from rice-wheat system (10.5 mha) [3], which contribute about 65% of food grain production[4]. In most of South Asia, common practice of establishing rice in the rice-wheat system is through puddling followed by manual transplanting. Although puddling helps in reducing water losses through percolation and controlling weeds by submergence of rice fields, but besides being costly, cumbersome and time consuming and results in degradation of soil and other natural resources and subsequently poses difficulties in seed bed preparation for succeeding wheat crop in rotation. Deterioration of soil structure, reduced soil aggregates stability and development of hard pan at soil depth 10-40 cm which were increase in bulk density and soil compaction [5] impediment in root growth of succeeding wheat due to formation of hard pan in rice during puddling [6] labor scarcity and drudgery among women workers [7] are some other disadvantages associated with puddled transplant rice. Under such situations, intervention in the form of mechanized transplanting or direct seeding of rice is the need of time to avoid puddling or manual transplanting or both. Direct seeding of *basmati* rice has already been reported remunerative and cultivation of direct seeded rice (DSR) has already been recommended for farmers in Punjab [8, 9]. In Haryana state 1.23 million hectares area reported under rice cultivation with total production of 3.99 million tonnes and productivity of 3.26 t/ha during 2013-14 and around 60 per cent area is covered under *basmati* group of rice in the state [10]. The response of a rice variety grown by different planting methods can be quite different in the similar growing environment. For manipulation of crop transplanting/planting environment to best advantage, for understanding the physiological process, phenological and agrometeorological bases of yield formation by analysing growth and yield with relation to transplanting methods could be greater help to gives higher and stable yields of rice.

Materials and Method

A field experiment was carried out during the *kharif* season of 2011 at Chaudhary Charan Singh Haryana Agricultural University (CCS HAU), Regional Research Station (RRS), Kaul, India. It lies approximately at 29°51' N latitude and 76°40' E longitude. It is about 242.9 meters above the mean sea level in north-east zone of Haryana and is accessible only by roads to study the comparative performance of scented/basmati rice (CSR 30) under five different methods of planting *viz.,* machine transplanting under pudlled (M_1) and unpuddled conditions (M_2), direct seeding under *vattar* conditions (M_3), direct seeding under zero tillage (with residue) (M_4) , conventional practice (nursery raising) (M_5) in a randomised block design with three replications and one variety.

Treatments: Five planting methods

M_1: Mechanical transplanting (bed- type nursery) under puddled conditions
M_2: Mechanical transplanting under unpuddled conditions
M_3: Direct seeding under *vattar* conditions
M_4: Direct seeding under zero- tillage technique (with residue)
M_5: Conventional practice (conventional nursery)

Growth indices computed by using of different variable (abbreviation) during different phenophase at different interval. Growth indices were computed with the help of following formula:

1) **Leaf area index (LAI)**
   LAI = L/S
2) **Crop growth rate (CGR), gday^{-1}m^{-2}**
   CGR = W_2-W_1/S (t_2 - t_1)
3) **Relative growth rate (RGR), mgmg^{-1}day^{-1}**
   RGR = (Ln W_2- Ln W_1) / (t_2 - t_1)
4) **Net assimilation rate (NAR), mg cm^{-2} day^{-1}**
   NAR = (Ln L_2 - Ln L_1/ t_2 - t_1) × (W_2 - W_1 / L_2 - L_1)
5) **Leaf area duration (LAD), day**
   LAD = LAI_1 + LAI_2 / 2 × t_2 - t_1
6) **Leaf area ratio (LAR), cm^{2}g^{-1}**
   LAR= A/W
7) **Leaf Weight ratio (LWR)**
   LWR = LW / W
8) **Specific leaf area (SLA), cm^{2}g^{-1}**
   SLA = (L_1 / LW_1 + L_2 / LW_2) / 2
9) **Specific leaf weight (SLW), mgcm^{-2}**
   SLW = (LW_1 / L_1 + LW_2 / L_2) / 2
10) **Unit leaf rate (ULR), mgcm^{-2}**
   ULR = W_2 - W_1 / L_2 - L_1 (Ln L_2 - Ln L_1)
11) **Leaf relative growth rate (LRGR), mgmg^{-1}day^{-1}**
   LRGR = Log LW_2 - Log LW_1 / t_2 - t_1
12) **Relative leaf growth rate (RLGR), cm^{2}cm^{-2}**
   RLGR = (Ln L_2) - (Ln L_1)
13) **Relative leaf area growth rate (RLAGR), cm^{2}cm^{-2}day^{-1}**
   RLAGR = Log L_2 - Log L_1 / t_2 - t_1
14) **Relative leaf area expansion rate (RLAER), cm^{2}cm^{-2}day^{-1}**
   RLAER= (Ln L_2 - Ln L_1) / t_2 - t_1
15) **Leaf area partitioning factor (LAPF), cm^{2}g^{-1}**
   LAPF = L_2 - L_1 / LW_2 - LW_1
16) **Harvest index (HI), per cent**
   HI = Economic yield (q ha^{-1}) / Biological yield (q ha^{-1}) ×100

