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Diurnal variation in transmission of PAR within wheat and mustard canopies under intercropping system

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ABSTRACT

Light transmission causes variation in light utilization under intercropping. To analyse the transmission of photosynthetically active radiation (PAR) in wheat-mustard intercropping, a two year experiment (2008-09 and 2009-10) with five treatments was conducted, (T_1:sole wheat, T_2-:sole mustard, T_3 :two wheat: six mustard, T_4: four wheat: four mustard and T_5: six wheat: two mustard) in a RBD with six replications in a 54 m^2 plot. PAR was measured from 7:30 to 15:30 h by means of line quantum sensor at two hour interval. PAR transmission was maximum at 15:30 h throughout the growth phase in wheat and at 07:30 h in mustard. Mean transmission in T_3 treatment was maximum (47.34 to 90.3%) during mid phase of growth in wheat, sole mustard recorded maximum transmission. Sunlit leaf area index (L) decreased significantly with the increment in transmission. About 74.6% variation in L* was explained by the variation of transmittance at 11:30 h in wheat.*

Keywords **:** Intercropping, mustard, PAR, transmission, wheat

The fraction of incident solar radiation reflected and transmitted by a dense stand of vegetation depends on scattering properties of foliage (Monteith and Unsworth, 2001). Besides, association of a component crop as in case of intercropping may also interfere with the general radiation profile of each other and bring a change in light transmission pattern of individual crops. The fractions of the incoming PAR which are absorbed by canopies of component crops in intercrop systems mainly depend on leaf area index and canopy structure (Spitters and Aerts, 1983; Lantinga *et al.,* 1999; Bastiaans *et al.,* 2000). These factors also govern the radiation transmission pattern in a crop stand. Although the principles are understood, Willey (1990) noted that it is a challenge to determine light capture by component crops in intercrops. The potential shares of the light that will be absorbed by components of intercrop are determined by the relative heights of their canopy and the efficiency with which they absorb light (Trenbath, 1979). This may lead to differential light transmission and utilization pattern of component crops. Paucity of information remains in this aspect. Present study reports diurnal variation in transmission of PAR in two component crops: wheat and mustard and the pattern of light transmission were compared under sole and intercropping system of wheat and mustard.

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MATERIALS AND METHODS

The experiment was carried out during *rabi* (November-February) seasons of 2008-09 and 2009-10 at the Instructional Farm, Jaguli, Bidhan Chandra Krishi Viswavidyalaya (Lat. 22º 58' N and long 88º 31' E, Altitude: 9.75 m above mean sea level), West Bengal, India. As per USDA modern taxonomical classification, the experimental soil is under the order of Entisol and the great group is under Fluvaquents. The texture of soil was sandy loam with a pH of 6.75.The experimental soil contains 0.54% organic carbon, 0.053% total N, 15 kg ha^{-1} available P_2O_5 and 153.57 kg ha^{-1} available K_2O. There were five treatments, comprising of two sole crop treatments (T_1: sole wheat and T_2: sole mustard) and three intercrop treatments (T_3: two wheat: six mustard, T_4: four wheat: four mustard, T_5: six wheat: two mustard) where two crops were associated in different row ratios. The experiment was conducted in a RBD with six replications and the each plot measured 54m^2 (9×6m). Six replications were used to reduce the experimental error.

The experimental plot was thoroughly cultivated with cultivator. At the interface of wheat and mustard rows, a furrow of 0.5m width was given to prevent irrigation water flow from wheat and mustard blocks and vice-versa. In case of T_3 treatments, in each block, there are two wheat rows and six mustard rows and in their interface there was a furrow. In this treatment, there were three blocks comprising of six wheat rows and 18 mustard rows. In T_4 treatments, four rows of wheat were associated with four rows of mustard, having a furrow in between them. There were twelve rows of wheat and twelve rows of mustard in this treatment. In T_5 treatment, six rows of wheat and two rows of mustard were sown alternately. The intra row spacing between wheat and mustard was 25 cm and the row orientation was north-south direction. The recommended dose of fertilizers for wheat (cv. PBW 343) was 120 kg N, 60 kg P_2O_5 and 40 kg K_2O per hectare and mustard crop was 60 kg N, 40 kg P_2O_5 and 40 kg K_2O per hectare. In case of wheat, N was applied in three splits *viz.* 50% N as basal, 25% N at crown root initiation and 25% at flowering. In mustard N was applied in two splits *viz.* 50% N as basal and 50% N at pre bloom stage. The mustard rows received two irrigations of 5cm each at pre-bloom and siliqua development stages whereas, the wheat rows received four irrigations, 5cm each at crown root initiation, late-jointing, flowering and milking stages.

