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Relationship of surface soil temperature on rice (*Oryza sativa* L.) yield under high density planting in tropics of India

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सार – धान भारत की सबससे महत्वपूर्ण खाद्य फसलों में से एक है। मृदा का तापमान एक महत्वपूर्ण मौसम प्राचल है और मृदा के तापमान में परिवर्तन से धान के उत्पादन पर प्रभाव पड़ता है। इस प्रभाव का अध्ययन करने के लिए तमिलनाडु कृषि वि. वि., कोयम्बटूर की 2018-19 की विलंबित सांबा ऋतु (सितंबर-जनवरी) के दौरान एक फील्ड प्रयोग किया गया । प्रयोग को तीन प्रतिकृतियों के साथ यादृच्छिक (बेतरतीब) पूर्ण ब्लॉक डिज़ाइन में व्यवस्थित किया गया था। रोपण के 13 दिन बाद से लेकर 111 दिन बाद तक साप्ताहिक अंतराल पर चार समयान्तरालों (0600 बजे, 1000 बजे, 1400 बजे तथा 1800 बजे) पर मृदा की सतह का तापमान रिकॉर्ड किया गया। परिणाम से पता चला कि मृदा की सतह का तापमान 0600 बजे, और 1000 बजे के दौरान अन्य सभी अधिक अंतराल के स्तरों की अपेक्षा कम अंतराल के स्तरों में अधिक था। हालांकि 1400 बजे, और 1800 बजे अधिक अंतराल पर रोपित धान के पौधों में मृदा की सतह का तापमान अधिकतम था। धान के दाने की उपज कम दूरी पर रोपे गए पौधों की अपेक्षा अधिक दूरी पर रोपे गए पौधों में अधिक थी। आरंभिक घंटो (0600 बजे और 1000 बजे) के दौरान मृदा के तापमान और उत्पादन के बीच नकारात्मक सहसंबंध था, जबकि बाद के घंटो में इनके बीच सकारात्मक सहसंबंध पाया गया।

ABSTRACT. Rice is one of the most important food crops of India. Soil temperature is an important weather parameter and changes in soil temperature may influence the rice yield. To study this impact, a field experiment was conducted during the late Samba (September-January) season of 2018-19 at Tamil Nadu Agricultural University, Coimbatore. The experiment was arranged in Randomised Complete Block Design with three replications. The surface soil temperature was recorded at weekly interval from 13 Days after transplanting (DAT) to 111 DAT during four time intervals (0600 hrs, 1000 hrs, 1400 hrs and 1800 hrs) of day at weekly interval. The result revealed that surface soil temperature was higher in closer spacing levels during 0600 hrs and 1000 hrs compared to all other wider spacing levels. However, at 1400 hrs and 1800 hrs, surface soil temperature was maximum in widely planted rice plants. The grain yield of rice was higher in wider planted treatments compared to closer spacing planted rice. Correlation between soil temperature and yield during early hours (0600 hrs and 1000 hrs) was negative, but was positive in later hours (1400 hrs and 1800 hrs).

Key words – Microclimate, Soil temperature, Rice, High density planting.

1. Introduction

Rice (*Oryza sativa* L.) is the most widely consumed food crop for larger number of people of the world, especially Asia. Rice productivity is largely determined by the meteorological parameters like solar radiation, temperature, rainfall and wind speed (Jayapriya *et al.*, 2016). Like other crops, rice yield is also determined by the soil temperature and soil volumetric content (Renaud *et al.*, 2001). Soil temperature is affected mainly by meteorological parameters such as air temperature (Decker *et al.*, 2003), rainfall, amount of light interception and row spacing (Flénet *et al.*, 1996). Above and below ground processes in soil is influenced by the distribution of plant canopies through intercepting incoming solar radiation and would modify the energy balance between the water and soil (Song *et al*., 2013). Soil temperature is also affected by soil microbial population, biological processes and dynamics of soil organisms, plant root growth, nutrient uptake and decomposition (Jacobs *et al.*, 2011). Soil temperature plays an important role in crop establishment and has a strong response on plant and root growth. It is reported that seed germination and early season growth rate were positively correlated with the daily maximum soil temperature than air temperature (Green *et al.*, 1984).