Where:
L_1 and L_2 = leaf area at time t_1 and t_2
W_1 and W_2 = Dry weight of plant at time t_1 and t_2
LW_1 and LW_2 = Leaf dry weight at time t_1 and t_2
t_2 - t_1 = Time interval (days)
LAI_1 = Leaf area index at first stage
LAI_2 = Leaf area index at second stage
L = Leaf area
S = Land area
Ln = Natural logarithm

Agrometeorological Indices

1. **Growing Degree Days (GDD), °C days**

Growing degree days = ∑ (T_{max} + T_{min}) / 2 - T_b

Where,
T_{max} = Daily maximum temperature (°C)
T_{min} = Daily minimum temperature (°C)
Tb = Minimum threshold / base temperature, taken as 10 °C

2. **Heliothermal units (HTU), °C day hr**

Heliothermal units = ∑ {GDD × BSS (n)}

Where,
GDD = growing degree days (°C days)
BSS = bright sun shine hours (hrs)

3. **Photothermal units (PTU), °C day hr**

Photothermal units = ∑ (GDD * N)

Where,
GDD = Growing degree days (°C days)
N = Maximum possible sunshine hours (hrs)

4. **Radiation use efficiency (RUE), g MJ^{-1}**

Radiation use efficiency = Biomass yield / Radiation intercepted

5. **Heat use efficiency (HUE), g ha^{-1} °C day^{-1}**

Heat use efficiency = Biomass yield / heat units utilized

Result and Discussion

Growth indices

Leaf area index (LAI)

The leaf area index (LAI) increased progressively with successive stage of crop growth upto 90 DAS irrespective of planting method, the LAI increase was at a slower rate from 90 DAS upto 105 DAS. After 105 DAS LAI declined upto maturity. The crop in M_1 (transplanted mechanically under puddled conditions) attained highest LAI at all the growth intervals followed by M_5 (conventional practice) as compared to other methods of planting of rice [Fig-1].

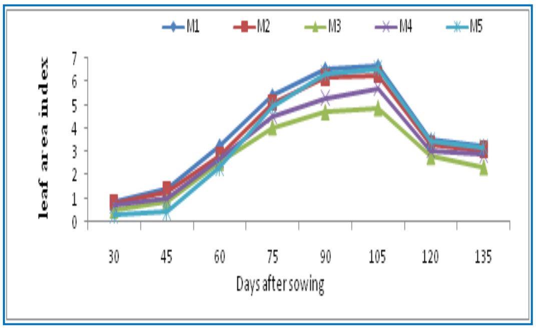

Fig-1 Effect of planting methods on leaf area index of rice at different growth intervals

Crop growth rate (CGR)

The CGR steadily increased after 45 DAS upto 75 DAS but decreased gradually afterwards till 135 DAS [Fig-2]. The CGR was significantly higher in M_1 (mechanical transplanting under puddle conditions) method of planting at 30, 45, 75 and maturity followed by conventional method of planting as compared to other methods.

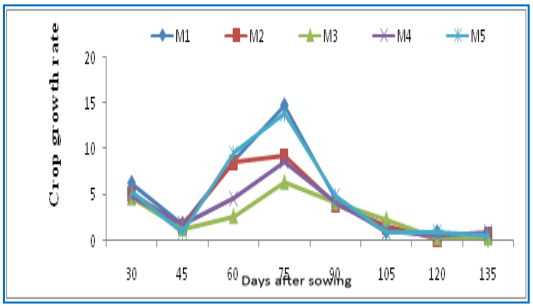

Fig-2 Effect of planting methods on crop growth rate (g day^{-1} m^{-2}) of rice at different growth intervals

Relative growth rate (RGR)

The RGR recorded its peak values during 0-30 days and then declined till harvest of the crop [Fig-3]. The RGR values were higher in M_1 method of planting (mechanical transplanting under puddled conditions) as compared to other methods.

