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Impact of weather on lowland rice cultivation and planning decisions over humid tropical India

H. P. DAS and S. B. GAONKAR

Agricultural Meteorological Division, Pune-411005, India

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सार - इस अध्ययन में धान की तीन विभिन्न किस्मों पर जलवायविक परिस्थितियों के प्रभाव की जाँच की गई है। वृद्धि की विभिन्न अवस्थाओं, उपभोगकारी उपयोग और विकिरण उपयोग दक्षता में फसल गुणांक का पता लगाया गया है और इसकी प्रत्येक मामले में चर्चा की गई। धान की दो किस्मों के अधिकतम उत्पादन के लिए उपयुक्त समय का निर्धारण किया गया है। फॉरवर्ड रैंकिंग पद्धति द्वारा फसल की बढ़वार की प्रत्येक अवस्था के मौसम प्राचलों का उपज के साथ सहसंबंध स्थापित किया गया है और सांख्यिकीय पूर्वानुमान निदर्श का विकास किया गया है। चुने गए पूर्वसूचकों पर पथ विश्लेषण का अनुप्रयोग किया गया है तथा उपज के पूर्वसूचकों के प्रत्यक्ष व अप्रत्यक्ष योगदान का पता लगाया गया है और उस पर चर्चा की गई है।

ABSTRACT. The present study investigates the effect of the climatic environment on three different varieties of paddy. Crop coefficient in different stages of growth, the consumptive uses and radiation use efficiency has been determined and discussed in each case. Ideal date which could give optimum yield, has been determined in two varieties. The yield was correlated with weather parameters for each of the phases of the crop growth by forward ranking method and a statistical prediction model developed. Path analysis was applied to the predictors thus selected and direct and indirect contribution of the predictors to yield determined and discussed.

Key words – Low land rice cultivation, Climatic environment, Crop yield, Path analysis.

1. Introduction

Rice (Oryza sativa L) is one of the most important cereal crops of India and is the staple diet of its people particularly in its eastern and southern parts. It is grown in a wide range of rainfall conditions. The crop is cultivated in about 43 million ha with a mean annual production of 82 million tons or a mean yield of 19q/ha (Swaminathan, 2000). The low productivity compared to 30-40q/ha in China and Japan is mainly due to erratic behaviour of southwest monsoon which accounts for nearly 80-90% of annual rainfall and insufficient infrastructure and subsistence agriculture. Several studies (Sreenivasan and Banerjee, 1978; Sreenivasan, 1980; Chowdhary and Gore, 1991; Lenka and Garnayak, 1991; Das *et al*., 1995; Sastry *et al*., 1996; Das and Datar, 1998; etc.) on crop weather relations of rice have been reported.

It is likely that growth and development of plants will be different for the same variety in two different climatic environments at the same location. Sreenivasan and Banerjee (1978) studied behaviour of CO-25 variety of rice under different irrigated environment of Aduthurai and Coimbatore and found the different group of climatic elements influencing the yield at the two locations. Such an attempt also has been made in the study.

Understanding the dynamics of wet land cultivation with particular reference to evapotranspiration and date of transplanting, usually the main components of the system, is a prerequisite for efficient use of water resources in humid areas like Kerala. In rain fed low lands of Kerala, rice is either directly seeded before onset of monsoon or transplanted in shallow depth soon after the onset.

An attempt has been made to theoretically determine date of seeding/transplanting of paddy plants in Kerala, which would give maximum yield, other factors remaining constant.

The purpose of the study is also to develop, from weather parameters, empirical models, which could help estimation of pre-harvest yield of rice. The extent to which the weather parameters directly or indirectly (through interaction among themselves) contribute to the yield, has also been evaluated.