TABLE 1

Influence of high density planting on soil temperature (°C) at surface of rice at 0600 hrs

Treatments	Days after transplanting (DAT)														
	13	20	27	34	41	48	55	62	69	76	83	90	97	104	111
T_1	25.37	24.77	24.97	23.37	23.13	21.07	22.83	24.77	24.00	22.07	22.03	21.77	20.10	23.10	24.77
T_2	25.40	24.80	25.07	23.30	23.10	21.03	22.83	24.70	23.93	22.40	22.13	22.00	20.33	23.37	25.07
T_3	25.40	24.87	25.00	23.30	23.10	21.00	22.80	24.73	23.97	22.37	22.10	22.00	20.33	23.37	25.07
T_4	25.47	24.83	25.07	23.27	23.00	20.97	22.77	24.70	23.90	22.40	22.07	22.07	20.33	23.37	25.07
T_5	25.67	25.40	25.20	23.60	23.27	21.10	22.97	24.87	24.33	22.47	22.07	22.07	20.30	23.37	25.07
T_6	25.60	25.30	25.10	23.67	23.37	21.27	22.90	24.80	24.57	22.90	22.80	22.10	20.37	23.37	25.07
T_7	25.63	25.33	25.13	23.50	23.40	21.20	23.17	24.83	24.50	22.90	22.80	22.17	20.37	23.33	24.96
T_8	-	25.37	25.17	23.87	23.60	21.50	23.40	25.00	24.67	22.97	22.87	22.20	20.40	23.40	25.10
SEd	0.07	0.05	0.06	0.05	0.06	0.06	0.06	0.05	0.05	0.06	0.05	0.05	0.05	0.06	0.07
CD (P = 0.05)	0.15	0.11	0.12	0.10	0.13	0.13	0.12	0.10	0.10	0.13	0.10	0.10	0.10	0.13	0.14

T_1 - 25 × 25 cm with 100% RDF (SRI)
T_2 - 25 × 20 cm with 100% RDF
T_3 - 25 × 15 cm with 100% RDF
T_4 - 25 × 15 cm with 125% RDF
T_5 - 20 × 20 cm with 100% RDF
T_6 - 20 × 15 cm with 100% RDF
T_7 - 20 × 15 cm with 125% RDF
T_8 - Conventional cultivation with 100% RDF

In rice, lower soil temperature reduce the rate of germination and temperature difference between soil and air, induces differential development between the radicle and coleoptile of rice seedlings (Stansel, 1975). Song *et al.* (2013) reported that soil temperature decreased with the reduction of height and density of reed weed plants. Zheng (2011) found that deceasing difference in temperature between soil and air affected the seeding height and mass, root length and root number of *Convolvulus arvensis*. Renaud *et al.* (2001) also found that flood water, canopy cover and air temperature had more influence on diurnal variation of soil temperature.

Though there was an established fact that soil temperature has greater role in crop yields, there is no such evidence in rice crop in the study region. Besides, the plant spacing would have greater role in modifying the soil temperature especially in the popular methodology like System of rice intensification (SRI). Hence, the present study was taken up to quantify the influence of different plant spacing levels on soil temperature distribution at surface of rice field, during whole cropping season.

2. Materials and method

2.1. *Location*

A field investigation was carried out during the late *Samba* (September to January) season of 2018-19 at Wetland farm of the Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore. The experimental site is geographically situated in the Semi-arid tropics of south India. Coimbatore comes under 11°83' N latitude, 76°71' E longitude with an elevation of 426.7 m above mean sea level (MSL).

2.2. *Soil characteristics*

The soil of the experimental field was clay loam in texture with pH and EC of the soil being 8.2 and 0.5 dS/m, respectively. The nutrient status of the field during start of the experiment was low in nitrogen (22.68 kg/ha), medium in phosphorous (19.25 kg/ha) and high in potassium (571.1 kg/ha) with organic carbon content of about 12.12 g/kg of soil.