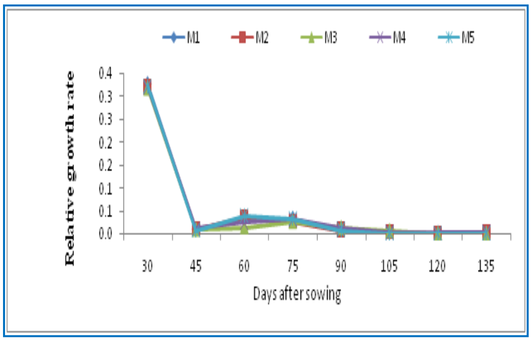

Fig-3 Effect of planting methods on relative growth rate (mg mg^{-1} day^{-1}) of rice at different growth intervals

Net assimilation rate (NAR)

The NAR was higher during 0-30 DAS and after that rapid decline in NAR was recorded. There was slight increase in all the planting methods from 45 DAS up to 75 DAS. The NAR values were higher in M_3 planting method at 30, 60 and 105 DAS as compared to other methods of planting [Fig-4]. However, no significant difference was observed between different methods of planting of the crop. Similar results were found [11].

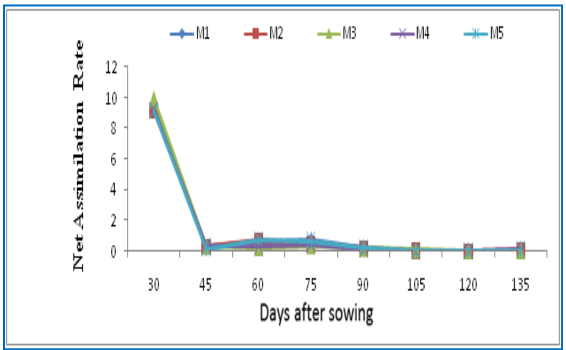

Fig-4 Effect of planting methods on net assimilation rate (mgcm^{-2} day^{-1}) of rice at different growth intervals

Leaf area duration (LAD)

Similar to LAI, there was continuous increase in LAD per day up to the growth period of 105 DAS under all the methods of planting, thereafter LAD fell down rapidly up to growth period 135 DAS [Fig-5]. It was generally higher in M_1 (Mechanical transplanting under puddle conditions) method of planting as compared to other methods of planting. Similar results were found [11].

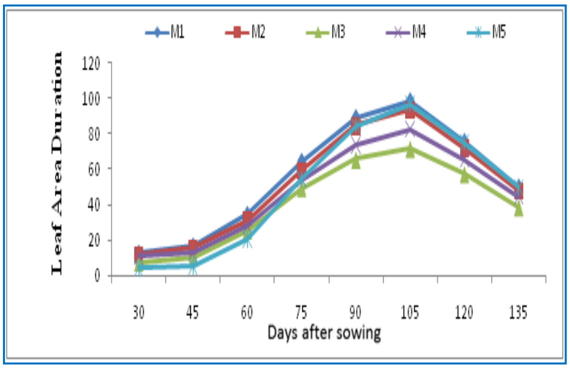

Fig-5 Effect of planting methods on leaf area duration (per day) of rice at different growth intervals

Leaf area ratio (LAR)

The LAR reached its maxima during crop growth period of 45-60 DAS and gradually declined thereafter, however, a small increase was noted during 75-90 DAS. LAR values were higher in M_3 method of planting at 60, 75, 90, 105 and 120 DAS as compared to other methods, whereas LAR values were higher in M5 at 30 and 45 DAS [Fig-6].

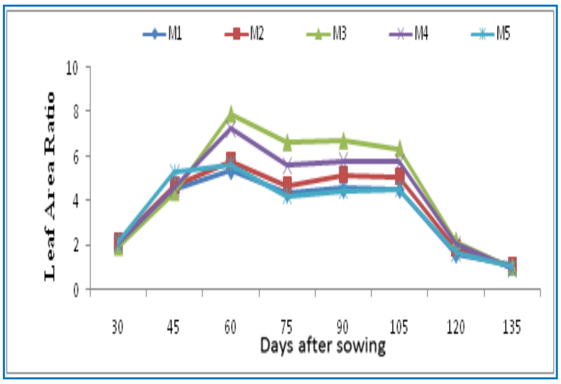

Fig-6 Effect of planting methods on leaf area ratio (cm^{-2} g^{-1}) of rice at different growth intervals

Leaf weight ratio (LWR)

The peak LWR was attained at 30 DAS irrespective of method of planting, thereafter a steady decline in LWR values was observed till harvest of the crop. The planting methods failed to influence LWR values till 30 DAS [Fig-7].