2. Material and method

In this study, an investigation has been undertaken for three varieties of rice crops at a single location *viz.* Pattambi (10.48°N, 76.12°E, 25 m a.s.l.). Rice was grown in this location as transplanted and rain fed after commencement of the summer monsoon. The soil around Pattambi is sandy loam with 18.1% clay and 12.9% sand. Triveni, the traditional variety was cultivated during 1981-90 in the monsoon crop season (June to October) except 1988 and during 1981-89, barring 1982-84 in the post-monsoon or the winter season. *Jyothi,* a new variety was cultivated during 1993-95 for monsoon crop season and 1993-94 for post-monsoon or winter season. The photo-insensitive *Jaya* variety was grown in 1978-90 and 1979-90 (except 1982-84) in each of the two respective crop seasons. *Jaya* variety is more sensitive to time of transplanting than the local varieties (Magor, 1984).

Rainfall, radiation, sunshine, humidity (as reflected by vapour pressure) and temperature, alone and/or jointly together, determine the transpiration rates and influence the crop growth and yield to a large extent, and so have been chosen in the analysis. Rainfall and temperature have been measured daily by conventional instruments located in the experimental farm. The daily evapotranspiration loss (ET) or water use was measured by a volumetric lysimeter installed within the crop field. The potential evapotranspiration (PET) was computed using Penman's formula as given in Doorenbos and Pruits (1977).

For the purpose of determining the ideal date of seeding/transplanting, period from 5th June to 15th October, which covered seeding or transplanting of monsoon or post-monsoon seasons was chosen. Dummy variables like 1, for the 5th June, 2 for 6th June etc. in monotonously increasing order were assigned to the period 5th June onwards to 15th October. A third degree polynomial was then fitted to the yield (Y) and each date (X) and multiple correlation obtained separately for the two varieties of the two crop seasons. As the available data period was just three years for the third variety, this exercise was not applied to it. From this data, that giving high multiple correlation in each case, was finally selected and the equation between Y & X formed. Differentiating the equations with respect to X gave second degree equations.

Equating the equators to zero and solving these for X and finding that value of X which gave the negative sign to d^2Y/dX^2, furnished the optimum date X for seeding/transplanting. For the development of pre-harvest multiple regression model the four elements and the six phenophases were selected (Appendix A) as independent variables with rice yield as the dependent variable.

Appendix A

Element	Symbol	Phase	Symbol
Rainfall	X_1	Post transplanting	a
Maximum temperature	X_2	Tillering	b
Minimum temperature	X_3	Flag leaf	c
Relative humidity	X_4	Panicle emergence	d
		Fruiting	e
		Maturity	f

The final selection of the parameters (*i.e.* weather/growth phase) was made following the forward ranking method. The method involves ranking the independent variables in the descending order of importance as determined from the variance ratio F. The most important independent variable is one which gives smallest F. Next, the remaining variables are considered individually. That variable which along with the first variable already selected gives, largest sum of squares value (or lowest F value) is the second ranked selected variable. This process is continued till the least important variable is identified. In this manner, model for both crop seasons and the two varieties were determined.

Path analysis was adopted to evaluate the extent to which the weather/growth stages parameters selected above, contribute directly towards the yield and indirectly through interaction among themselves. A path coefficient is simply a standard partial regression coefficient, which permits its separation into direct and indirect effects. The path coefficients are obtained by simultaneous solution of equations, which express basic relationship between correlation and path coefficients (Dewey and Lu, 1959).

3. Results and discussion

3.1. *Crop coefficient, consumptive water and radiation use*

The match of mean K_C of *Triveni* variety [Fig. 1(a)] shows a familiar pattern with a peak near flowering in both monsoon and post-monsoon seasons. The peak during monsoon attained 9 weeks after planting (WAP) while in post-monsoon it is a week earlier. The match of K_C in *Jyothi* variety shows a familiar pattern with a peak near flowering in both post-monsoon and monsoon seasons. The peak, like *Triveni*, is also attained 9 weeks