2.3. *Experimental details*

The experiment was laid out in a randomized complete block design having three replications. The treatments, *viz.*, T_1 - 25 × 25 cm + 100% RDF (Recommended dosage of fertilizer, under SRI), T_2 - 25 × 20 cm + 100% RDF, T_3 - 25 × 15 cm + 100% RDF, T_4 - 25 × 15 cm + 125% RDF, T_5 - 20 × 20 cm + 100% RDF, T_6 - 20 × 15 cm + 100% RDF, T_7 - 20 × 15 cm + 125% RDF) following System of rice intensification (SRI) principles and T_8 - Conventional cultivation, were imposed in the field. Latest released

variety of Rice (CO-52) with field duration of 130-135 days was planted in this field experiment.

2.4. *Crop cultivation*

Recommended dose of fertilizers (150: 50: 50 kg N: P_2O_5: K_2O/ha) were applied as urea, single super phosphate and muriate of potash to all the plots as per the treatment. Nitrogen and potassium were given in four equal split doses at basal, active tillering (50 DAT), panicle initiation (70 DAT) and flowering stages (100 DAT). Full dosage of phosphorus, 25 per cent of nitrogen and potassium were applied as basal prior to transplanting. Top dressing was done based on LCC observations in all plots. Excluding the conventional cultivation plots, weeding operation was done on 15, 25, 35 and 45 DAT using hand operated rotary weeder in both direction for square planted plots, while in one direction in all other plots. All other practices were followed as per CPG (2012).

2.5. *Measurement of surface soil temperature*

Surface soil temperature was measured at weekly intervals (13, 20, 27, 34, 41, 48, 55, 62, 69, 76, 83, 90, 97, 104 and 111 DAT) during 0600 hrs, 1000 hrs, 1400 hrs and 1800 hrs. The soil temperature was measured using digital thermometers (Model KUSAM MECO - 936) attached with a probe consisting a thermocouple sensor, to record temperature of surface soil.

2.6. *Harvesting and yield estimation*

After attaining maturity the rice crop was harvested. The border rows in the plots were removed and the net plots were then harvested, hand threshed, sun dried to 14 per cent moisture content and weighed. The final grain yield was converted to kg/ha.

2.7. *Statistical analysis*

The collected data were subjected to Analysis of Variance (ANOVA) and correlation analysis using SPSS 16.00 software. The significant differences between mean values were evaluated using Least Significant Difference (LSD) at 5 per cent probability level as suggested by Gomez and Gomez (2010).

3. Results and discussion

3.1. *Surface soil temperature (°C) at 0600 hrs*

The surface soil temperature data recorded in the early morning (0600 hrs) from rice fields had significant influence under high density planting (Table 1). At 13 DAT, the plant spacing of 20 × 20 cm applied with 100% RDF (T_5) recorded higher temperature (25.7 °C) compared to all other treatments, but, statistically on par with high density plant spacing of 20 × 15 cm with 100% RDF (T_6) and 125% RDF (T_7). It is the highest surface soil temperature recorded, when compared to all weeks. Lower (25.4 °C) surface soil temperature was recorded at a spacing level of 25 × 25 cm with 100% RDF (T_1), but was on par with all row spacing treatments of 25 cm (T_2, T_3 and T_4). Similar trend of results were observed on 20 and 27 DAT also, where, T_5 recorded significantly higher soil temperature along with T_6, T_7 and T_8 treatments. On 34 DAT, the closely planted conventional method of planting (T_8) recorded significantly higher soil temperature (23.87 °C) than all other treatments. Minimum surface soil temperature (23.27 °C) was noted under treatment (T_4) and was remained at par with 25 cm row spaced rice (T_3, T_1 and T_2). On 41, 48, 55, 62 and 69 DAT also the similar trend was observed. At 76 DAT, the conventional method of planting (T_8), plant spacing of 20 × 15 cm with 100% RDF (T_6) and 20 × 15 cm with 125% RDF (T_7) recorded on par and significantly more soil temperature compared to all other treatments. The lowest soil temperature (22.07 °C) was noted at 25 × 25 cm with 100% RDF (T_1). Similar nature of result was repeated during 83 and 90 DAT also. On 97 DAT, significantly higher soil temperature (20.40 °C) was noted in conventional method of planting (T_8) which was on par with all other treatments except T_1 (25 × 25 cm) which recorded lower soil temperature (20.10 °C). Rest of weeks also, similar trend was observed. The above results indicated that though there was minor variation among treatments at weekly intervals, there was a clear trend that closer spacing recorded higher surface soil temperature than wider spacing levels. Generally, there was no influence of fertilizer was noted. The reason for higher soil temperature during 0600 hrs in closer spacing levels (T_6, T_7 and T_8) might be due to higher density of plant. Heat released by the soil during radiative cooling is insulated by denser plant canopy structure due higher leaf area index (as evidence in the present study), which might have prevented the atmospheric gas exchange between air and rice field soil. During night time, surface soil would be cooler compared to deeper layer and to nullify that heat transfer to upper region of soil. Hanks (1992) indicated that absorbed radiation during daytime would be released to the atmosphere by radiative cooling process. Hence, the released heat during night time is trapped by denser planting which makes soil surface warmer in closer spacing compared to wider spacing levels.