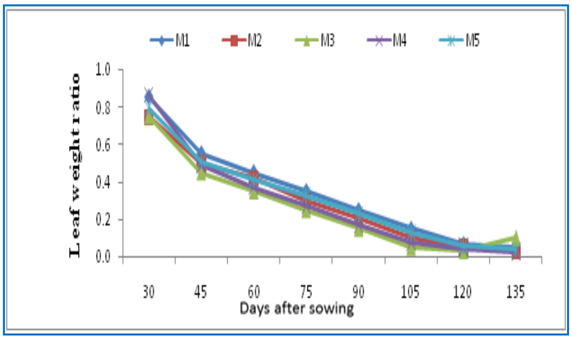

Fig-7 Effect of planting methods on leaf weight ratio of rice at different growth intervals

Specific leaf area (SLA)

A continuous increase in SLA was observed till 105 DAS as shown in the [Fig-8]. A steady decrease occurred thereafter. The SLA values were almost similar in all the planting initial growth period of 0-30 DAS, after which higher SLA values were recorded in M_1 (Mechanical transplanting under puddled conditions) followed by M_5 (conventional practice) and thereafter M_2, M_4 and M_5, respectively.

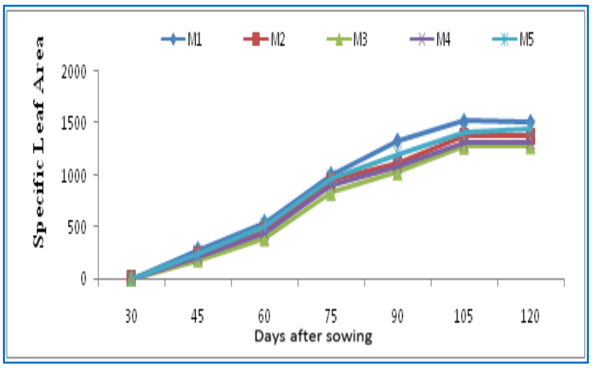

Fig-8 Effect of planting methods on specific leaf area (cm^{-2} g^{-1}) of rice at different growth intervals

Specific leaf weight (SLW)

The increase in SLW values was rapid till growth interval of 30-45 DAS. After that a gradual decline was observed upto 105 DAS with a sharp increase during 120-135 DAS. Methods of planting could not influence the SLW significantly [Fig-9].

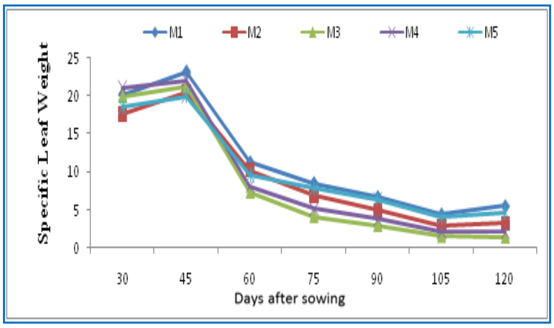

Fig-9 Effect of planting methods on specific leaf weight (mg cm^{-2}) of rice at different growth intervals

Unit leaf rate (ULR)

Similar to NAR, ULR is also the measure of net photosynthesis, while ULR exhibit formation of photosynthates over a period instead of measuring it on daily basis and its calculation is quicker and easier than NAR. There was rapid increase in ULR at growth stage of 0-30 DAS, thereafter decrease in ULR was observed with upswing during growth intervals of 45-75 DAS as shown in [Fig-10] and almost similar trend was observed in all the method of planting. The NAR and ULR increased when LAI decrease.