PAR was measured with the help of line quantum sensor (Model MQ301, APOGEE, Logan, UK). It was placed 100cm above the crop across the row to measure the incident PAR; it is lowered down to the 50cm height above ground to get the transmitted PAR. The observations were recorded from 7.30 to 15.30 hours at two hour interval to get a picture of diurnal variation in transmission of PAR. The transmittance was computed as follows:

Transmittance= Transmitted PAR/ Incident PAR

The Sunlit LAI (L*) is the illuminated part of the leaf area corresponding to its land area. L* for wheat was calculated using the following formulae developed by Monteith and Unsworth (2001):

$$L^* = \int_O^{L_t} I_{(L)}/I_{(O)} d_L = \int_O^{L_t} \exp(-Ks \times L)\, d_L = \frac{1}{Ks}[1-\exp(-Ks \cdot Lt)]$$

For spherical and ellipsoid and leaf distribution, Ks = 0.5 cosec â, where â, solar elevation angle, $I_{(L)}$ and $I_{(0)}$ are the incident PAR within and above crop height, and L_t, the total LAI.

RESULTS AND DISCUSSION

Transmission of PAR under wheat canopy

Results showed a higher transmission of PAR during the earlier and later part of the day as compared to the noon hours. During early morning and late afternoon hours, radiation travels a slant path illuminating the lower tier of the canopy, thus resulting in higher transmission than the noon hours (Fig. 1). In addition, during early growth stage, the transmission was very high, thereafter it gradually decreased. Reduction in transmission of PAR at the later phase of crop growth may be attributed to increase in foliage density, crop height and vegetative growth (Table 1). Absorption of PAR increased as the age of the crop increased, which might be attributed to the chlorophyll content of leaves as well as leaf volume (Gates, 1981, Monteith and Unsworth, 2001).

While studying, the radiation transmission pattern under different treatments, it was seen, that sole wheat recorded minimum transmission as compared to intercropped wheat. Closer canopy association under sole cropping might be the reason for lower transmission (Smith, 2000; Liu et al., 2012). Among the intercrop treatments, maximum and minimum transmission were recorded in T_3 and T_4 treatments respectively. Unlike sole wheat, presence of mustard rows in case of intercropping situation, must have allowed more light to reach to the ground level due to absence of canopy overlapping at the lower tier of mustard, thus increasing the transmission. However, as the number of associated mustard rows increased, it increased canopy volume. Hence relatively lesser transmission of PAR was observed in T_4 and T_5 treatments (Fig 1).

Transmission of PAR within mustard canopy

In the present study, PAR transmission pattern in mustard canopy was studied in two tiers: ground level to 50 cm above ground level and beyond 50 cm above ground level to have a picture of light transmission profile.

Lower tier

Result showed gradual decrease in transmission of PAR from 7:30h to 11:30h, thereafter it increased upto 15: 30h under all the treatments irrespective of years of observation (Fig. 2). Solar elevation angle remained low during early morning and late afternoon hours; hence radiation was received through a slanting path for which the lower portion of canopy was more illuminated resulting higher transmission. On the other hand, when the sun reached at zenith, maximum radiation absorption occurred at the top of the canopy, which led to decrease in transmission.

Unlike wheat, sole mustard recorded higher transmission as compared to intercropped mustard irrespective of dates and years of observation. The reason might be attributed to the lower LAI

Table 1: Leaf Area Indices of wheat under wheat-mustard intercropping (2008-09 & 2009-10)