3.2. *Surface soil temperature at 1000 hrs*

High density planting in rice had significant influence on surface soil temperature of rice field during

TABLE 2

Influence of high density planting on soil temperature (°C) at surface of rice at 1000 hrs

Treatments	Days after transplanting (DAT)														
	13	20	27	34	41	48	55	62	69	76	83	90	97	104	111
T_1	35.97	34.77	33.90	34.47	32.10	26.37	31.63	29.50	29.90	25.60	24.03	21.97	24.00	23.47	24.40
T_2	35.97	34.77	33.87	34.47	32.07	26.40	31.67	29.53	29.97	25.67	24.07	22.00	24.07	23.47	24.43
T_3	34.70	34.70	33.80	34.40	32.03	26.47	31.70	29.53	30.00	25.70	24.10	22.07	24.07	23.50	24.47
T_4	35.57	34.50	33.87	34.37	32.07	26.47	31.77	29.63	30.93	25.70	24.17	22.10	24.10	23.57	24.50
T_5	33.87	34.47	31.97	33.37	30.80	27.47	32.07	29.87	30.80	25.90	24.47	22.27	24.47	23.80	24.80
T_6	33.87	33.37	31.87	33.27	30.70	27.57	32.90	30.07	30.97	26.10	24.97	22.47	25.13	24.93	24.93
T_7	33.97	33.37	31.90	33.30	30.77	27.60	32.87	30.07	30.97	26.13	25.00	22.43	25.07	24.97	24.97
T_8	-	33.40	31.93	33.47	31.37	27.67	32.97	30.17	31.97	26.17	25.10	22.50	25.17	25.03	25.00
SEd	0.08	0.06	0.05	0.06	0.06	0.05	0.06	0.06	0.07	0.05	0.07	0.06	0.07	0.07	0.06
CD (P = 0.05)	0.17	0.13	0.10	0.13	0.12	0.10	0.12	0.13	0.14	0.11	0.15	0.13	0.15	0.15	0.13

T_1 - 25 × 25 cm with 100% RDF (SRI)
T_2 - 25 × 20 cm with 100% RDF
T_3 - 25 × 15 cm with 100% RDF
T_4 - 25 × 15 cm with 125% RDF
T_5 - 20 × 20 cm with 100% RDF
T_6 - 20 × 15 cm with 100% RDF
T_7 - 20 × 15 cm with 125% RDF
T_8 - Conventional cultivation with 100% RDF

