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Research Article

Growth, Yield and Radiation Interception of Rice under Conservation Agriculture Practices

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ABSTRACT

Conservation agriculture has multiple benefits. Research on this aspect may be emphasized; awareness among the farmers to be created and large scale adoption can be promoted. A study was conducted on rice (cultivar Pusa Sugandh 5) under rice-wheat cropping system at IARI farm, New Delhi, during the *kharif* season of 2017 with conventional (transplanted rice in puddled field) and conservation agriculture (including zero tillage and residue incorporation) treatments. Observations on plant growth parameters like LAI, biomass, yield and yield attributes were recorded. Weather parameters were collected from a nearby agrometeorological observatory and micrometeorological parameters like IPAR were recorded at regular intervals. The growth index, like harvest index and meteorological indices like fIPAR, TIPAR and GDD were computed. In the crop-weather relationship study, it was found that higher leaf area index (LAI) in conventional treatment intercepted more PAR and produced more biomass and grain yield. Among the conservation agriculture treatments, zero-tilled rice crop with legume (mung bean) residue incorporation performed better than other treatments.

Key words: Conservation agriculture, rice, radiation interception, growth, yield

Introduction

Conservation agriculture (CA) may be defined as an agricultural crop production system that is aimed at saving resources, while at the same time strives to achieve profits as well as improving the production level and conserving the environment. The three guiding principles of CA are continuous minimum disturbance to the soil, having a permanent organic soil cover through crop residue retention and practicing crop rotations (FAO, 2011). CA began around 1935 as a result of the dust bowl in the USA. The main aim was to maintain at least 30% of soil cover by crop residue in order to protect the soil from wind erosion. Zero tillage began in Brazil in the 1970's in order to control water erosion of soil (Derpsch, 2001). CA is continuing to be adopted as a resource-saving agricultural system which enhances soil fertility and benefit farmers economically. Farmers are adopting CA due to its ability to achieve higher yields, reduce the cost of production, save labour and ultimately increase farm income. The main focus of CA is

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Table 1. Treatment details

Treatments	*Kharif* (Rainy Season)	*Rabi* (Winter)	*Zaid* (Summer)
T_1	ZTDSR	ZTW	Fallow
T_2	WR+ZTDSR	RR+ZTW	Fallow
T_3	ZTDSR	ZTW	ZTSMB
T_4	MBR+ZTDSR	RR+ZTW	WR+ZTSMB
T_5	TPR	CTW	Fallow

ZTDSR - Zero Tillage Direct Seeded Rice
ZTW - Zero Tillage Wheat
RR - Rice Residue
TPR - Transplanted Rice
CTW - Conventional Tillage Wheat
WR - Wheat Residue
ZTSMB - Zero Tillage Summer Mung Bean
MBR - Mung Bean Residue

the soil, not only the nutrient status but also the biological and structural components as well. The outcome of CA is a healthy, well-functioning agro-ecosystem. CA provides the opportunity for an undisturbed soil to support healthier plants. An undisturbed soil will also maintain its structural integrity by not destroying the vertical macro-pores which aid in the percolation of water into the profile. Weed seeds within the soil are also prevented from germinating when the soil remains undisturbed. Apart from having an undisturbed soil cover, there is also need for protection of the soil from wind, rain and sun. A permanent organic soil cover can be achieved through retention of crop residue which will provide a healthy source of organic matter to enhance soil fertility. Soil cover also helps to suppress the germination of weeds while at the same time providing suitable habitat for beneficial insects and food source for soil organisms. The final aspect of CA is having a proper crop rotation system that enables sustainable management. Crop rotation helps in controlling weeds and pest problems by breaking their life cycles. These rotations also facilitate crops that explore the soil nutrients differently due to their different rooting habits. This practice ensures efficient use of the soil nutrients. Therefore, the combination of these techniques can lead to sustainable system of resource-saving agriculture while at the same being productive and profitable. CA has also demonstrated benefits in the fight against global warming. Researchers have shown that CA has the ability to increase carbon sequestration in the soil (Grace *et al*., 2003; Derpsch, 2003). On an average, CA has the ability to capture organic carbon at a rate of half ton/ha/year.

The first author was a student from Guyana, South America. At present, he is a scientist at Guyana Rice Development Board. While conservation agriculture (CA) is gaining popularity in India and other parts of the world, farmers in Guyana are yet to adopt this practice. CA may also be very helpful to Guyana's agricultural sector in terms of savings on input and labour costs. This study therefore aims at exploring the relationship between the growth and yield of rice and radiation interception and to identify the best conservation agriculture practice for rice cultivation.

Materials and Methods

Field experiment

The field experiment was conducted at IARI farm, New Delhi (28°37′N latitude, 77°12′E longitude and 228.6 m above mean sea level) during the *kharif* season of 2017 on a sandy clay loam soil with the rice cultivar Pusa Sugandh 5 in a randomized block design layout of five treatments (four CA practices and one conventional practice) of four replications each (Table 1). Date of sowing for all treatments was 24 June, 2017, and date of transplanting for conventional practice was 20 July, 2017. Recommended doses of N, P and K fertilizer were applied. Standard agronomic practices were followed in terms of weed control, irrigation and pest control. Daily weather data were collected from the Agrometeorological Observatory of the Division of Agricultural Physics, IARI, New Delhi, situated nearby the experimental plot.

