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Pattern of Absorption and Interception of Photosynthetically Active Radiation in Sesamum-Greengram Intercropping System

[1]Sarika Jena, [1]Rajib Nath, [2]D. Mazumdar, [1]Pintoo Bandyopadhyay and [3]P.K. Chakraborty
[1]Department of Agronomy, [2]Department of Agricultural Statistics,
[3]Department of Agricultural Meteorology and Physics, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal, India

Abstract: A 2 years study was conducted to analyze the pattern of interception and absorption of PAR (Photosynthetically Active Radiation) in sesamum-greengram intercrop in relation to growth, development and yield of the intercropping system. Nine treatment combinations with four replications were tested with sole crops of sesamum (cv. Rama) and greengram (two greengram cultivars: cv. B-105 and WBM-4-34-1-1) with the rest representing the sesamum and greengram intercropping in 1:1, 2:1 and 4:1. The experiment was conducted at the Instructional Farm, BCKV, Jaguli W.B., India. The diurnal variation in absorption and interception of PAR by sesamum and greengram showed the peak at 11.30 h. Absorption of PAR in sole stand of sesamum was higher than intercropped sesamum when grown with greengram in 1:1 or 2:1 row ratios; however under 4:1 row ratio, sesamum absorbed maximum PAR among all the treatment combinations, the converse was recorded in case of greengram crop. The interception of PAR in sesamum canopy was maximum in 4:1 row ratio whereas the sole greengram intercepted more PAR than the intercropped one. The dry matter accumulation and yield in sesamum were highest in 4:1 row ratio whereas the sole greengram recorded the reverse. Dry matter accumulation in sesamum and greengram were significantly related to the absorption and interception of PAR. The interception of PAR during the early phase was proved to be single determining factor affecting the seed yields of both the crops.

Key words: PAR, absorption, interception, dry matter, yield, sesamum, greengram, intercropping

INTRODUCTION

Now a days, any discussion over climate leads to the focal theme of climate change. Large number of predictions has suggested that the climatic condition will become more variable and extreme in the arid, semi arid and sub humid tropics (Rosenzweig *et al*., 2004; IPCC, 2008). Gregory and Ingram (2000) observed that the farmers may combat the effect of climate change by reverting to more natural systems which provide beneficial ecological functions. Lott *et al*. (2009) stressed that this suggestion was particularly pertinent for those farmers who can not adopt technological solutions because of poor resources. In this context, growing of different crops together and estimating the radiation environment, within this combined cropping system becomes important. Microclimatic variation affects the performance of crop in a remarkable manner (Slingo *et al*., 2005). Radiation environment within a crop canopy has the most important function regulating different physiological processes. Radiation absorption and interception within a crop canopy and their effects on physiological processes have been delineated in different crops. Under the present scenario, it will be beneficial to the resource poor farmers to grow crops together for combating crop failure in subhumid tropics because of climatic variability particularly the variability in the rainfall pattern. Information on the complexity of radiation environment in inter cropping systems is poorly available. The present experiment is planned with an objective to study the complex nature of radiation environment which has been emanated from the scattering and reflection of PAR from the component crops and its effect on growth and productivity of sesamum and greengram under intercropping system so that proper advice may be given to those farmers who are growing these important crops together in eastern India.

MATERIALS AND METHODS

Study site: The field experiment was carried out at the Instructional Farm, Jaguli, Bidhan Chandra Krishi

Corresponding Author: Sarika Jena, Department of Agronomy, Meteorology and Physics, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal, India

Viswavidyalaya, West Bengal, India during pre-kharif seasons of 2007 and 2008. The Farm is located at 22°56′ N latitude and 88°32′ E latitude at an elevation of 9.75 m above mean sea level. The zone is classified as having a tropical humid climate with three distinct seasons divided into winter (November to February), Pre-kharif (March to May) and kharif (June to October). The annual rainfall generally varies from 1400-1500 mm, most of which is received from June to September during active SW monsoon, the onset and departure of which have been remarkably shifted in the present days. January is the coldest month with a mean temperature. The atmospheric mean temperature begins to rise from the end of February and reaching maximum during the month of May. The mean relative humidity remains high (82-95%) during June to October and reaches at 70% in January. Throughout the year, the wind speed varies from 0.6-6.8 km h^{-1}. In general the Pan-evaporation loss ranges from 0.8-1.2 mm day^{-1} in the month of January which reaches >9 mm day^{-1}. Soil of the experimental site is classified as sandy loam, Aeric Haplaquept. Basic chemical properties of the surface (0-15 cm) soil were pH 6.80 organic carbon 5.4 g kg^{-1}, available N, P_2O_5 and K_2O as 85, 15.3 and 40 kg ha^{-1}, respectively.