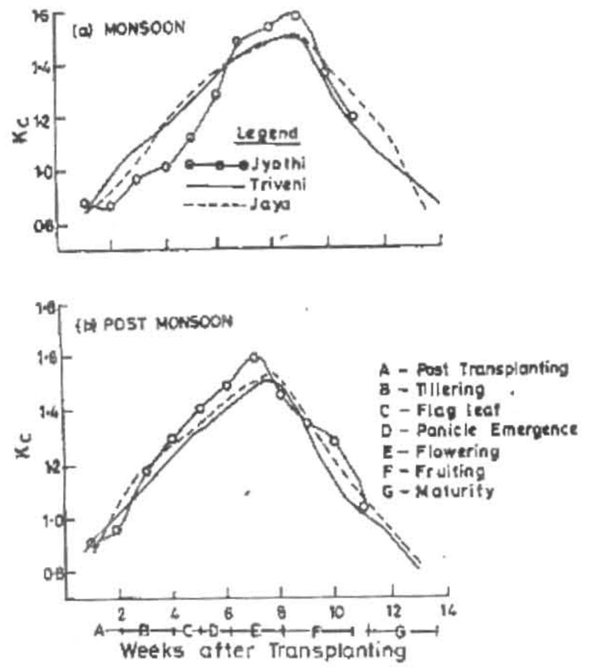

Fig. 1. Distribution of crop coefficient K_C in different phases

after planting (WAP) in post-monsoon, while it is 7 WAP in monsoon season. K_C for *Jaya* [Fig. 1(b)] during the two crop seasons shows identical pattern as in *Triveni*. Both *Triveni* and *Jaya* attain peak K_C (of about 1.5) in both the seasons, but for *Jyothi* it is 1.6 in both seasons. Tomer and O' Toole (1979) found the ratio of ET to pan evaporation as 1.5 for wet land rice in Pantnagar (India).

Mean values of rainfall from transplanting to harvest, water use (ET) etc. for the varieties are given in Table 1. It may be seen that *Triveni* needs about 9% less water in monsoon for maturity than in post-monsoon while *Jaya*, about 6% less. Year to year variability in consumptive use for each variety was also observed.

Because of the difference in genetic composition, one may be tempted to assume that each variety may have water requirement different from the other. This observation has also been made in the present analysis. The traditional variety *Triveni* uses less water in any season than the hybrid *Jaya*. The total consumptive use of paddy in monsoon for *Triveni* variety varies from about 360 to 600 mm with a mean of 440 mm while during post-monsoon, the consumptive use varied from 310 to 570 mm with a mean of nearly 475 mm. For *Jyothi* variety total consumptive use is rather high and varies from 555 to 700 mm with a mean of 625 mm in monsoon season and varies from 670 to 880 mm with a mean 775 mm in post-monsoon. In case of *Jaya*, the mean values of total consumptive use are about 480 mm and 500 mm during monsoon and post-monsoon seasons respectively. These values compare favourably with total ET found by Nakagawa (1966), Vamadevan and Dastane (1968), IRRI (1969), Das *et al.*, (1995) etc. *Triveni* in the mean consumes nearly 8% more water during post-monsoon season than in monsoon. Total monsoon crop season rainfall is twice the ET for *Triveni* and nearly thrice the ET in case of *Jaya* and *Jyothi* variety. In post-monsoon season the rainfall is nearly half of ET for all three varieties. The mean weekly evapotranspiration rates (Table 1), is more in post-monsoon than in monsoon for all varieties.

During both monsoon and post-monsoon seasons, the water use efficiency (WUE) for *Jyothi* is less than that of *Triveni* and *Jaya* varieties. *Triveni* generally uses water more efficiently in monsoon than in post-monsoon. For *Jaya*, WUE is found to be the same during both the seasons, the value being 7.3 kg/ha, For *Jyothi* WUE is slightly more in monsoon than in post-monsoon. Solar energy, among the three varieties, is used most efficiently by *Jyothi* in both the crop seasons and is 3.4 and 2.9 kg/ha/MJ/m^2 respectively in the monsoon and the post-monsoon. Radiation use efficiency (RUE) is slightly more in the monsoon than in post-monsoon season for *Triveni* and *Jyothi* varieties, whereas it is reversed in the case of *Jaya*. Thus for any season from RUE point of view *Jyothi* is best suited at Pattambi whereas from WUE consideration *Jaya* appears ideal.