1000 hrs of observation (Table 2). During starting day of observation (13 DAT), the plant spacing of 25 × 20 cm with 100% RDF (T_2) had recorded significantly higher temperature (35.97 °C) compared to all other treatments except T_1 (25 × 25 cm with 100% RDF) which recorded same values. Lesser soil temperature values (33.87 °C) were noted under the spacing of 20 × 15 cm with 125% RDF (T_6). However, T_6 was remained on par with T_5 (20 × 20 cm with 100% RDF) and T_7 (20 × 15 cm with 125% RDF) treatments. At 20 DAT, significantly higher soil temperature (34.77 °C) was recorded in the plant spacing levels of 25 × 25 cm and 25 × 20 cm with 100% RDF (T_1 and T_2) than all other treatments. Significantly lower soil temperature (33.37 °C) was observed under the spacing of 20 × 15 cm with 100 and 125% RDF (T_7) but, it was on par with the same spacing with 100% RDF (T_6) and conventional method of planting (T_8). At 27 DAT, the plant spacing of 25 × 25 cm with 100% RDF (T_1) recorded significantly more soil temperature (33.90 °C) compared to other treatments. However, the treatment T_1 was at par with all the treatments with 25 cm row spacing levels (T_2, T_3 and T_4). Significantly lesser soil temperature values (31.87 °C) was noted in T_6 (20 × 15 cm with 100% RDF) but was on par with T_7 and T_8. Similar nature of results was noted on 34 DAT. On 41 DAT, significantly higher soil temperature (32.10 °C) was observed under the plant spacing of 25 × 25 cm fertilized with 100% RDF (T_1), however, it was on par with spacing of 25 × 20 cm with 100% RDF (T_2), 25 × 15 cm either 100% RDF or 125% RDF (T_3 and T_4) than others. Significantly lower soil temperature (30.70 °C) was recorded under spacing level of 20 × 15 cm with 100% RDF (T_6), but it was on par with T_5 and T_7. At 48 DAT, the conventional method of planting (T_8) had greater soil temperature values (27.67 °C) than all other treatments, however it was on par with spacing of 20 × 15 cm with either 125% RDF (T_7) or 100% RDF (T_6). Significantly lesser soil temperature values (26.37 °C) was noted under spacing of 25 × 25 cm with 100% RDF (T_1) and remained on par with all the treatment with 25 cm row spacing (T_2, T_3 and T_4). Similar trend of soil temperature was prevailed during 55, 62, 69, 76, 83, 90, 97, 104 and 111 DAT also. During the entire cropping period, the highest soil temperature was observed during 13 DAT, while the lowest soil temperature was observed during 90 DAT. The trend in soil temperature was decreased as plant grows. In general, during initial stages, surface soil temperature was higher in wider plant spacing levels, but the trend was reverse at later stages (After 48 DAT). Reason for higher surface soil temperature during initial active tillering at wider spacing levels might due to low leaf area index, since crop growth is not covered the soil and incoming solar radiation was used to heat the water in rice field (Heat capacity of water is more than soil). Discussion made at 0600 hrs was also holds good here.

TABLE 3

Influence of high density planting on soil temperature (°C) at surface of rice at 1400 hrs

Treatments	Days after transplanting (DAT)														
	13	20	27	34	41	48	55	62	69	76	83	90	97	104	111
T_1	37.50	35.87	36.30	36.20	33.30	35.87	35.87	34.20	33.27	28.17	31.67	27.60	28.57	28.97	29.17
T_2	37.57	35.83	36.27	36.13	33.26	35.77	35.80	34.03	33.07	28.00	31.37	27.40	28.57	28.97	29.17
T_3	37.20	35.10	35.80	36.00	32.70	35.70	35.50	33.77	32.10	27.87	31.10	27.20	28.50	28.93	29.10
T_4	36.67	35.10	35.33	35.50	32.70	35.60	35.53	33.97	32.00	27.87	30.87	26.77	28.53	28.87	29.10
T_5	36.57	35.47	35.60	35.57	32.73	35.67	35.40	33.77	32.03	27.77	30.67	27.07	28.47	28.87	29.13
T_6	36.07	35.53	34.63	34.77	32.70	35.57	35.37	33.87	31.83	27.77	30.57	26.87	28.30	28.77	29.03
T_7	36.10	35.50	34.63	34.80	31.87	35.37	35.27	33.90	31.27	27.70	30.50	26.97	28.27	28.67	29.00
T_8	-	34.77	34.40	34.57	31.60	35.10	35.07	33.37	31.10	27.50	30.17	26.57	28.10	28.50	28.87
SEd	0.07	0.06	0.06	0.08	0.06	0.06	0.08	0.06	0.06	0.06	0.09	0.05	0.05	0.07	0.05
CD (P = 0.05)	0.15	0.13	0.13	0.19	0.13	0.13	0.17	0.13	0.13	0.13	0.19	0.10	0.10	0.14	0.10