Treatments	30 DAE		37 DAE		44 DAE		51 DAE		58 DAE		65 DAE		72 DAE		80 DAE	
	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
T_1 Sole W	0.25	0.22	0.67	0.57	0.99	1.24	1.26	2.03	1.86	2.53	3.98	3.38	4.84	3.81	5.18	4.36
T_3(2W:6M)	0.20	0.11	0.39	0.47	0.79	0.72	1.10	1.40	1.58	2.22	3.50	2.65	4.42	3.29	4.84	3.67
T_4(4W:4M)	0.23	0.16	0.51	0.53	0.88	1.03	1.21	1.76	1.66	2.27	3.61	3.23	4.55	3.62	4.96	4.20
T_5(6W:2M)	0.19	0.16	0.48	0.53	0.82	0.80	1.12	1.69	1.59	2.24	3.52	3.13	4.43	3.57	4.88	4.11
SEm(±)	**0.004**	**0.005**	**0.014**	**0.021**	**0.016**	**0.024**	**0.018**	**0.033**	**0.023**	**0.031**	**0.025**	**0.044**	**0.039**	**0.048**	**0.038**	**0.070**
LSD(0.05)	**0.01**	**0.015**	**0.043**	**0.063**	**0.048**	**0.072**	**0.055**	**0.101**	**0.070**	**0.093**	**0.076**	**0.133**	**0.12**	**0.146**	**0.11**	**0.212**

Table 2: Leaf Area Indices of mustard (lower tier) under wheat-mustard intercropping system (2008-09 & 2009-10)

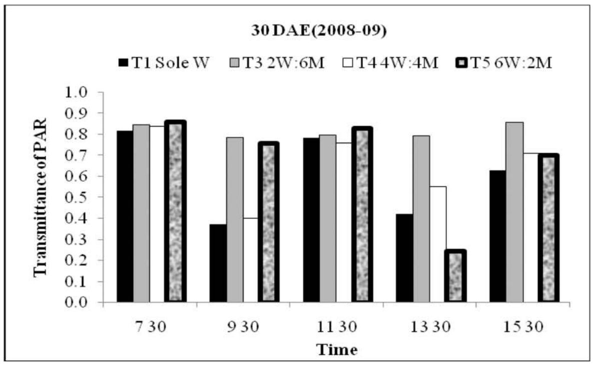
Treatments	30 DAE		37 DAE		44 DAE		51 DAE		58 DAE		65 DAE		72 DAE	
	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
T_2Sole M	0.32	0.24	0.70	0.69	0.74	0.70	0.84	0.79	1.28	0.99	0.72	0.69	0.22	0.62
T_3 2W:6M	0.56	0.37	0.80	0.98	0.85	0.99	0.90	1.03	1.32	1.49	0.73	0.76	0.24	0.64
T_4 4W:4M	0.70	0.52	0.90	1.05	0.91	1.08	0.96	1.11	1.38	1.79	0.81	0.96	0.30	0.71
T_5 6W:2M	0.43	0.34	0.72	0.70	0.80	0.74	0.91	0.87	1.36	1.52	0.76	0.82	0.24	0.65
SEm(±)	**0.012**	**0.019**	**0.013**	**0.035**	**0.015**	**0.040**	**0.010**	**0.030**	**0.011**	**0.079**	**0.019**	**0.024**	**0.008**	**0.014**
LSD(0.05)	**0.037**	**0.058**	**0.039**	**0.107**	**0.046**	**0.121**	**0.031**	**0.091**	**0.035**	**0.24**	**0.057**	**0.074**	**0.026**	**0.044**

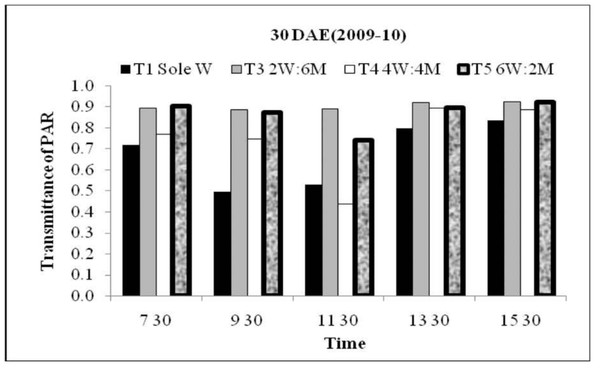
Table 3: Leaf Area Indices of mustard (upper tier) under wheat-mustard intercropping system (2008-09 & 2009-10)