3.2. *Effect of transplanting dates on yield*

A crop has to complete its growth cycle within a period of favorable weather. As a result, time of transplanting largely determine the crop yield. In rain fed low lands of Kerala, rice is either directly seeded before onset of monsoon or transplanted in shallow depths soon after onset of monsoon. As transplanting is most common practice, date of onset of monsoon is naturally crucial for realizing the yield potential of any variety. During monsoon season, rice is transplanted depending on the advance of monsoon rains over the area. Joseph (1991), from an experiment of rice varieties planted at different dates at Pattambi found maximum yield from seedlings planted on 10 August. In Gangetic plains, Pande and Agarwal (1991) found that rice grain yield was more when planted during last week of July. Jensen *et al.* (1993) recommended 14 August as transplanting date for wet east Bangladesh for Aman rice.

Following the method detailed in section 2 above, optimum dates for *Triveni*, *Jaya* for both seasons have been determined and discussed below. This analysis could not be applied to *Jyothi*, as the sample size was small.

TABLE 1

Mean values of yield rainfall, evapotranspiration, water use efficiency (WUE) radiation and radiation use efficiency

Variety	Crop duration (weeks)	Crop season	Yield (kg/ha)	Rainfall (mm)	Total ET (mm)	Mean ET (mm/week)	W.U.E (kg/ha/mm)	Radiation (MJ/m^2)	R.U.E ($kg/ha/MJ/m^2$)
Triveni	13	Monsoon	2759	1096.4	439.1	33.8	6.3	1632	1.7
Jaya	14	do	3487	1539.4	477.6	34.1	7.3	1826	1.9
Jyothi	18	do	3067	2087.4	626.4	34.8	4.9	908	3.4
Triveni	11	Post monsoon	2114	230.0	474.1	43.1	4.5	1663	1.3
Jaya	12	do	3658	253.1	501.4	41.8	7.3	1729	2.1
Jyothi	17	do	3125	467.8	773.1	48.3	4.0	1065	2.9

Monsoon season

Triveni : $Y = 2491.3+603.2\,X-77.9\,X^2+0.4\,X^3$, r=0.86 (1)

Jaya : $Y = 3495.1+197.4\,X-19.3\,X^2+0.4\,X^3$, r=0.75 (2)

Post-monsoon season

Triveni : $Y = 3243.1+61.9\,X-29.5\,X^2-0.8\,X^3$, r=0.90 (3)

Jaya : $Y = 3542.7+92.8X-16.9\,X^2$, r=0.69 (4)

The correlation coefficients were all statistically significant at 1% level except for *Jaya* variety in post-monsoon season, which was significant at 5% level. The high correlation in the above equations clearly brings out the non-linear nature of response of rice yield to varying dates of transplanting.

The optimum date for realizing full production potential and yield expected for two seasons are given in Table 2. During the monsoon for optimal performance, the ideal date for transplanting at Pattambi appears to be 8th June for *Triveni* and 9th June for *Jaya*. Reddy and Reddy (1991) were of the view that rice yield at Warangal (17° 58 N, 79° 28 E) in the Deccan Plateau of India increases with the delay in planting. Sharma and Reddy (1991) found that long duration photosensitive rice varieties flowering by mid-November are suitable for the late planting under shallow rainfed conditions. Mathematically, it appears that after the establishment of monsoon on 1st June, transplanting of *Triveni* variety on 8th June could fetch 3700 kg/ha. Transplanting of *Jaya* variety a day later *i.e.* on 9th June could give a yield of about 4000 kg/ha. For the post-monsoon season, dates for these two varieties respectively are 15th October and 20th October, the corresponding yields being 3300 and 3700 kg/ha. Potential for maximizing yield probably exists for both varieties in monsoon season rather than post-monsoon season when the tillering and anthesis phases coincide with rising temperature trend leading to reduced spikelets, shriveling of grains and reduction in yield.