T_1 - 25 × 25 cm with 100% RDF (SRI)
T_2 - 25 × 20 cm with 100% RDF
T_3 - 25 × 15 cm with 100% RDF
T_4 - 25 × 15 cm with 125% RDF
T_5 - 20 × 20 cm with 100% RDF
T_6 - 20 × 15 cm with 100% RDF
T_7 - 20 × 15 cm with 125% RDF
T_8 - Conventional cultivation with 100% RDF

TABLE 4

Influence of high density planting on soil temperature (°C) at surface of rice at 1800 hrs

Treatments	Days after transplanting (DAT)														
	13	20	27	34	41	48	55	62	69	76	83	90	97	104	111
T_1	27.00	30.50	27.17	26.43	27.13	27.07	26.60	26.60	28.77	25.67	26.87	26.33	25.97	26.17	27.10
T_2	27.00	30.47	26.87	26.17	26.77	26.87	26.47	26.57	28.73	25.63	26.80	26.30	25.90	26.13	27.07
T_3	26.57	30.17	26.40	26.13	26.77	26.63	26.37	26.37	28.47	25.40	26.50	26.17	25.87	26.10	27.00
T_4	26.43	29.87	26.10	26.07	26.63	26.67	26.27	26.37	28.43	25.30	26.37	25.93	25.90	26.13	26.97
T_5	26.27	29.97	26.37	26.10	26.57	26.70	26.37	26.27	28.50	25.47	26.37	26.00	25.80	26.00	26.97
T_6	26.20	29.67	25.90	25.70	26.20	26.63	26.17	26.17	28.47	25.23	26.37	26.07	25.77	25.93	26.93
T_7	26.20	29.67	25.97	25.77	26.23	26.60	26.10	25.97	28.43	25.40	26.30	25.67	25.77	25.97	26.97
T_8	-	29.60	25.87	25.67	26.17	26.57	26.10	25.80	28.27	25.07	26.10	25.50	25.60	25.70	26.80
SEd	0.05	0.07	0.06	0.07	0.07	0.05	0.05	0.06	0.07	0.07	0.06	0.05	0.06	0.06	0.05
CD (P = 0.05)	0.10	0.14	0.12	0.14	0.16	0.15	0.10	0.12	0.14	0.15	0.12	0.10	0.12	0.13	0.11

T_1 - 25 × 25 cm with 100% RDF (SRI)
T_2 - 25 × 20 cm with 100% RDF
T_3 - 25 × 15 cm with 100% RDF
T_4 - 25 × 15 cm with 125% RDF
T_5 - 20 × 20 cm with 100% RDF
T_6 - 20 × 15 cm with 100% RDF
T_7 - 20 × 15 cm with 125% RDF
T_8 - Conventional cultivation with 100% RDF

3.3. *Surface soil temperature at 1400 hrs*

In the afternoon (Table 3), during 13 DAT, soil temperature at the surface of rice soils was significantly higher (37.57 °C) in the plant spacing of 25 × 20 cm with 100% RDF (T_2) than other treatments, however, it was on par with SRI planting of 25 × 25 cm with 100% RDF (T_1). Rice planted at a spacing of 20 × 15 cm with 100% RDF