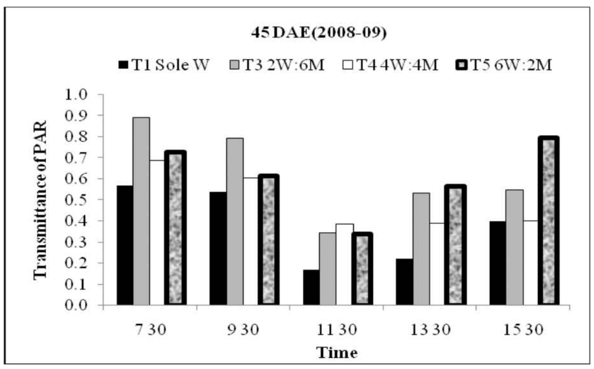
Treatments	30 DAE		37 DAE		44 DAE		51 DAE		58 DAE		65 DAE		72 DAE		80 DAE	
	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
T_2Sole M	0.0	0.0	0.25	0.0	0.96	1.04	1.34	1.32	1.88	1.60	1.35	1.10	0.95	0.92	0.55	0.53
T_3 2W:6M	0.0	0.0	0.26	0.0	1.13	1.14	1.37	1.33	2.04	1.96	1.44	1.29	1.03	1.01	0.66	0.58
T_4 4W:4M	0.0	0.0	0.31	0.0	1.15	1.19	1.42	1.44	2.08	2.04	1.52	1.53	1.06	1.32	0.69	0.63
T_5 6W:2M	0.0	0.0	0.28	0.0	1.10	0.98	1.38	1.32	2.03	1.73	1.40	1.22	0.97	0.97	0.65	0.57
SEm(±)	**-**	**-**	**0.011**	**-**	**0.010**	**0.050**	**0.012**	**0.025**	**0.015**	**0.020**	**0.017**	**0.031**	**0.018**	**0.031**	**0.014**	**0.009**
LSD(0.05)	**-**	**-**	**0.034**	**-**	**0.033**	**0.151**	**0.036**	**0.076**	**0.047**	**0.062**	**0.053**	**0.092**	**0.056**	**0.092**	**0.041**	**0.027**

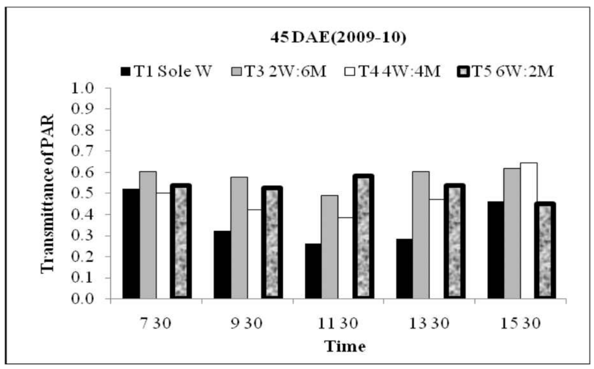
development at this tier of mustard canopy. Besides, horizontal leaf distribution of mustard crop may be another factor for higher transmission of radiation. On the other hand, presence of associated wheat rows in intercropping situation, might had intercepted the radiation being transmitted through the mustard canopy resulting in reduced transmission of radiation (Monteith and Elston, 1983).

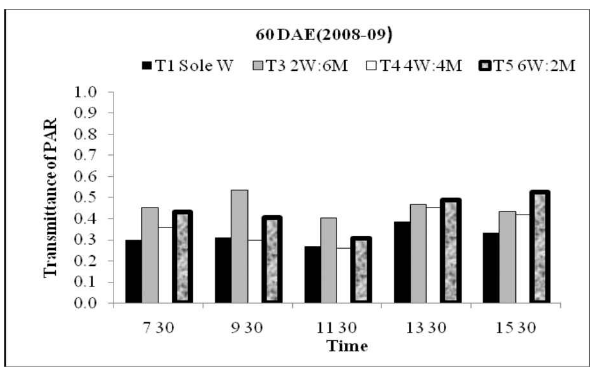
When two rows of wheat were alternated with six mustard rows, interference with the transmitted radiation from mustard canopy became weaker, which resulted in higher transmission. Apart from this relatively less canopy development in wheat under this treatment might be another reason for higher transmission. On the contrary, canopy association was comparatively closer under T_4 treatment, which led to higher absorption and ultimate reduction in transmission. In addition, better growth of both component crops under these particular treatments may contribute towards lower transmission of radiation. The transmission under T_5 did not follow a specific trend. There was a gradual increase in radiation transmission with advancement of crop age. The T_5 treatment has only two rows of mustard sandwiched between six wheat rows on each side. Therefore, the leaf shedding in mustard was maximum in this treatment compared to other treatments because of higher competition offered by wheat crop.