Experimental design: The experiment was set up in Randomized Block Design (RBD) where two crops i.e., sesamum (CV.Rama) and greengram (CV.B-105 and WBM-4-34-1-1) were grown as sole and intercrop in different number of row combinations which created nine different combinations namely sole sesamum, sole greengram (CV.B-105), sole green gram (CV.WBM-4-34-1-1), sesamum: greengram (CV.B.-105) 1:1, sesamum: greengram (CV.WBM-4-34-1-1) 1:1, sesamum:greengram (CV.B-105) 4:1 and sesamum: greengram (CV.WBM-4-34-1-1) 4:1. Each treatment was replicated four times and distributed randomly to a RBD plot having the plot size of 15 m^2 to minimize the effect of difference between the plots. Each treatment was repeated in the same plot during successive years of the experimentation.

Agronomic practices: Land preparation was done by two crosswise passes of rotary power tiller with a depth of 100 mm followed by surface leveling. Seeds of sesamum and greengram were sown on 28th February as sole and intercrops in 2007 and 2008, respectively. The row to row and plant to plant spacing s in between two crops were 30 and 10 cm, respectively. A fertilizer dose of ***, ** and ******* kg ha^{-1} for N, P_2O_5 and K_2O were applied uniformly to each plot at the time of land preparation. Another ***** N was applied as topdressing at 21 days after sowing after first weeding and thinning.

Observations: The Photosynthetic Active Radiation (PAR) was measured at 9.30, 11.30 and 13.30 h on 30, 45 and 60 Days after Sowing (DAS) using line quantum sensors (APOGEE Logan UT). Sensors were placed across the row >50 cm. Height of the crop to measure the incident radiation and were inverted to measure the reflected PAR from the crop canopy of each component crops. Similarly, sensors were placed 20 cm above the soil surface to measure the incident radiation at the bottom of the crop canopy and reflectivity from the soil was measured by the inversion of the sensor. The Photosynthetically active radiation was measured with the help of line quantum sensor on 30, 45, 60 days after sowing.

From the measured PAR values, absorbed and intercepted PAR was calculated by using the following formula (Gallo and Daughtry, 1986):

$$\text{Absorbed PAR (APAR)} = [PAR_{(O)} + RPAR_{(S)}] - [TPAR + RPAR_{(c)}]$$

Where:

$PAR_{(O)}$ = Incident PAR above the canopy

$RPAR_{(S)}$ = Reflected PAR from soil i.e., at the bottom of canopy

TPAR = Transmitted portion of PAR through the canopy to the soil surface (incident PAR value at the bottom of canopy)

$RPAR_{(c)}$ = Reflected PAR from the crop (Reflected PAR value at the upper most layer of the canopy)

$$\text{Intercepted PAR (IPAR)} = PAR_{(O)} - TPAR - RPAR_{(c)}$$

(Dhaliwal *et al*., 2007)

The dry matter (g m^{-2}) accumulated in sesamum and greengram crop were estimated from the destructive samples taken from 1 m^2 area of each plot. The measurement was done on the same days as in the case of PAR. The seed yields were measured from 10 m^2 area and converted into kg ha^{-1}.

Statistical analysis: The statistical differences in case of dry matter production and seed yield among the different treatment combinations were tested with DMRT technique for a RBD design. The relationship among absorption, interception, dry matter production and seed yields were worked out through, the Principal Component Regression Analysis technique (PCR). The statistical measurements of coefficient of determination (R^2) were determined to indicate the degree of association between two variables.

RESULTS AND DISCUSSION

Absorption of PAR by sesamum: Pattern of diurnal variation in absorption of PAR by sesamum has been shown in Table 1.

Thirty days after sowing: The diurnal pattern of absorption of PAR showed a peak at 11.30 h with two troughs, at 9.30 and 13.30 h. As the sun remains at the zenith at 11.30 h, the pattern showed conformity with the incoming radiation.

The maximum absorption was observed in the combination where four rows of sesamum were grown with one row of greengram when compared with the sole and other intercrop combinations. The absorption of PAR by sesamum varied due to variation in reflectivity of greengram leaves. The percent reduction of absorption in sole sesamum in comparision to 4:1 row ratio were 4.5 and 14.31 in 2007 and 3.93 and 6.11 in 2008 for the varieties of B-105 and WBM-4-34-1-1, respectively.

Forty five days after sowing: The diurnal trend of absorption of PAR by the sesamum was similar to that of 30th DAS. Mean reduction of absorption in sole, 1:1 and 2:1 combination in comparison to 4:1 were 7.77, 14.48 and 10.76% in 2007 and 3.70, 13.47 and 7.88% in 2008, respectively. The absorption of PAR by the sesamum crop was more on 45 DAS in comparison to 30 DAS due to the age of sesamum leaves.