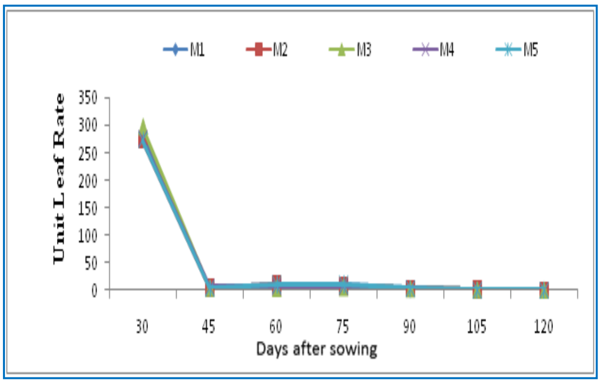

Fig-10 Effect of planting methods on unit leaf rate (mg cm^{-2}) of rice at different growth intervals

Leaf relative growth rate (LRGR)

The peak LRGR values were observed during growth period of 0-30 DAS, after which a continuous decline occurred. Negative values were recorded at 105, 120 and 135 DAS. No significant difference could be found between different methods of planting [Fig-11].

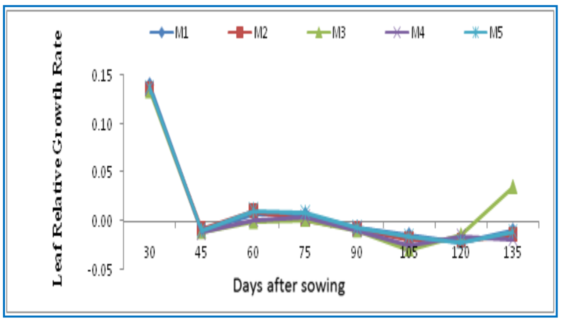

Fig-11 Effect of planting methods on leaf relative growth rate (mg mg^{-1} day^{-1}) of rice at different growth intervals

Relative leaf growth rate (RLGR)

The RLGR is a measure of leaf growth over longer period and the maximum values were observed during 0-30 DAS, thereafter a sharp decline was observed and values were negative at later phase after 120 DAS. During early growth phase of 0-30 DAS RLGR was slightly higher in M_1 followed by M_5, M_2, M_4 and M_3, respectively but it was not significant as seen in [Fig-12].

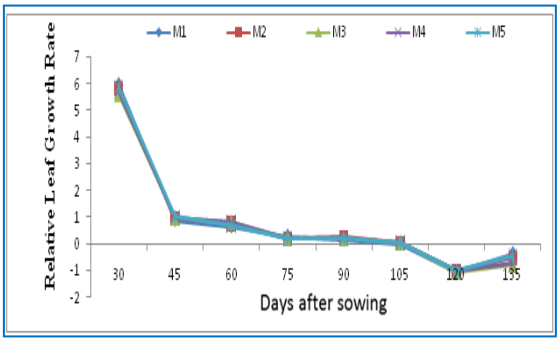

Fig-12 Effect of planting methods on relative leaf growth rate (cm^2 cm^{-2}) of rice at different growth intervals

Relative leaf area growth rate (RLAGR)

The RLAGR exhibits growth of leaf area per day. Maximum values were observed during 0-30 DAS with a sharp decline thereafter. The values were negative during latter phase after 120 DAS. The planting methods could not influence the RLAGR significantly, however during early growth phase of 0-30 DAS it was slightly higher in M_1 followed by M_5, M_2, M_4 and M_3, respectively. The trend in RLAGR was similar to that of RLGR [Fig-13].

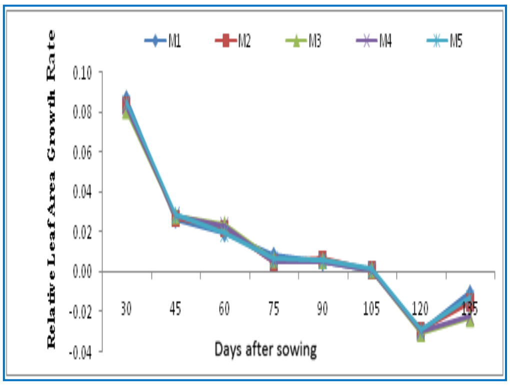

Fig-13 Effect of planting methods on relative leaf area growth rate (cm^2 cm^{-2} day^{-1}) of rice at different growth intervals,

Relative leaf area expansion rate (RLAER)

The trend was similar to that of RLGR and RLAGR [Fig-14].