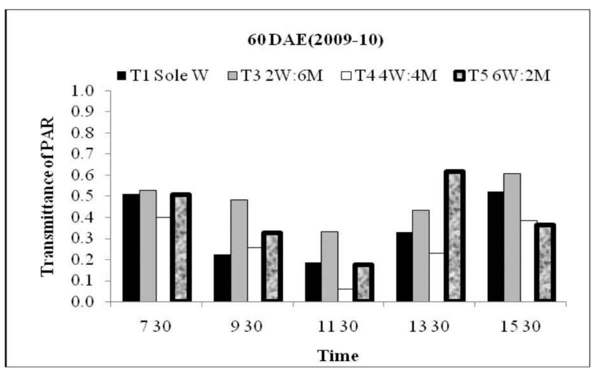












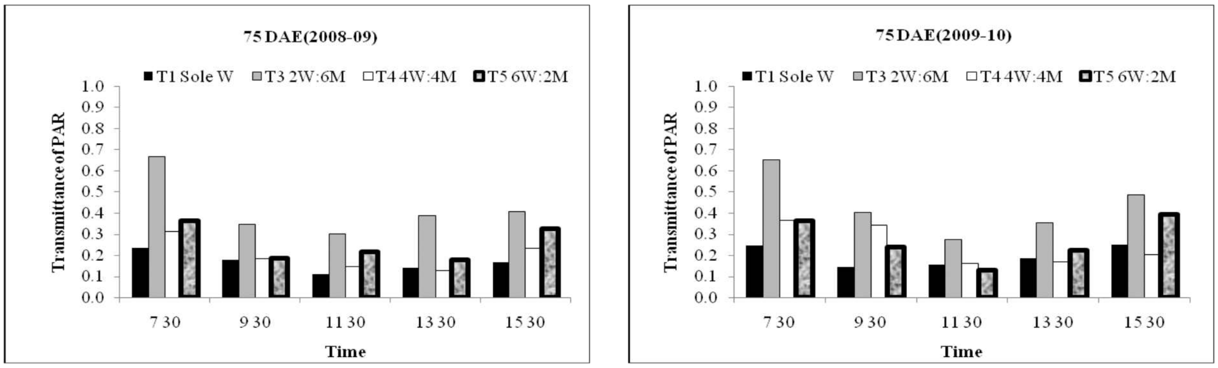
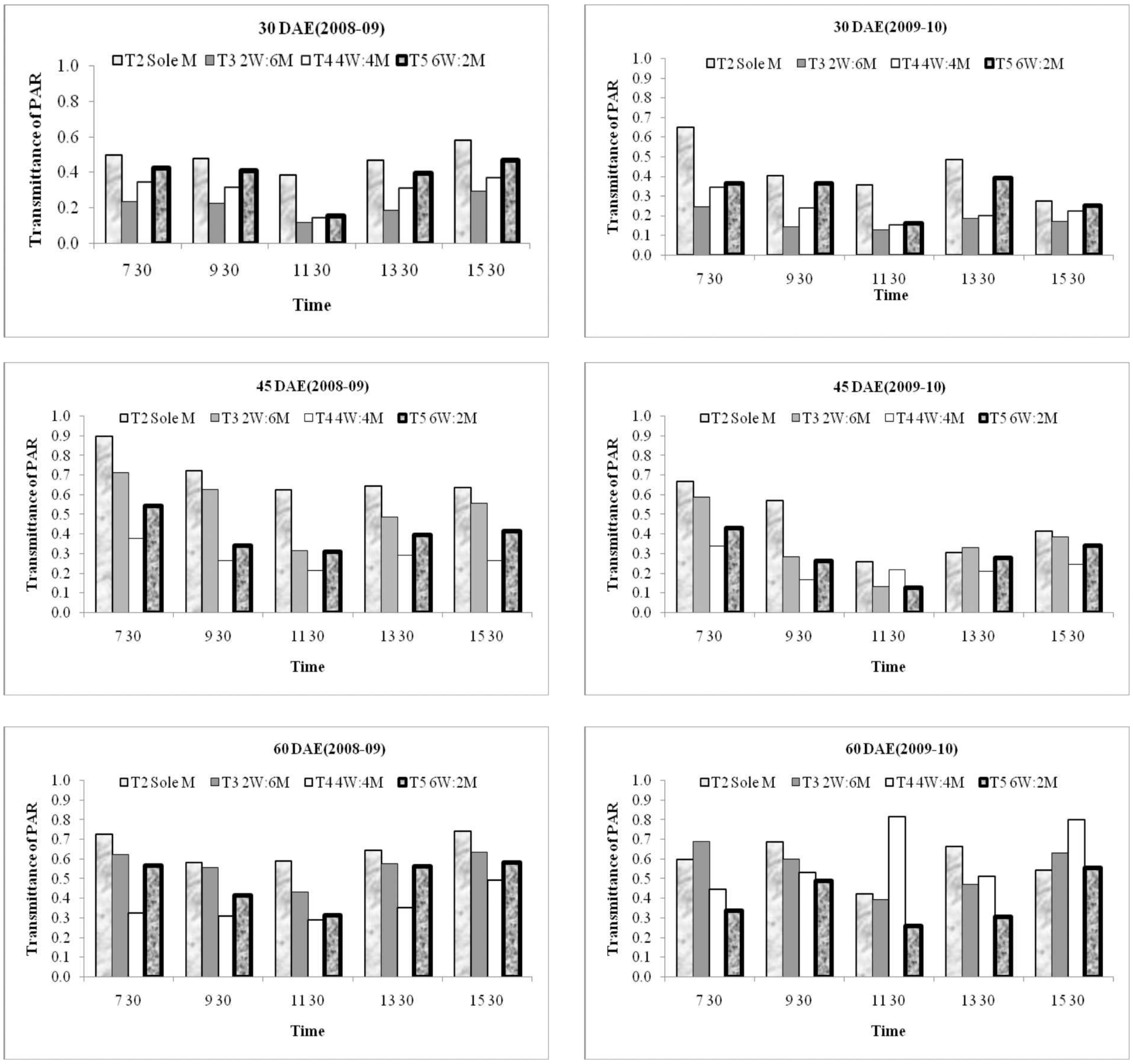