3.3. *Assessment of rice yield*

Economic benefits accrued from pre-harvest prediction of crop yield has been pointed by Baier (1977). This is more important for developing countries where receipt of relevant information is rather slow while the yield sample method normally practiced in these countries is not generally adequate (Lomas and Herrara, 1985). Rice yield shows significant variations with regards to different weather parameters in various phytophases. Ultimate yield is a product of interaction of meteorological factors and growth phase. As such for a specific variety, differential response to meteorological factors for a given season as well as among the two crop seasons seems normal.

Subjecting the 6 phenological phases and the 4 weather parameters (Appendix A) to the multiple correlation and regression analysis, effect of a weather parameter during any phase has been determined, provided it is statistically significant. The regression equations are given below :

Rice yield prediction models

Monsoon season

Triveni

$$Y = 4580.9 + 9.3 X_1 \text{ (b)} + 1.8 X_1 \text{ (a)} - 97.1 X_2 \text{ (b)} - 4.4 X_4 \text{ (f)}$$

Jaya

$$Y = -2723.7 + 74.2 X_1 \text{ (a)} + 0.2 X_1 \text{ (c)} - 754.9 X_2 \text{ (e)} + 458.6 X_2 \text{ (f)} + 383.2 X_3 \text{ (c)}$$

Post-monsoon season

Triveni

$$Y = 48909.5 - 1356.1 X_2 \text{(c)} + 352.5 X_2 \text{(d)} - 251.4 X_3 \text{(a)} - 117.0 X_4 \text{(b)}$$

Jaya

$$Y = -87735.6 - 13.5 X_2 \text{ (a)} + 119.2 X_2 \text{ (b)} + 116.5 X_3 \text{ (a)} + 105.9 X_4 \text{ (a)}$$

Not only the individual parameters but the F values were found significant at 5% level. The analysis does not include *Jyothi* variety, as its data set was rather small.

3.3.1. *The regression model*

(a) *Triveni*

(*i*) *Monsoon*

High correlation with rainfall is observed during tillering phase which, perhaps suggests that in this phase, more rainfall is needed. Short duration but little rainfall during maturity also helps *Triveni* yield. High maximum temperature during tillering is observed to have depressing effect on yield. High humidity during maturity stage may lead to pest outbreak and could bring the yield down.

(*ii*) *Post-monsoon*

Crops during post-monsoon or winter season are mostly raised on stored moisture and/or supplemental irrigation, as rainfall during this season is mostly absent or very low in quantum. Overall growth of a plant is the product of growth duration and growth rate. As growth duration is more affected by temperature, a high temperature during winter usually results in depressed growth and hence reduction in grain yield (Kakde, 1985). As such persistent high maximum temperature during flag leaf in post-monsoon season affects growth and crop yield adversely. However, during panicle emergence, *Triveni* needs clear skies and high day temperature. Nishiyima (1976) observed that initial temperature for panicle differentiation is about 15-18°C. High minimum temperature in the post-transplanting phase causes a drain on the energy also adversely affect this variety. This unfavourable condition causes high tiller mortality, spikelet sterility and impairs total dry matter production and the yield. High relative humidity during early tillering also has lethal influence as it leads to higher sterility.