(T_6) registered significantly lower soil temperature values (36.07 °C) but was on par with the 20 × 15 cm applied with 125% RDF (T_7). At 20 DAT, higher soil temperature (35.87 °C) was in the same trend, but significantly lower temperature values (34.77 °C) were noted under conventional planting (T_8) compared to others. Similar trend was observed on 27, 34, 41, 48 and 55 DAT also. During 62 DAT, the spacing of 25 × 25 cm with 100% RDF (T_1) recorded significantly higher soil temperature (34.20 °C) compared to all other treatments. The least soil temperature (33.37 °C) was recorded in conventional method of planting (T_8). On 69, 76, 83 and 90 DAT, the similar trend was observed under high density planting. At 97 DAT, both 25 × 25 cm and 25 × 20 cm plant spacing levels with 100% RDF (T_1 and T_2) registered significantly higher soil temperature values (28.57 °C) than other treatments, however they were statistically on par with plant spacing of 25 × 15 cm given with either 100% RDF (T_3) and 125% RDF (T_4) and 20 × 20 cm plant spacing with 100% RDF (T_5). Conventional method of planting (T_8) recorded the minimum soil temperature (28.10 °C). Similar trend was recorded on 104 and 111 DAT also. Generally, wider spacing levels irrespective of fertilizer levels did register higher soil temperature in the afternoon hours and lower soil temperature was noted in closer spacing treatments. The reason for higher soil temperature at wider spacing was due to more solar radiation penetrates into the plant canopy than closer spacing levels. With less interception by top canopy due to poor canopy cover in wider spacing levels allows the solar radiation to penetrate into canopy and reach the soil surface more than closer spacing levels. Besides, soil gets heated up by conductive heat transfer or convective heat flux process which is important determinant in heating or cooling of soil (Lal and Shukla, 2004). However, in closer spacing lesser levels, soil temperature was noted irrespective of fertilizer levels throughout the crop growth period might be due to the evaporative cooling (more latent heat flux) and shading, which reduces the sunlight reaching to the soil surface (Rutten *et al.*, 2010). Hence, cooler surface was observed in closer spacing compared to wider spacing levels.

3.4. *Surface soil temperature at 1800 hrs*

Soil temperature of rice at surface (0 cm) recorded during 1800 hrs are presented in Table 4. On 13 DAT, the rice planted at a spacing level of 25 × 25 cm with 100% RDF (T_1) and 25 × 20 cm with 100% RDF (T_2) recorded significantly higher soil temperature (27.00 °C) than all other treatments. Significantly lesser soil temperature was observed in denser plant spacing of 20 × 15 cm with either 125% RDF (T_7) or 100% RDF (T_6). At 20 DAT, warmer soils (30.50 °C) at surface were noted at a spacing of 25 × 25 cm with 100% RDF (T_1) compared to all other treatments, however it was on par with rice planted with spacing of 25 × 20 cm and fertilized with 100% RDF (T_2). Significantly lower soil temperature (29.60 °C) was observed in T_8 (conventional planting method) and was at par with T_6 (20 × 15 cm + 100% RDF) and T_7 (20 × 15 cm + 125% RDF). Similarly, during 27 DAT, warmer soil surface (27.17 °C) was prevailed in wider spacing of 25 × 25 cm with 100% RDF (T_1) than all other treatment under study. Significantly cooler soil surface (25.87 °C) was observed in conventional method (T_8), however it was statistically on par with plant spacing of 20 × 15 cm either with 100% RDF (T_6) or 125% RDF (T_7). Similar nature of results as like 27 DAT was also recorded during 34, 41, 48 and 55 DAT. At 62 DAT, higher soil temperature of 26.60 °C was recorded in rice planted at 25 × 25 cm spacing and applied with 100% RDF (T_1) than other treatments but, was on par with 25 × 20 cm with 100% RDF (T_2). Cooler soil surface (25.80 °C) was prevailed in conventional method of planting (T_8). During 69, 76, 83 and 90 DAT, similar trend of results as like 62 DAT was noted. At 97 DAT, SRI method of planting with 100% RDF (T_1) registered significantly higher soil temperature (25.97 °C) than others. However, it maintained statistical parity with T_2 (25 × 20 cm + 100% RDF), T_3 (25 × 15 cm + 100% RDF)

TABLE 5

Correlation between surface soil temperature and yield of rice

Days After Transplanting (DAT)	Time of observation			
	0600 hrs	1000 hrs	1400 hrs	1800 hrs
13	-0.26	0.42	0.53	0.34
20	-0.50	0.85	0.21	0.58
27	-0.14	0.58	0.73*	0.49
34	-0.66	0.56	0.74*	0.69
41	-0.79*	0.46	0.64	0.62
48	-0.81*	-0.62	0.66	0.33
55	-0.67	-0.83*	0.56	0.62
62	-0.58	-0.72*	0.37	0.70
69	-0.71*	-0.53	0.55	0.42
76	-0.84**	-0.74*	0.50	0.54
83	-0.90**	-0.80*	0.51	0.44
90	-0.40	-0.72*	0.39	0.54
97	-0.27	-0.81*	0.83*	0.63
104	-0.06	-0.87**	0.75*	0.68
111	-0.15	-0.69	0.78*	0.53