Fig.1: Diurnal variation in transmittance of PAR in wheat canopy under wheat-mustard intercropping



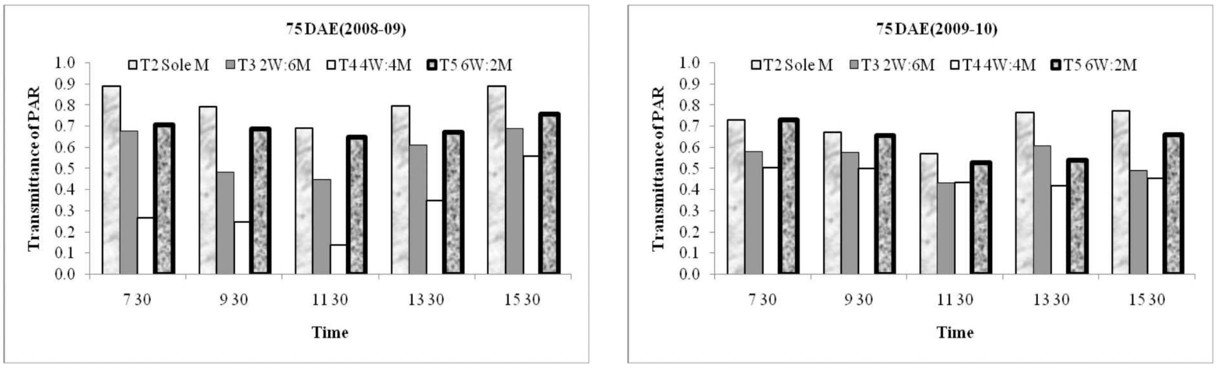


Fig. 2 : Diurnal variation in transmittance of PAR within mustard canopy (lower tier) under wheat mustard intercropping system

