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Research Article

CORRELATION STUDY OF GROWTH, DEVELOPMENT AND YIELD WITH AGROMETEOROLOGICAL INDICES UNDER DIFFERENT PLANTING METHOD OF RICE

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Abstract- An field experimental trail was carried out in the *kharif* season of 2011 at Chaudhary Charan Singh Haryana Agricultural University, Regional Research Station, Kaul, India 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. The growth indices like LAI, CGR, RGR, NAR, LAD, LWR, SLA, SLW, ULR, LRGR, LAPF and agrometeorological indices *i.e*. AGDD, AHTU, APTU, RUE and HUE showed significantly positive correlation with yield and yield attributes whereas LAR, RLGR, RLAGR ,RLAER ,AGDD, AHTU and APTU was negatively correlated with yield and yield attributes at different vegetative growth phase (DAS).

Keywords- Rice, Planting method, Yield, Yield attributes correlation, Weather and agromet indices

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Introduction

Weather is one of the most important parameters to decide the growth, development and yield of crop. Fifty per cent of the human population consuming rice as the basic 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 [1]. The major contribution in the national food basket comes from rice-wheat system (10.5 mha) [2], which contribute about 65% of food grain production [3]. In this paper, aim to study the actual relation exiting of weather parameters with different planting methods and their suitability with environment. Some growing environment of rice planted under different planting methods and performance were check with the statistically for their significant contribution in the yield and yield parameters in the actual weather condition of kaul. 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 a depth of 10-40 cm, increase in bulk density and soil compaction [4], impediment in root growth of succeeding wheat due to formation of hard pan in rice field during puddling [5], labor scarcity and drudgery among women workers [6] 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 as remunerative and cultivation of direct seeded rice (DSR). Already been recommended for farmers in Punjab [7], [8] for direct seeded rice.

In Haryana 1.23 million hectares area was 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 was covered under *basmati* group of rice in the state [9].The response of a rice variety grown by different planting methods can be quite different. For manipulation of crop environment the best advantage, is understanding of physiological, phenological and agrometeorological bases of yield formation by analysing growth and yield in relation to planting methods could be of great help in higher and stable yields of rice. The main objective of this work was correlation study of growth, development and yield with agrometeorological indices under different planting method of rice.

Materials and Method

A field experiment was conducted during the *kharif* season of 2011 at Chaudhary Charan Singh Haryana Agricultural University, Regional Research Station, 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 replicationsand 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
M4: Direct seeding under zero- tillage technique (with residue)
M5: Conventional practice (conventional nursery)

Growth indices

Following growth indices were calculated by using the above observations:

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^2g^{-1}**
   LAR= A/W

7) **Leaf Weight ratio (LWR)**
   LWR = LW / W

8) **Specific leaf area (SLA), cm^2g^{-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^2cm^{-2}**
    RLGR = (Ln L_2) - (Ln L_1)

13) **Relative leaf area growth rate (RLAGR), $cm^2cm^{-2}day^{-1}$**
    RLAGR = Log L_2 - Log L_1 / t_2 - t_1

14) **Relative leaf area expansion rate (RLAER), $cm^2cm^{-2}day^{-1}$**
    RLAER= (Ln L_2 - Ln L_1) / t_2 - t_1

15) **Leaf area partitioning factor (LAPF), cm^2g^{-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

Growing Degree Days (GDD), °C days

The cumulative growing degree-days were determined by summing the daily mean temperature above the base temperature. It states with the assumption that the growth of plants is dependent on the total amount of heat to which, it is subjected during its lifetime. This can be worked out by using the following formula:

$$\text{Growing degree days} = \sum (T_{max} + T_{min}) / 2 - T_b$$

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

Heliothermal units (HTU), °C day hr

The heliothermal units for a day represent the product of GDD and the hours of bright sunshine for that day. The sum of HTU for particular phenophases of interest was determined according to the equation:

$$\text{Heliothermal units} = \sum \{GDD \times BSS (n)\}$$

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

Photothermal units (PTU), °C day hr

The day and night period is one of the basic factors controlling the period of vegetative growth for photosensitive varieties. In case of long day plants the length of night is critical for determining, whether plant will enter into reproductive phase or not. Photo - thermal units are the cumulative value of growing degree days, multiplied by bright sunshine hours. This can be mathematically represented using the following formula:

$$\text{Photothermal units} = \sum (GDD * N)$$

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

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

The radiation use efficiency is a ratio of biological yield and the radiation intercepted. It can be represented by using the following formula: Radiation use efficiency = Biomass yield / Radiation intercepted