Crop-weather relationship

Crop phenology was closely monitored by observing the plants during field visits twice weekly. Crop growth parameters were recorded at regular intervals during the duration of the cropping period. Plant height was measured every thirty days interval while leaf area index, LAI (using LAI-2000 plant canopy analyzer) was recorded at fifteen days interval. Above-ground biomass was also measured at thirty days interval. Yield attributes (tillers population, panicle properties, fertility percentage and grain weight) were recorded during the duration of the cropping period. Yield data (straw yield, grain yield and harvest index) was collected at the time of harvesting.

Calculation of thermal time in terms growing degree days (GDD) was done for each phenological stage using the method:

$$GDD = \Sigma(T_{mean} - T_b)$$

Where,

GDD is the cumulative value any phenological stage

$T_{mean} = (T_{min} + T_{max}) / 2$ of that day

T_b = Base temperature of rice

Micrometeorological parameters (intercepted photosynthetically active radiation, IPAR and fractional IPAR, fIPAR) were recorded (using the line quantum sensor, LICOR-3000, USA) for the various treatments.

$$IPAR = I_o - I_t$$

$$fIPAR = (I_o - I_t) / I_o$$

Where,

I_o = Incident PAR at the top of the canopy

I_t = Transmitted PAR at the bottom of the canopy

Radiation use efficiency (RUE) was computed with the use of the data collected.

$$(H/H_o) = a + b\ (n/N)$$

Where,

H = Average daily global solar radiation (MJ m^{-2} day^{-1})

H_o = Average daily extraterrestrial solar radiation on a horizontal surface (MJ m^{-2} day^{-1}) at a particular latitude

a & b = Regression constants for the measurement site

n = Daily bright sunshine hours (BSS)

N = Average daily maximum possible sunshine hours from monthly values

Regression analysis was performed on the data using statistical analysis software (SAS) program in order to establish the relationship weather and growth and yield of rice.

Results and Discussion

It was noted that the conventional treatment (T_5) achieved the various phenological stages earlier than the CA practices (Table 2). This occurrence therefore resulted in T_5 requiring less accumulated GDD as compared to the four CA practices. For 50% flowering T_5 required the least accumulated GDD (1496 days ^oC) while T_2 required the most accumulated GDD (1636 days ^oC). For the achievement of physiological maturity, T_5 required the least accumulated GDD (2134 days ^oC) while T_2 required the most the most accumulated GDD (2198 days ^oC). High residue retention reported to delay the phenological development in rice by retaining soil moisture and supporting vegetative growth for longer time (Devkota, 2013). The zero-tilled and residue incorporated conservation treatment probably conserved moisture and enhanced vegetative growth.

Positive correlations were observed in all treatments for the relationship between LAI and fIPAR (Table 3). For every unit increase in LAI, fIPAR is expected to increase in the range of 0.15 (T_2) and 0.24 (T_5) units. The coefficient of determination (R^2) values ranged between 0.86 (T_2) and 0.92 (T_5). Higher LAI among these

Table 2. Thermal time requirement of rice cultivar Pusa Sugandh 5 as influenced by different treatments during *kharif* season 2017

Crop Stages	Growing Degree Days (GDD) (day °C)				
	T_1	T_2	T_3	T_4	T_5
Seedling Stage	207	187	187	207	169
Tillering Stage	518	538	538	518	497
Panicle Initiation	1069	1091	1069	1048	1028
Booting Stage	1289	1348	1309	1289	1252
Heading Stage	1439	1458	1439	1439	1419
Flowering (50%)	1575	1636	1554	1534	1496
Milking Stage	1677	1695	1677	1636	1616
Dough Stage	1927	1945	1927	1909	1872
Physiological Maturity	2166	2198	2182	2166	2134
Harvest Maturity	2228	2228	2228	2228	2228

T_1 - ZTDSR-ZTW
T_2 - WR+ZTDSR-RR+ZTW
T_3 - ZTDSR-ZTW-ZTSMB
T_4 - MBR+ZT DSR-RR+ZTW-WR+ZTSMB
T_5 - TPR-CTW-SMB

Table 3. Relationship between LAI and fIPAR in rice cultivar Pusa Sugandh 5 as influenced by different treatments during *kharif* season, 2017

Treatments	Equation	R^2
T_1	$y = 0.2556\ln(x) + 0.5273$	0.89
T_2	$y = 0.1992\ln(x) + 0.4507$	0.86
T_3	$y = 0.2236\ln(x) + 0.4701$	0.88
T_4	$y = 0.2219\ln(x) + 0.5417$	0.89
T_5	$y = 0.2168\ln(x) + 0.5323$	0.92

Treatment details given in Table 2

treatments led to higher PAR interception. A positive linear relationship between fIPAR and LAI was found by Zhou *et al*. (2002) in maize. The differences in fIPAR can also be explained by solar radiation (PAR) penetration and distribution within the canopy of the crop. Initially fIPAR increased with increasing LAI and after the onset of senescence, when LAI substantially diminished, fIPAR slightly declined (Fig. 1).