** Correlation is significant at the 0.01 level
* Correlation is significant at the 0.05 level

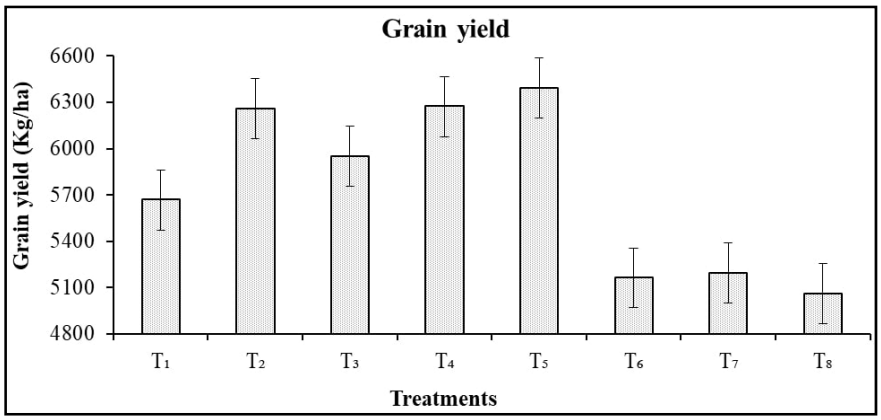

Fig. 1. Influence of high density planting on grain yield of rice (Vertical bar in graph represent standard errors)

and T_4 (25 × 15 cm + 125% RDF). Significantly lower soil temperature value (25.60 °C) was recorded in closer plant spacing of 20 × 10 cm (T_8). As like 97 DAT, the similar nature of results were also recorded during 104 and 111 DAT. The results of soil temperature obtained at 1800 hrs indicated the similar trend as like 1400 hrs. However, the soil temperature values were comparatively lower than the values noted in the afternoon. The reason for temperature difference was similar as like 1400 hrs observations.

3.5. *Influence of high density planting on grain yield of rice*

There existed a significant variation in grain yield due to high density planting in rice (Fig. 1). Significantly higher rice grain yield (6392 kg/ha) was recorded when rice planted with spacing of 20 × 20 cm with 100% RDF (T_5) than all other treatments, however it was very much comparable yield was obtained in plant spacing of 25 × 15 cm with application of 125% RDF (6272 kg/ha) (T_4) and in plant spacing of 25 × 20 cm with 100% RDF (T_2) with application of 100% RDF and rice planted with wider spacing of 25 × 15 cm (T_3). The least grain yield (5061 kg/ha) was noticed in conventional method of cultivation (T_8). Higher yield under these treatments can be attributed to the optimum plant population and better yield attributes recorded from the treatments. Better light interception and dry matter accumulation had paved the way for better yield attributes. Similar results where planting geometry of 20 × 20 cm producing higher yield compared to wider and closer spacing levels had been reported by Thakur *et al.* (2010).

3.6. *Correlation analysis*

Correlation analysis between soil temperature and yield had mixed results. Morning hours (0600 and 1000 hrs), the soil temperature had influenced negatively with the grain yield (Table 5). Whereas, there existed a positive correlation of soil temperature with grain yield of rice during afternoon (1400 and 1800 hrs).

4. Conclusions

In conclusion, surface soil temperature was higher during early growing period and it decreased as crop grows in all time of observations. Closer plant spacing levels had higher surface soil temperature during 0600 hrs and 1000 hrs and also negatively correlated with the grain yield. While, during 1400 hrs and 1800 hrs, wider spacing levels had enhanced surface soil temperature and had positive correlation with grain yield. Fertilizer levels used in this study didn't have any marked influence on soil temperature at surface of rice.

Disclaimer

The contents and views expressed in this research paper are the views of the authors and do not necessarily reflect the views of the organizations they belong to.

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