Journal of Agrometeorology

ISSN : 0972-1665 (print), 2583-2980 (online)
Vol No. 24(2) : 192-195 (June 2022)

https://journal.agrimetassociation.org/index.php/jam

Short Communication

Evaluating the influence of conservation agricultural practices and fertilizer on PAR use efficiency and biophysical parameters of maize grown under new alluvial zone of West Bengal

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Conservation agriculture (CA) can be adopted as a resource saving management practice which aims to achieve acceptable profits with high and sustainable productivity in long run (FAO, 2014).CA relies on three linked principles, namely, minimum soil disturbance, permanent soil cover and diversified crop rotation (FAO, 2014). CA practices such as zero tillage (ZT) and reduced tillage (RT)can modify microclimates in the crop fields and influence soil water regimes, nutrient uptake and ultimately crop yield. The crop growth rate mainly depends on the ability of crop canopy to intercept the incident photosynthetically active radiation (PAR) and conversion efficiency of the energy captured by the plant into new biomass (Kar and Kumar, 2016). The PAR utilization is also influenced by levels of fertilizer application and available soil moisture. Much work has been done on effects of tillage, residue and nitrogen on soil physical, chemical and biological properties vis-à-vis crop growth. However, studies on the effects of tillage, residue and nitrogen towards microclimatic modification and PAR use efficiency (PARUE) were carried out to lesser extent. Considering the fact, the present research work aims to study the PAR interception pattern, absorbed PAR and PARUE of *Rabi* maize grown under different conservation agricultural practices in the new alluvial zone of West Bengal.

The field experiment was conducted on maize (cultivar PAC 751) during *Rabi* season of 2018-2019 at the Balindi Farm, Bidhan Chandra Krishi Viswavidyalaya, West Bengal (22º96' N latitude and 88º53' E longitude). The experimental site falls under the subtropical zone with a mean annual rainfall of 1467.5mm. The surface soil (0-15cm) is clay loam in structure with a pH of 7.7 (1:2.5 soil water suspension). The experiment was carried out in split plot design with three levels of tillage i.e., conventional tillage (CT), zero tillage (ZT) and reduced tillage (RT) as a main plot factor and crop residue mulching and fertilizer as sub plot factor [NR-1= '0% rice residue mulching + 100% recommended dose of fertilizer' (RDF) and NR-2= '100% rice residue mulching (6.3 t ha^{-1}) + 50% RDF']. 140:70:70 kg per ha N:P:K was taken as 100% RDF. Thus, there were six treatments in total with three replications each and size of sub plot was 7.2 m × 6.6 m. Plant to plant distance was 20 cm and the seed rate was 20 kg ha^{-1}.

Seven phenological stages were considered in the present study, namely, early vegetative stage (P1), late vegetative stage (P2), tasseling (P3), silking (P4), milking (P5), dough (P6), 100% maturity (P7). Data on micro meteorological parameters, namely, PAR, Canopy Temperature, and plant samples (g/plant) were collected covering all the growth stages along with Leaf Area Index. A Line Quantum Sensor (Model: APOGEE/MQ-301) was used to measure different components of PAR, such as incident PAR, transmitted PAR, reflected PAR from crop and soil. The intercepted PAR (IPAR) by the crop were calculated using the following equations (Gallow and Daughtry, 1986).

IPAR = Incident PAR – Transmitted PAR………… (Eq 1)

Reflected PAR percentage from canopy (R_C PAR percentage) was determined by using the following equation:

R_C PAR= (PAR reflected from crop canopy /Incident PAR) ×100%….…. (Eq 2)

Reflected PAR percentage from soil (R_S PAR percentage) was determined by using the following equation:

R_S PAR= (PAR reflected from soil /Incident PAR) ×100%…(Eq 3).