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

Heat use efficiency is also represented by thermal time use efficiency (TTUE), which indicates the amount of dry matter produced per unit of growing degree days or thermal time. This was computed by using the following formula:
Heat use efficiency = Biomass yield / heat units utilized

Correlation Studies

The coefficient of correlation was computed by dividing the sum of the product of deviations from the mean by the square root of the product of sum of squares of deviations from the respective means of the two variables [10] and its significance was tested at 5 and 1 percent levels of significance. The following formula was used: The dependent variable considered as the yield and yield attributes and independent as growth and agrometeorological indices.

$$r = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2\sum(y-\bar{y})^2}}$$

r = correlation coefficient
x = independent variable
y = dependent variable

Results and Discussion

Relationship of yield and its attributes with growth indices

The data on correlation coefficients of yield and yield attributes with growth indices are presented in [Table-1a, 1b and 1c]

Table-1a *Correlation coefficients of yield and yield attributes with growth indices during vegetative phase (0-60 DAS) of rice*

Growth indices	Yield attributes							
	Seed yield	Eff. tillers	Panicle length	Panicle wt.	Grains/ panicle	1000 grainwt.	Straw yield	Biomass
LAI	0.23	0.24	0.16	0.19	0.25	0.26	0.42	0.34
CGR	0.91	0.70	0.91	0.90	0.97	0.96	0.90	0.91
RGR	0.82	0.61	0.84	0.82	0.90	0.90	0.79	0.81
NAR	0.86	0.64	0.87	0.86	0.94	0.95	0.85	0.86
LAD	0.11	0.09	0.04	0.08	0.16	0.19	0.30	0.22
LAR	-0.92	-0.73	-0.91	-0.91	-0.97	-0.96	-0.94	-0.94
LWR	0.86	0.71	0.85	0.86	0.91	0.91	0.94	0.91
SLA	0.98	0.92	0.94	0.95	0.94	0.87	0.99	0.99
SLW	0.83	0.66	0.82	0.83	0.89	0.90	0.92	0.89
ULR	0.86	0.64	0.87	0.86	0.94	0.95	0.85	0.86
LRGR	0.80	0.54	0.83	0.81	0.91	0.93	0.79	0.80
RLGR	-1.00	-0.91	-0.99	-0.99	-0.96	-0.89	-0.98	-0.99
RLAGR	-1.00	-0.91	-0.99	-0.99	-0.96	-0.89	-0.98	-0.99
RLAER	-1.00	-0.91	-0.99	-0.99	-0.96	-0.89	-0.98	-0.99
LAPF	0.49	0.60	0.35	0.33	0.41	0.32	0.45	0.48

During vegetative phase (0-60 DAS) of crop LAI, CGR, RGR, NAR, LAD, LWR, SLA, SLW, ULR, LRGR and LAPF showed significantly positive correlation with yield and yield attributes whereas, LAR, RLGR, RLAGR and RLAER was negatively correlated with yield and yield attributes.

Table-1b *Correlation coefficients of yield and yield attributes with growth indices during reproductive phase (60-90 DAS) of rice*

Growth indices	Yield attributes							
	Seed yield	Eff. tillers	Panicle length	Panicle wt.	Grains/ panicle	1000 grain wt.	Straw yield	Biomass
LAI	0.93	0.77	0.91	0.91	0.96	0.94	0.94	0.94
CGR	0.74	0.76	0.76	0.75	0.62	0.51	0.62	0.68
RGR	-0.86	-0.74	-0.82	-0.82	-0.89	-0.87	-0.90	-0.89
NAR	-0.14	-0.07	-0.07	-0.10	-0.22	-0.28	-0.32	-0.24
LAD	0.90	0.75	0.88	0.88	0.94	0.92	0.94	0.93
LAR	-0.97	-0.87	-0.94	-0.93	-0.96	-0.90	-0.95	-0.96
LWR	0.98	0.87	0.96	0.97	0.97	0.92	1.00	1.00
SLA	0.92	0.90	0.87	0.88	0.85	0.77	0.96	0.95
SLW	0.99	0.88	0.98	0.98	0.98	0.93	0.99	1.00
ULR	-0.14	-0.07	-0.07	-0.10	-0.22	-0.28	-0.32	-0.24
LRGR	0.99	0.89	0.99	0.99	0.97	0.91	0.98	0.99
RLGR	-0.58	-0.81	-0.48	-0.49	-0.37	-0.21	-0.58	-0.59
RLAGR	-0.58	-0.81	-0.48	-0.49	-0.37	-0.21	-0.58	-0.59
RLAER	-0.58	-0.81	-0.48	-0.49	-0.37	-0.21	-0.58	-0.59
LAPF	0.94	0.95	0.85	0.85	0.86	0.76	0.93	0.94