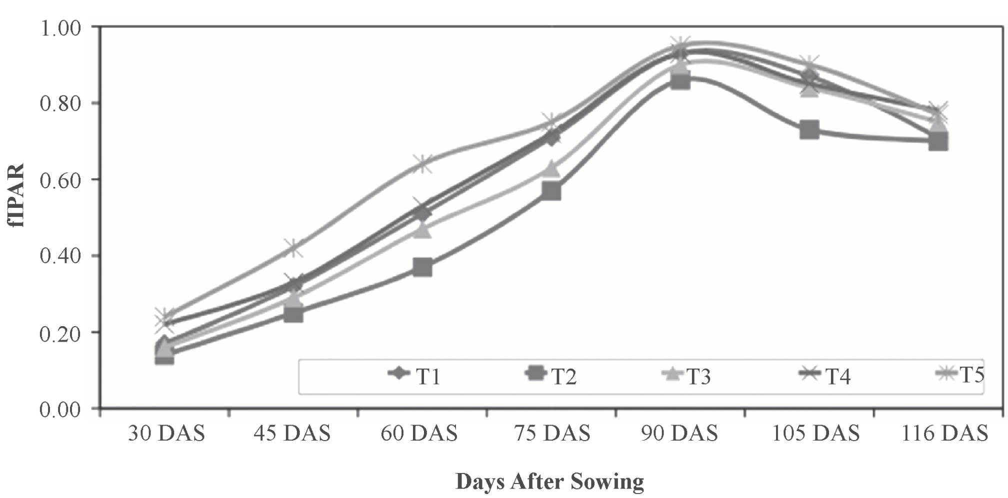

Fig. 1. Effect of different treatments on fIPAR of rice cultivar Pusa Sugandh 5 at different DAS during *kharif* season, 2017

Table 4. Relationship between fIPAR and biomass in rice cultivar Pusa Sugandh 5 as influenced by different treatments during *kharif* season, 2017

Treatments	Equation	R^2
T_1	y = 1283.5x - 192.69	0.84
T_2	y = 1297.1x - 150.25	0.79
T_3	y = 1259.1x - 188.86	0.79
T_4	y = 1515.7x - 308.18	0.87
T_5	y = 1624.1x - 380.28	0.81

Values followed by same letter do not differ significantly by DMRT

Treatment details given in Table 2

Results for fIPAR and final biomass also indicated positive correlation for all treatments (Table 4). For every unit increase in fIPAR, biomass is expected to increase in the range of 1070 g m^{-2} (T_3) and 1244 g m^{-2} (T_5) units. The coefficient of determination (R^2) values ranged between 0.79 (T_2 and T_3) and 0.87 (T_4). More LAI led to more PAR interception which resulted in more biomass accumulation. A positive linear relationship was found between fIPAR and biomass accumulation in this study.

There were statistical differences in RUE among the treatments (Table 5). T_5 showed the highest RUE value (2.35 g MJ^{-1}) while T_2 and T_3 showed the lowest value (2.15 g MJ^{-1}). According to Monteith (1977), crop growth (biomass) could be determined as the time integral of PAR, fIPAR and RUE. In the present study also it was found that T_5 had higher biomass and subsequently higher RUE.

Table 5. Final biomass, total IPAR (TIPAR) and radiation use efficiency (RUE) of rice cultivar Pusa Sugandh 5 as influenced by different treatments during *kharif* season, 2017

Treatments	Biomass (g m^{-2})	TIPAR (MJm^{-2})	RUE (g/MJ)
T_1	967^{C}	445^{C}	2.17^{C}
T_2	922^{E}	429^{D}	2.15^{C}
T_3	941^{D}	438^{CD}	2.15^{C}
T_4	1121^{B}	498^{B}	2.26^{B}
T_5	1216^{A}	517^{A}	2.35^{A}
LSD at 5%	6.8	14.0	0.07

Values followed by same letter do not differ significantly by DMRT

Treatment details given in Table 2

Conclusion

Higher LAI in rice leads to higher interception of PAR which in turn produces more biomass, for which conventional practice was found to be superior to conservation agriculture practices.

Among the conservation agriculture practices, legume (mung bean) residue-incorporated treatment was found to be the best with respect to crop growth as well as for radiation interception. Maximum harvest index was observed in T_2 and T_4 treatments which were incorporated with wheat and mung bean residues respectively.

It can be concluded that the conventional practice of rice is still superior to conservation practices in rice-wheat cropping system in terms of yield. But the conservation agriculture with direct seeding and legume residue incorporation also performed well and can be adopted in India and other developing countries in great scale for its multiple benefits.

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