Similarly, Absorbed PAR (APAR) was worked out by

Article info - DOI: *https://doi.org/10.54386/jam.v24i2.1548*
Received: 26 April 2021; Accepted: 6 March 2022; Published online: 28 May 2022
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Table 1: Yield and yield attributes of maize as influenced by tillage, residue and nitrogen management

Treatments		LAI			Yield Components			
		30 DAS	60 DAS	90 DAS	Grain Yield (t ha^{-1})	Biomass Yield (t ha^{-1})	No. of cobs per sq.-m	No. of grains/ cob
Tillage	Conventional (C)	0.50^{C}	2.44^{C}	2.24^{C}	9.46^{C}	6.22^{B}	8.5^{B}	429.33^{C}
	Zero (Z)	0.72^{B}	3.34^{B}	3.07^{B}	11.84^{B}	11.57^{A}	9.5^{AB}	562.44^{B}
	Reduce (R)	0.87^{A}	3.85^{A}	3.63^{A}	13.10^{A}	11.87^{A}	10.67^{A}	589.36^{A}
	Significance	***	***	***	***	***	*	***
Residue and Nutrient (NR)	NR1	0.77^{A}	3.45^{A}	3.17^{A}	13.51^{A}	10.75^{A}	10.77^{A}	577.42^{A}
	NR2	0.62^{B}	2.96^{B}	2.68^{B}	9.41^{B}	9.02^{B}	8.3^{B}	476.67^{B}
	Significance	***	***	***	***	***	*	***
Interactions (Tillage ×NR)	CNR1	0.52^{E}	2.65^{D}	2.44^{D}	10.40^{D}	6.30^{D}	9.33^{AB}	483.00^{C}
	CNR2	0.48^{F}	2.23^{E}	2.04^{E}	8.52^{F}	6.14^{D}	7.66^{B}	375.67^{D}
	ZNR1	0.82^{B}	3.41^{B}	3.21^{B}	14.83^{B}	12.97^{A}	10.66^{AB}	607.11^{A}
	ZNR2	0.63^{D}	3.26^{C}	2.99^{C}	8.85^{E}	10.18^{C}	8.33^{B}	517.8^{BC}
	RNR1	0.98^{A}	4.29^{A}	3.93^{A}	15.32^{A}	12.99^{A}	12.33^{A}	642.17^{A}
	RNR2	0.76^{C}	3.40^{B}	3.12^{BC}	10.89^{C}	10.75^{B}	9^{B}	536.56^{B}
	Significance	***	***	**	***	***	NS	***

(“***” Significant at P< 0.001% probability level, “**” Significant at P< 0.01% probability level, “*” Significant at P< 0.01% probability level, NS = non-significant. The values in the column followed by same letters are not significantly different. CT = Conventional tillage, ZT = Zero tillage, RT = Reduced tillage, NR = Nutrient + Residue)

Table 2: Relationship between accumulated biomass (Acc.BM) and IPAR of maize and radiation use efficiency under different conservation agricultural practices

SI NO.	Treatments	Equation	PARUE (g MJ^{-1})
1	CNR1	Acc BM = 2.81 Acc IPAR + 35.47	2.81
2	CNR2	Acc BM = 2.25 Acc IPAR + 52.80	2.25
3	ZNR1	Acc BM = 3.38 Acc IPAR + 90.59	3.38
4	ZNR2	Acc BM = 2.67 Acc IPAR + 73.65	2.67
5	RNR1	Acc BM = 3.80 Acc IPAR + 57.42	3.80
6	RNR2	Acc BM = 3.08 Acc IPAR + 43.28	3.08

(Here, C = conventional tillage, Z= zero tillage, R=reduced tillage, NR-1= 0% residue+100% RDF and NR-2= 100% residue + 50% RDF)

adopting the equation:

$$APAR = [(\text{Incident PAR} - R_C\ \text{PAR} - \text{Transmitted PAR} + R_s\ \text{PAR})] \quad \text{.........(Eq 4)}$$

PARUE is defined as the ratio of accumulated crop mass (i.e., dry matter) to cumulative intercepted solar radiation. It is a key factor in the determination of the photosynthetic performance of plants growing in any environment (Oluwasemire and Odugbenro, 2014). PARUE was calculated by regressing dry matter accumulation against intercepted PAR and was expressed in g MJ^{-1} unit. Significance of treatment differences in yield attributes and yield measurements were tested by analysis of variance and means were separated by least significant difference using R software.