During active reproductive phase (60-90 DAS) of crop LAI, CGR, , LAD, LWR, SLA, SLW, ULR, LRGR and LAPF showed significantly positive correlation with yield and yield attributes whereas, RGR, NAR LAR, RLGR, RLAGR and RLAER was negatively correlated with yield and yield attributes.

Table-1c *Correlation coefficients of yield and yield attributes with growth indices during ripening phase (90DAS to harvest) of rice*

Growth indices	Yield attributes							
	Seed yield	Eff. tillers	Panicle length	Panicle wt.	Grains/ panicle	1000 grain wt.	Straw yield	Biomass
LAI	0.88	0.79	0.82	0.82	0.88	0.83	0.87	0.88
CGR	0.10	0.05	0.16	0.20	0.11	0.13	0.22	0.17
RGR	-0.29	-0.33	-0.19	-0.15	-0.25	-0.20	-0.19	-0.23
NAR	-0.40	-0.22	-0.50	-0.53	-0.48	-0.52	-0.52	-0.47
LAD	0.91	0.80	0.87	0.86	0.92	0.88	0.91	0.92
LAR	0.69	0.40	0.75	0.76	0.83	0.90	0.80	0.75
LWR	-0.38	-0.43	-0.25	-0.23	-0.34	-0.28	-0.33	-0.36
SLA	0.97	0.87	0.92	0.92	0.95	0.89	0.97	0.97
SLW	0.65	0.55	0.72	0.74	0.64	0.61	0.70	0.68
ULR	-0.40	-0.22	-0.50	-0.53	-0.48	-0.52	-0.52	-0.47
LRGR	-0.55	-0.59	-0.42	-0.41	-0.50	-0.43	-0.52	-0.54
RLGR	0.95	0.79	0.96	0.97	0.99	0.97	0.98	0.98
RLAGR	0.95	0.79	0.96	0.97	0.99	0.97	0.98	0.98
RLAER	0.95	0.79	0.96	0.97	0.99	0.97	0.98	0.98
LAPF	0.31	0.40	0.16	0.14	0.24	0.18	0.26	0.28

During post reproductive phase (90 DAS to harvest) of crop LAI, CGR, LAD, SLA, SLW, RLGR, RLAGR, RLAER and LAPF showed significantly positive correlation with yield and yield attributes whereas, RGR, NAR LAR, LWR, ULR, and LRGR was negatively correlated with yield and yield attributes.

Most of the growth indices exhibited significant relationship with yield and yield attributes. LAI, LAD and CGR were significantly and positively correlated with yields and yield attributes during vegetative and active reproductive phase because of greater significance of the leaf area and dry matter accumulation. It may, in fact be a consequence of the relatively longer duration of these growth phases in the crop.

Table-2a *Correlation coefficients of yield and yield attributes with agrometeorological indices during vegetative phase (0-60 DAS) of rice*

Growth indices	Yield attributes							
	Seed yield	Eff. tillers	Panicle length	Panicle wt.	Grains/ panicle	1000 grain wt.	Straw yield	Biomass
AGDD	0.49	0.16	0.55	0.55	0.70	0.80	0.56	0.53
AHTU	0.50	0.17	0.56	0.56	0.71	0.81	0.57	0.54
APTU	0.49	0.16	0.55	0.55	0.70	0.80	0.56	0.53
RUE	0.73	0.66	0.74	0.71	0.68	0.61	0.57	0.65
HUE	0.87	0.69	0.85	0.86	0.93	0.93	0.93	0.90

During vegetative phase (0-60 DAS) of crop AGDD, AHTU, APTU, RUE and HUE showed positive correlation with yield and yield attributes, however, the correlation coefficient was same for AGDD, AHTU and APTU.