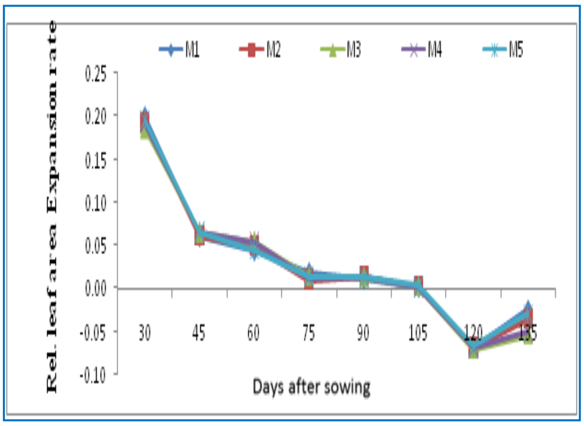

Fig-14 Effect of planting methods on relative leaf area expansion rate (cm^2 cm^{-2} day^{-1}) of rice at different growth intervals

Leaf area portioning factor (LAPF)

The LAPF as shown in [Fig-15] registered a zigzag trend with alternate increase starting from 30-45 DAS and 105-120 DAS and decreased from 45-75 DAS, 90-105 DAS and 120-135 DAS. The method M_3 showed slightly higher values at almost all the growth intervals.

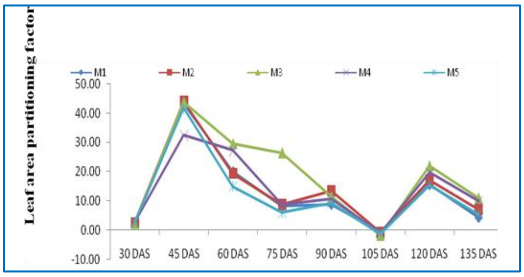

Fig-15 Effect of planting methods on leaf area partitioning factor (cm^2 g$^-$) of rice at different growth intervals

Agrometeorological indices

Accumulated growing day degree (AGDD)

The accumulated growing day degree (AGDD) to reach various growth stages did not showed appreciable variation among the planting methods, which are incorporated in [Table-1]. Among various planting methods, the higher growing degree days were accumulated by M_3, M_2 and M_5 (2702.7 °C days) as compared to M_1 and M_4 (2692.7 °C days) methods of planting.

Table-1 *Effect of planting methods of rice on accumulated growing degree days at various phenophases(°C days)*

Planting methods	Emergence	Tillering	Booting	Heading	Anthesis	Milking	Dough	Ripening
M_1	64.1	1032.5	2126.2	2223.0	2267.7	2434.4	2572.1	2692.7
M_2	64.1	1052.5	2126.2	2207.5	2267.7	2434.4	2582.8	2702.7
M_3	86.1	1012.8	2092.7	2223.0	2267.7	2422.4	2572.1	2702.7
M_4	86.1	1012.8	2109.2	2207.5	2267.7	2422.4	2572.1	2692.7
M_5	64.1	1032.5	2126.2	2223.0	2281.5	2434.4	2572.1	2702.7
Mean	**72.9**	**1028.6**	**2116.1**	**2216.8**	**2270.5**	**2429.6**	**2574.2**	**2698.7**

Accumulated heliothermal units (AHTU)

Accumulated heliothermal units to attain different phenophases under various planting methods are shown in [Table-2]. Among planting methods, the higher AHTU were accumulated by M_3, M_2 and M_5 (17809.6 °C day) as compared to M_1 and M_4 (17767.6 °C day) methods of planting.

Table-2 *Effect of planting methods of rice on accumulated heliothermal units, (°C day)*

Plantingmethods	Emergence	Tillering	Booting	Heading	Anthesis	Milking	Dough	Ripening
M_1	362.9	5537.3	13395.9	14256.6	14571.2	15825.4	16708.6	17767.6
M_2	362.9	5685.3	13395.9	14100.0	14571.2	15825.4	16818.2	17809.6
M_3	565.3	5385.2	13064.3	14256.6	14571.2	15725.8	16708.6	17809.6
M_4	565.3	5385.2	13229.3	14100.0	14571.2	15725.8	16708.6	17767.6
M_5	362.9	5537.3	13395.9	14256.6	14686.7	15825.4	16708.6	17809.6
Mean	**443.8**	**5506.1**	**13296.3**	**14194.0**	**14594.3**	**15785.5**	**16730.5**	**17792.8**

Accumulated photothermal units (APTU)

Accumulated photothermal units (APTU) under different planting methods are presented in [Table-3]. Among planting methods, the higher APTU were accumulated by M_3, M_2 and M_5 (34526.5 ° C days) as compared to M_1 and M_4 (34420.8 ° C days) methods of planting.