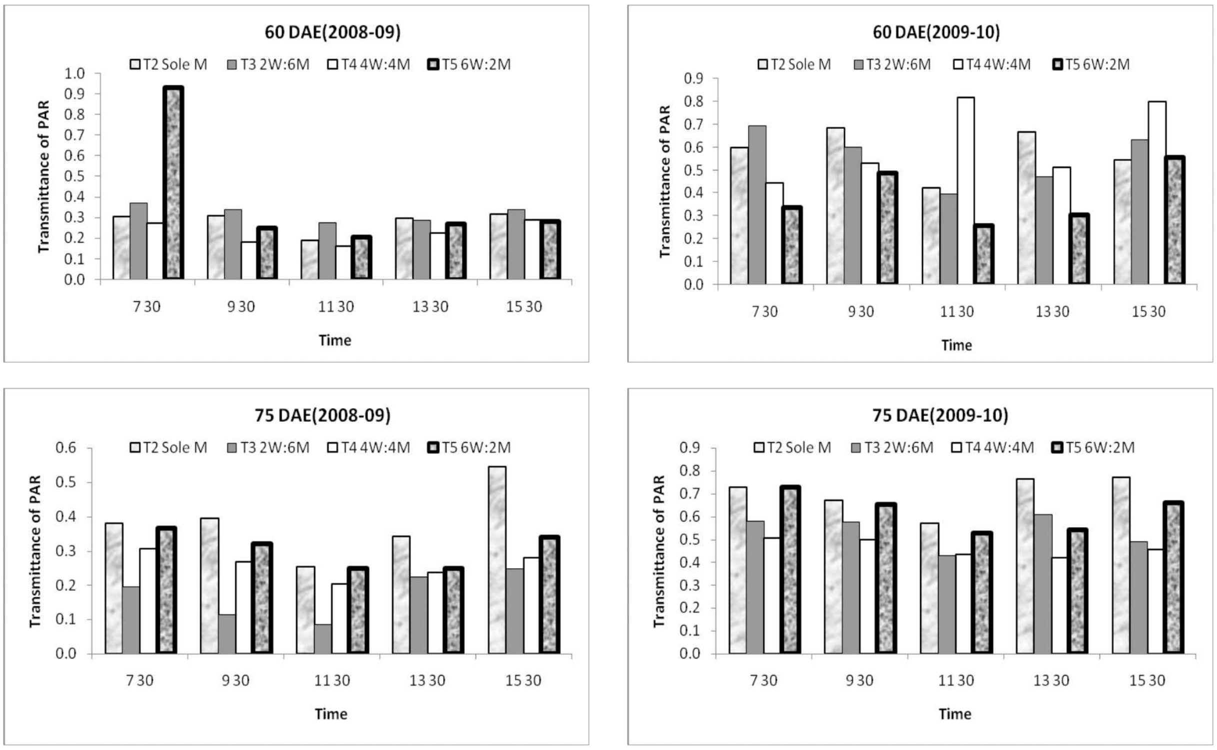
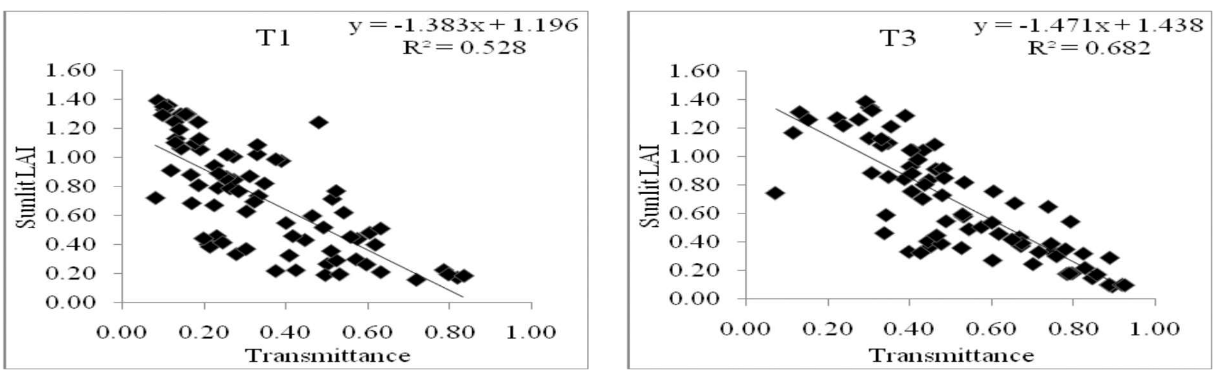