Table-2b *Correlation coefficients of yield and yield attributes with agrometeorological indices during reproductive phase (60-90 DAS) of rice*

Growth indices	Yield attributes							
	Seed yield	Eff. tillers	Panicle length	Panicle wt.	Grains/ panicle	1000 grain wt.	Straw yield	Biomass
AGDD	0.55	0.48	0.61	0.58	0.52	0.46	0.38	0.46
AHTU	0.55	0.48	0.61	0.58	0.52	0.46	0.38	0.46
APTU	0.55	0.48	0.61	0.58	0.52	0.46	0.38	0.46
RUE	0.92	0.88	0.90	0.88	0.85	0.75	0.82	0.87
HUE	0.99	0.89	0.97	0.97	0.97	0.91	0.99	1.00

During active reproductive phase (60-90 DAS) of crop AGDD, AHTU, APTU, RUE and HUE showed positive correlation with yield and yield attributes, however, the correlation coefficient was same for AGDD, AHTU and APTU.

Table-2c *Correlation coefficients of yield and yield attributes with agrometeorological indices during ripening phase (90DAS to harvest) of rice*

Growth indices	Yield attributes							
	Seed yield	Eff. tillers	Panicle length	Panicle wt.	Grains/ panicle	1000 grain wt.	Straw yield	Biomass
AGDD	-0.19	-0.50	-0.01	-0.02	0.02	0.15	-0.24	-0.22
AHTU	-0.19	-0.50	-0.01	-0.02	0.02	0.15	-0.24	-0.22
APTU	-0.19	-0.50	-0.01	-0.02	0.02	0.15	-0.24	-0.22
RUE	0.96	0.93	0.92	0.91	0.89	0.79	0.88	0.92
HUE	0.99	0.89	0.98	0.98	0.97	0.92	0.99	1.00

During post reproductive phase (90 DAS to maturity) of crop RUE and HUE showed positive correlation with yield and yield attributes, whereas AGDD, AHTU and APTU showed negative correlation with yield and yield attributes. However, the correlation coefficient was same for AGDD, AHTU and APTU.

Most of the agrometeorological indices exhibited significant relationship with yield and yield attributes. AGDD, AHTU and APTU were significantly and positively correlated with yields and yield attributes during vegetative and active reproductive phases. However, RUE and HUE showed negative correlation at latter stages of growth.

[11] Observed that the rice grown under aerobically (T_1), flooded for the entire growth period (T_2) or flooded for two weeks after transplanting, given supplemental irrigation up to panicle initiation and then flooded from panicle initiation to physiological maturity (T_3). The study showed that rice crop was significantly reduced growth in term of leaf area index (LAI), leaf area duration (LAD), crop growth rate (CGR), total dry matter accumulation (TDM) and net assimilation rate (NAR), when it was grown in aerobic condition. However, the crop was not affected significantly different from normal flooded rice (T_2) when it was grown in modified rice culture (T_3).

Conclusion

The growth and agrometeorological indices during vegetative phase (0-60 DAS) of crop LAI, CGR, RGR, NAR, LAD, LWR, SLA, SLW, ULR, LRGR, LAPF, AGDD, AHTU, APTU, RUE and HUE showed significantly positive correlation with yield and yield attributes whereas, LAR, RLGR, RLAGR, RLAER, AGDD, AHTU and APTU was negatively correlated with yield and yield attributes. During active reproductive phase (60-90 DAS) of crop LAI, CGR, , LAD, LWR, SLA, SLW, ULR, LRGR, LAPF, AGDD, AHTU, APTU, RUE and HUE showed significantly positive correlation with yield and yield attributes whereas, RGR, NAR LAR, RLGR, RLAGR, RLAER, AGDD, AHTU and APTU was negatively correlated with yield and yield attributes and during post reproductive phase (90 DAS to harvest) of crop LAI, CGR, LAD, SLA, SLW, RLGR, RLAGR, RLAER, LAPF , RUE and HUE showed significantly positive correlation with yield and yield attributes whereas, RGR, NAR LAR, LWR, ULR, LRGR, AGDD, AHTU and APTU was negatively correlated with yield and yield attributes. However, the correlation coefficient was same for AGDD, AHTU and APTU.

.Conflict of Interest: None declared

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