Table-3 *Effect of planting methods of rice on accumulated photothermal units, (°C day)*

Planting methods	Emergence	Tillering	Booting	Heading	Anthesis	Milking	Dough	Ripening
M_1	902.0	14305.0	28103.1	29227.8	29742.7	31623.2	33131.5	34420.8
M_2	902.0	14573.2	28103.1	29048.7	29742.7	31623.2	33247.6	34526.5
M_3	1211.8	14039.7	27709.5	29227.8	29742.7	31489.6	33131.5	34526.5
M_4	1211.8	14039.7	27903.6	29048.7	29742.7	31489.6	33131.5	34420.8
M_5	902.0	14305.0	28103.1	29227.8	29900.2	31623.2	33131.5	34526.5
Mean	**1025.9**	**14252.5**	**27984.5**	**29156.2**	**29774.2**	**31569.8**	**33154.7**	**34484.2**

Radiation use efficiency (RUE)

The most important aspect of crop development affecting the dry matter production and economic yield is concerned with the development of leaf canopy and its effect on the efficiency of radiation interception. Radiation use efficiency values of rice crop are shown in [Table-4]. The RUE value was highest under M_5 method of planting at all growth intervals (1.08 gMJ^{-1} at 135 DAS) followed by M_1 (0.99 gMJ^{-1} at 135 DAS), M_2 and M_4 (0.82 gMJ^{-1} at 135 DAS) while it was lowest under M_3 (0.66 gMJ^{-1} at 135 DAS) method of planting.

Table-4 *Effect of planting methods of rice on radiation use efficiency (g MJ^{-1})*

Planting methods	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS	120 DAS	135 DAS
M_1	5.29	2.89	2.50	2.36	1.72	1.27	1.10	0.99
M_2	4.25	2.49	2.44	1.93	1.41	1.06	0.90	0.82
M_3	4.67	2.68	1.74	1.42	1.09	0.86	0.73	0.66
M_4	7.43	3.77	2.40	1.96	1.42	1.04	0.89	0.82
M_5	9.06	6.39	4.24	3.20	2.06	1.43	1.20	1.08
Mean	**6.14**	**3.64**	**2.66**	**2.18**	**1.54**	**1.13**	**0.96**	**0.87**

Heat use efficiency (HUE)

Heat use efficiency values of rice crop are shown in [Table-5]. The HUE value was highest under M_1 (0.249 gha^{-1} °C day^{-1}) method of planting, followed by M_5, M_2, M_4 and M_3, respectively.

Table-5 *Effect of planting methods of rice on heat use efficiency (g ha^{-1} °C day^{-1})*

Planting methods	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS	120 DAS	135 DAS	Maturity
M_1	0.30	0.24	0.28	0.38	0.35	0.31	0.29	0.26	0.24
M_2	0.23	0.20	0.26	0.29	0.28	0.25	0.23	0.21	0.19
M_3	0.23	0.18	0.16	0.19	0.20	0.19	0.17	0.16	0.15
M_4	0.26	0.20	0.19	0.24	0.24	0.21	0.19	0.18	0.17
M_5	0.25	0.19	0.25	0.35	0.33	0.30	0.27	0.25	0.23
Mean	**0.25**	**0.20**	**0.23**	**0.29**	**0.28**	**0.25**	**0.23**	**0.21**	**0.20**

Conclusion

The highest leaf area index (6.64), relative growth rate, leaf area duration, leaf weight ratio, specific leaf area, unit leaf area, leaf relative growth rate, relative leaf growth rate, relative leaf area growth were significantly higher in M_1 planting method and relative leaf area expansion rate, and net assimilation rate, leaf area ratio, leaf area portioning factor were higher in M_3 planting method.

Agrometeorological indices like accumulated growing degree days (2702.7 °C days), accumulated helio-thermal units(17809.6 °C days hr), accumulated photo thermal units (34526.5°C days hr) were obtained highest in M_3, M_2 and M_5 planting method respectively and highest radiation use efficiency were obtained in M_5 (1.08 gMJ^{-1}) and lowest under M_3 (0.66 gMJ^{-1}) method of plating at 135 DAS, higher radiation use efficiency were obtained in M_1 (0.249 gha^{-1o} C^{-1}day^{-1}) followed by M_5, M_2, M_4 and M_3 planting method respectively

Conflict of Interest: None declared

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