In general, irrespective of tillage treatment, it was observed that the value of R_C PAR was higher (6.6 - 8.81 %) at the earlier growth stages (P1 and P2). Thereafter, the value (5.2 -7.0 %) gradually becomes lower with the age of crop. But after milking stage, the value tends to upward as the crop was heading towards maturity (P6 and P7). The percent R_S PAR showed the similar trend as the % R_CPAR value. The percent of R_C PAR and R_S PAR were consistently higher in CT followed by ZT and the lowest value was observed under RT. Thus, conservation tillage (RT and ZT) with application of 100 per cent recommended dose of fertilizer may reduce the R_C PAR and R_S PAR value and intercepted more PAR, which may be due to better canopy architecture. Bergamaschi *et al*. (2010) also observed that conservation agriculture practice was responsible for higher IPAR in maize. Pradhan *et al*. (2018) also found highest fraction IPAR (%) for ‘N160’ treatment (160 kg N ha^{-1}) than ‘N40’ treatment (40 kg N ha^{-1}) in wheat crop. The pattern of APAR followed a trend opposite to that of Rs PAR and Rc PAR (Fig. 1). The maximum APAR value was seen in RT (227.8 to 759.2 Micromoles m^{-2} sec^{-1}) than ZT (156 to 687.4 Micromoles m^{-2} sec^{-1}) and CT (117.2 to 638.4 Micromoles m^{-2} sec^{-1}), irrespective of residue and RDF treatments. The results on LAI also confirmed that RT produce higher LAI than ZT and CT. Residue and nutrient trial confirmed that ‘0% residue with 100% RDF’ absorbed more PAR (117.2 to 759.2 Micromoles m^{-2} sec^{-1}) than ‘100% residue + 50% RDF’ (123 to 645.4 Micromoles m^{-2} sec^{-1}) treatment. It may occur due to higher LAI (Table. 1) values, resulted from application of 100 per cent recommended dose of fertilizers.