TABLE 2

Optimum date of planting and maximum possible corresponding yield

Variety	Monsoon		Post-monsoon	
	Date	Yield (kg/ha)	Date	Yield (kg/ha)
Triveni	8 th Jun	3683	15 th Oct	3267
Jaya	9 th Jun	3987	20 th Oct	3687

(b) *Jaya*

(*i*) *Monsoon*

Jaya variety also needs more rainfall after transplanting and during flag leaf stage like *Triveni* grown in the monsoon season. High maximum temperature during fruiting leads to fall in yield in the photo-sensitive *Jaya* variety. However, clear skies, which give somewhat higher day temperature, are needed during maturity. During the flag leaf stage, high minimum temperature appears favorable for productivity.

(*ii*) *Post-monsoon*

Immediately after transplanting, a high relative humidity helps in better growth and ultimately leads to increased yield of the *Jaya* variety cultivated during winter. A large maximum temperature immediately after transplanting and during tillering, as in the case with *Triveni* brings yield down by causing higher tiller

TABLE 3

Path coefficients

(a) Triveni (Monsoon)

	Y	X_1 (a)	X_1(b)	X_1 (f)	X_2 (b)	X_4 (f)
Y	1	0.42	0.84**	-0.14	-0.11	0.65*
X_1 (a)		1	0.27	-0.32	-0.55	-0.07
X_1 (b)			1	-0.58*	-0.02	-0.80**
X_1 (f)				1	0.31	-0.41
X_2 (b)					1	-0.10
X_4 (f)						1

(b) Jaya (Monsoon)

	Y	X_1 (a)	X_1(c)	X_2 (e)	X_2 (f)	X_3 (c)
Y	1	0.55	0.68*	-0.34	0.46	0.49
X_1 (a)		1	-0.17	-0.32	0.07	0.20
X_1 (c)			1	0.21	0.57*	-0.41
X_2 (e)				1	0.45	0.27
X_2 (f)					1	0.33
X_3 (c)						1

(c) Triveni (Post-monsoon)

	Y	X_2 (c)	X_2(d)	X_3 (a)	X_4 (b)
Y	1	-0.20	0.26	-0.70**	0.68**
$X2$ (c)		1	0.93	-0.26	-0.36
$X2$ (d)			1	-0.13	-0.23
$X3$ (a)				1	0.55
$X4$ (b)					1

(d) Jaya (Post-monsoon)

	Y	X_2 (a)	X_2(b)	X_3(a)	X_3(b)	X_4 (a)
Y	1	-0.57	0.08	-0.16	-0.26	0.73**
X_2 (a)		1	0.10	0.16	0.01	-0.72
X_2 (b)			1	-0.16	-0.13	-0.26
X_3 (a)				1	0.20	-0.27
X_3 (b)					1	0.01
X_4 (a)						1

* Significant at 5% level ** Significant at 1% level

mortality. Large minimum temperature and high humidity in post-transplanting stage may, on the other hand, have some positive influence.

The multiple correlation in all cases except *Jaya* (post-monsoon) exceeds 0.90 and are significant at 1% level. In case of *Jaya* (post-monsoon), the correlation is rather less *i.e.* 0.83 which, however, is significant at 5% level. The results presented above suggest that early assessment and prediction service for rice is possible from the models.

3.4. *Path analysis*

Those independent weather parameters which bore large linear correlation with yield in the above analysis, were then subjected to "Path analysis". A brief description on path analysis is given in section 2. Results of the analysis are given in Table 3. For the want of space, for each variety, for each crop season a case each, has been discussed below.

(a) *Triveni*

(*i*) *Monsoon*

Rainfall during tillering bear correlation of 0.84 (significant at 1% level) with yield.

Direct effect of rainfall in tillering stage	1.19
Indirect effect *via* rainfall during maturity	- 0.38
Indirect effect *via* rainfall during initial stage of tillering	0.06
Indirect effect *via* maximum temperature during initial stage of tillering	0.04
Indirect effect in relative humidity during early maturity	-0.03
	0.84

Thus, it is seen that when the correlation coefficients are partitioned into components, rainfall during tillering directly influences the yield; rainfall during maturity contributes indirectly *via* rainfall in tillering to some extent but other factors hardly affect indirectly through their interaction with the rainfall in tillering and contribute to the high correlation corresponding with yield.