Fig. 3 : Diurnal variation in transmittance of PAR within mustard canopy(upper tier) under wheat - mustard intercropping system



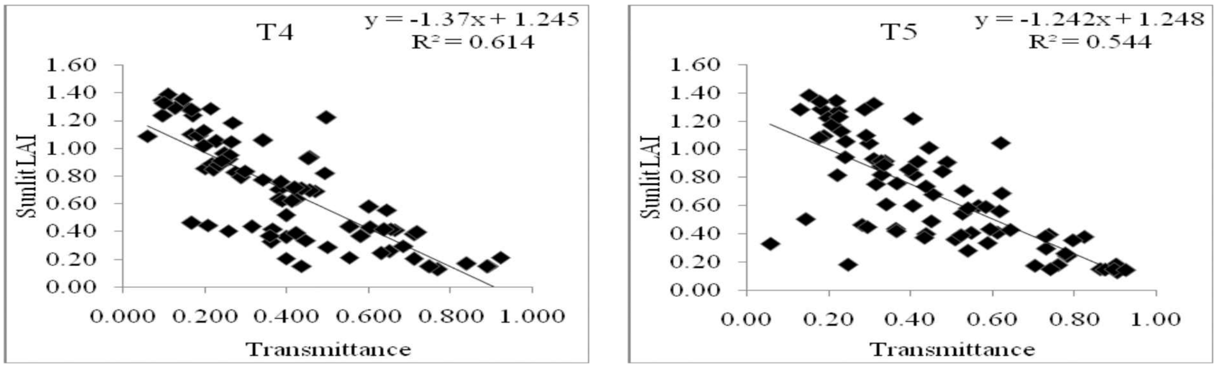


Fig. 4 : Relationship between transmittance and sunlit LAI in wheat (treatment wise) (2008-09 and 2009-10)

upper tier

When diurnal variation in transmission of PAR was considered in the upper tier of mustard canopy, similar trend as that of lower tier was recorded (Fig. 3). On most of the dates of observation, transmission declined from 7 30 to 11 30h, thereafter it recorded an increase. Higher transmission of radiation was observed under sole stand and it reduced under intercropping. The reason might be attributed to difference in LAI development under sole and intercropping situation (Table 2 & 3). Among the intercropped treatments, T_3 recorded minimum transmission. It was followed by T_4 and T_5 respectively. Unlike lower tier of mustard canopy, no interference of component wheat crop was found in the upper tier. However, the reduction in transmission may be due to better foliage development of mustard under intercropping.

Percent transmission in the upper tier of mustard canopy was higher as compared to that of lower tier, during the early stage of crop growth, whereas at the later stage, reverse trend was observed, irrespective of treatments. The leaf fall and senility was observed in the lower tier, which reflected in reduction of LAI at the later stage, ultimately increasing the transmission. When plants produce their new leaves at the upper tier, older leaves become progressively shaded and in many species they die, where their irradiance fall to a few percent of full sunlight (Monteith and Unsworth, 2001). The mean transmission gradually declined upto 60 days after emergence under sole crop, thereafter recorded a marginal increase. Similar trend was observed, under intercropping situation. The reduction in transmission with the advance of crop age might be attributed to the increment in height and foliage volume of crop. Parya *et al.,* (2011) reported the reduction of transmittance through the wheat canopy with the advancement of crop age.

Relation between Transmittance and sunlit LAI in wheat

The transmittance of the wheat canopy in different treatments significantly increased with the reduction of sunlit leaf area index. The R^2 values ranged from 0.528 to 0.682, the highest value was obtained in T_3 treatment (Fig. 4). The L* increased with the intercepted radiation. Increasing interception by the crop decreases transmission, thus increasing the L* (Maji *et al.,* 2013).

Radiation transmission inside a crop canopy indirectly determines the light utilization pattern of the crop. Hence, light transmission under an intercropping system, may influence the radiation profile of component crops. In the present investigation, minimum transmission was recorded under sole wheat as compared to intercropping situation, whereas the trend was reversed in mustard. Reduction in transmission with advance of crop growth was observed in both the crops. However mustard recorded a marginal increase in transmission at the later stage of crop growth. Association between sunlit leaf area index and transmittance of radiation was higher in intercropped wheat as compared to sole crop. This observation suggested that the taller stand scattered the incident radiation which illuminated the short height canopy.

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