Along with LAI, grain yield, biomass and yield attributing

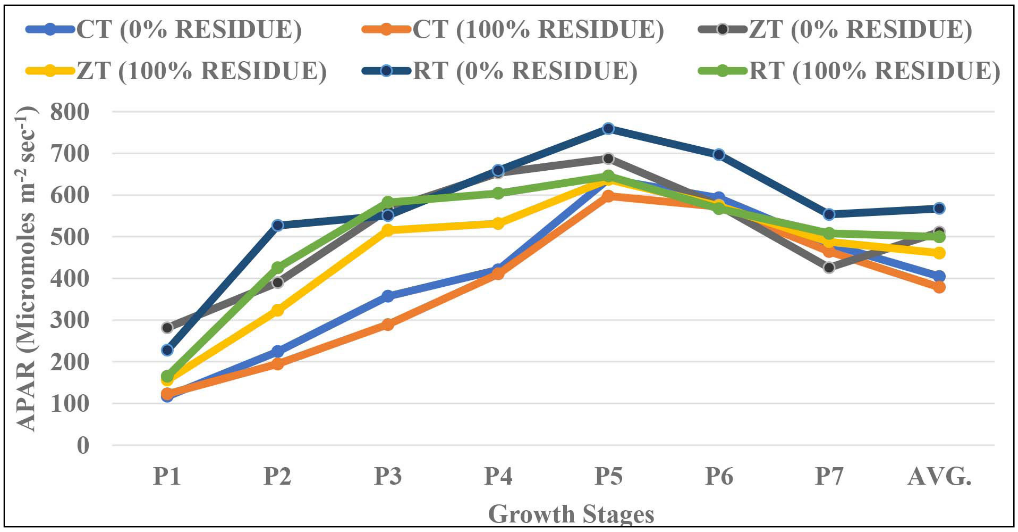

Fig.1: Absorbed PAR (APAR) of maize at different tillage and residue practices

characteristics of maize are presented in Table.1. The grain yield and biomass yield were found to be highest in the crops from RT (13.10 t ha^{-1} and 11.87 t ha ha^{-1}), whereas in ZT grain yield and biomass yield was 11.83 t ha ha^{-1} and 11.57 t ha^{-1}, irrespective of residue and RDF treatment. The least grain and biomass yield was obtained from CT, which was 9.46 tha^{-1}and 6.22 tha^{-1}, respectively. '0% residue+100 % RDF' treatment produced more grain and biomass (13.51 tha^{-1} and 10.75 tha^{-1}) than '100% residue + 50% RDF' (9.41 tha^{-1} and 9.02 tha^{-1}) treatment. Same fashion was observed for number of cobs m^{-2} and number of grains per cob also. The lower yield in '100% residue+50% RDF' treatment might be associated with nitrogen immobilization resulted from application of higher residue in early growth stage (Kundu *et al*., 2013). Therefore, conservation tillage with improved nutrient management can improve yield attributing character as well as grain and biomass yield. Parihar *et al*. (2019) was also found that grain and biomass yield of wet season maize was significantly higher in CA.

In this present study, PARUE is calculated for three different tillage-practices based on above ground biomass under two residue and RDF practices. PARUE was not affected by residue management practices but increased significantly with increased RDF application. Table 2 clearly showed that the intercepted PAR in '0% residue + 100% RDF' was higher than '100% residue+50% RDF' treatment. Similarly, irrespective of tillage practices, PARUE in '0% residue + 100% RDF' (2.8 g MJ^{-1} to 3.8 g MJ^{-1}) was higher than '100% residue+50% RDF' treatment (2.2 g MJ^{-1} to 3.08 g MJ^{-1}). Among different tillage practices, the PARUE was found to be highest in RT (3.8 g MJ^{-1}to 3.08 g MJ^{-1}), whereas in the ZT, PARUE was between 2.6 gMJ^{-1}to 3.3 g MJ$^{-1.}$ The lowest PARUE was recorded in CT, which range between 2.2 g MJ^{-1} to 2.8 g MJ^{-1}. CT treatment also had the lowest grain and biomass yield. So, the poor yield might be a cause of poor RUE value in this case.

From this study, it can be concluded that conservation agriculture practices (RT and ZT) modified the microclimate which was responsible for enhanced IPAR, APAR and PARUE. The conservation agricultural practices also improved different biophysical parameters including LAI, biomass and grain yield of maize. Irrespective of tillage practices, IPAR, APAR and PARUE was increased with application of recommended dose of fertilizer (RDF). However, there was no significant difference between '0% residue and 100% residue' application with respect to grain and biomass yield of maize. The highest PARUE was obtained in case of RT with '0% residue and 100% RDF' treatment (3.80 g MJ^{-1}) followed by ZT with '0% residue and 100% RDF' treatment. The lowest PARUE was observed in case of CT with '100% residue and 50% RDF' treatment. Hence, maize may be grown with the recommended dose of fertilizer under conservation agriculture practices (RT and ZT) to obtain higher grain yield, radiation interception and PARUE in subtropical climate of the new alluvial zone of West Bengal.

ACKNOWLEDGEMENT

The fellowship received from C.A.A.S.T. on "Conservation Agriculture" project in the form of P.G. Fellow to undertake this research work as a part of M.Sc. Degree is duly acknowledged.

Conflict of Interest Statement: The author (s) declares (s) that there is no conflict of interest.

Disclaimer: The contents, opinions and views expressed in the research article published in Journal of Agrometeorology are the views of the authors and do not necessarily reflect the views of the organizations they belong to.

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