(*ii*) *Post-monsoon*

The yield is found to be significantly correlated (r = − 0.70) with minimum temperature in post-transplanting stage (significant at 1% level).

Direct effect of relative humidity in tillering	−0.62
Indirect effect *via* minimum temperature in early tillering	0.30
Indirect effect via maximum temperature in flag leaf stage	−0.32
Indirect effect via maximum temperature in panicle emergence phase	−0.06
	−0.70

In this case, the yield is directly affected by the minimum temperature to a very large extent, but indirect effect of minimum temperature *via* relative humidity and maximum temperatures during flag leaf stage are also substantial.

(b) *Jaya*

(*i*) *Monsoon*

Rainfall during maturity bears a large correlation of $r = -0.68$.

The direct influence of this rainfall on yield and indirect effect of other selected parameters *via* rainfall is clear from the following Table.

Direct effect of rainfall on yield	0.04
Indirect effect of rainfall *via* minimum temperature in early post-transplanting phase	–0.03
Indirect effect *via* maximum temperature in fruiting stage	–0.14
Indirect effect *via* maximum temperature in late maturity stage	–0.37
Indirect effect *via* minimum temperature in flag leaf stage	–0.18
	–0.68

Although rainfall during maturity bears a high correlation with yield, its direct influence on the latter is minimal ($r = 0.04$). Most of its effect on yield is indirect, through interaction with other parameters. Thus, in association with maximum temperature in late maturity stage, minimum temperature in flag leaf stage and maximum temperature in fruiting stage, the influence of rainfall during maturity on yield are –0.37, –0.18 and 0.14 respectively.

(*ii*) *Post-monsoon*

Relative humidity during initial post-transplanting had highly significant ($r = 0.73$) correlation with yield. The partitioning of the effect of relative humidity into direct and indirect components is shown below:

Direct effect of humidity on yield	0.84
Indirect effect of humidity on yield *via* maximum temperature in initial post-transplanting stage	0.01
Indirect effect *via* maximum temperature in tillering stage	–0.08
Indirect effect *via* minimum temperature in initial post-transplanting phase	–0.05
Indirect effect *via* minimum temperature in flag leaf stage	0.00
	0.73

Obviously, relative humidity directly affects the *Jaya* yield, in post-monsoon season but its indirect effect, in interaction with other factors are negligibly small and insignificant.

4. Conclusions

The following conclusions could be drawn from the analysis:

(*i*) In spite of shorter phenological duration, the post-monsoon rice use more water than that in the monsoon season. The photo-insensitive *Jaya* variety needs more moisture than *Triveni* and *Jyothi* varieties and also uses water more efficiently.

(*ii*) For an optimum monsoon season production, Triveni and Jaya cultivars should be transplanted in first week of June. In post-monsoon season both these varieties could give highest yield when transplanted in second and third week of October respectively.

(*iii*) Rainfall during tillering and flag leaf in the monsoon season helps increasing paddy yield. During monsoon, high maximum temperatures during tillering (for *Triveni*) and during fruiting on photo- insensitive *Jaya* variety exert negative effect.

(*iv*) In the post-monsoon season, high maximum temperature during the post-transplanting and tillering phase probably result in higher and tiller mortality and hence has adverse impact on *Jaya*. High day temperature also exerts negative impact on flag leaf stage of *Triveni*.

(*v*) Rainfall during tillering on the monsoon directly influence the *Triveni* yield while relative humidity directly affects the yield in post-monsoon season through its indirect effect *via* temperature in the flag leaf phase is also significant in this variety.

(*vi*) During monsoon, rainfall indirectly affects *Jaya* variety *via* maximum temperature (during fruiting and maturity) and minimum temperature (during flag leaf). In the post-monsoon, relative humidity in the post-transplanting stage mostly directly contributes to the yield.

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