Sixty days after sowing: The pattern of diurnal absorption of PAR by the sesamum crop was similar to that of 30 and 45 days after sowing. Mean absorption of PAR, in different intercropped row ratios ranged from 54.3-69.7% in 2007 and 62.3-74.3% in 2008. The results clearly revealed that sesamum when grown in 1:1 or 2:1 row ratios with the green gram crop, the absorption of PAR was less in comparison to sole crop. The green gram leaf has the different leaf size and reflectivity which created an aberration in receiving the solar radiation by the middle or lower part of the sesamum canopy. When row ratios were increased (i.e., 4:1), the radiation environment was totally changed, even scattered radiation from the green gram canopy was absorbed by the sesamum crop which led to the more absorption of PAR by the sesamum crop in 4:1 combination. The absorption of PAR gradually increased from 30-60 DAS because of the maturity of leaf. The absorption of PAR by sesamum in an intercropping system where greengram is associated as component crops has an important 5 bearing in the productions of these 2 crops in combination. The particular 4:1 row ratio may indicate the augmentation of yield of both the crops (oil seeds and pulses) based on the most important environmental input.

Table 1: Pattern of diurnal variation in absorption of photosynthetically active radiation in sesamum under sesamum-greengram intercropping

	30 DAE (Absorption %)					
	2007			2008		
Treatments	9.30	11.30	13.30	9.30	11.30	13.30
S (Sole)	49	56	46	62	77	59
S:G1(1:1)	47	53	45	59	70	54
S:G2 (1:1)	47	52	45	58	67	50
S:G1 (2:1)	48	54	45	60	74	56
S:G2 (2:1)	50	57	46	60	76	58
S:G1 (4:1)	50	60	48	64	80	62
S:G2 (4:1)	56	70	50	65	83	63
45 DAE						
S (Sole)	53	70	48	65	80	62
S:G1 (1:1)	50	65	46	60	72	58
S:G2 (1:1)	48	63	45	60	70	52
S:G1 (2:1)	50	64	48	62	76	57
S:G2 (2:1)	52	67	50	62	79	60
S:G1 (4:1)	54	72	52	65	83	63
S:G2 (4:1)	62	75	56	66	86	67
60 DAE						
S (Sole)	55	73	52	66	81	64
S:G1 (1:1)	52	68	49	62	75	60
S:G2 (1:1)	50	65	48	61	71	55
S:G1 (2:1)	51	65	50	65	78	58
S:G2 (2:1)	56	72	52	66	80	62
S:G1 (4:1)	60	78	55	68	85	64
S:G2 (4:1)	66	81	62	68	87	68

Absorption of PAR by greengram: Pattern of diurnal variation in absorption of PAR by green gram has been shown in Table 2.

Thirty days after sowing: Absorption of PAR, by the greengram crop was highest at 11.30 h. Absorption by

Table 2: Pattern of diurnal variation in absorption of photosynthetically active radiation in greengram cultivars under sesamum-greengram intercropping

	30 DAE (Absorption %)					
	2007			2008		
Treatments	9.30	11.30	13.30	9.30	11.30	13.30
G1 (Sole)	52	60	48	50	76	56
G2 (Sole)	56	62	60	52	78	51
S:G1 (1:1)	40	56	48	48	58	44
S:G2 (1:1)	48	62	60	48	65	45
S:G1 (2:1)	40	50	42	40	48	43
S:G2 (2:1)	42	52	46	41	50	44
S:G1 (4:1)	38	48	40	40	46	38
S:G2 (4:1)	40	50	42	41	48	38
45 DAE						
G1 (Sole)	53	60	50	52	56	53
G2 (Sole)	57	65	62	53	78	52
S:G1 (1:1)	42	57	50	58	65	48
S:G2 (1:1)	50	58	54	59	66	50
S:G1 (2:1)	41	52	43	44	52	45
S:G2 (2:1)	43	53	48	45	54	46
S:G1 (4:1)	40	50	42	42	48	40
S:G2 (4:1)	42	51	43	44	50	42
60 DAE						
G1 (Sole)	56	62	51	57	60	54
G2 (Sole)	58	68	63	60	78	56
S:G1 (1:1)	43	60	51	60	66	50
S:G2 (1:1)	52	62	55	62	67	52
S:G1 (2:1)	42	53	44	45	55	46
S:G2 (2:1)	44	54	48	46	56	48
S:G1 (4:1)	41	52	43	43	52	42
S:G2 (4:1)	43	52	43	44	53	45

sole green gram was higher than the green gram varieties growing under intercropped situation. Reduction in absorption of PAR, gradually increases, as one goes for more number of sesamum rows growing with the greengram varieties. The lowest absorption was recorded in 4:1 row ratio. Percent reduction of mean absorption of PAR by the greengram in comparison to sole crop were 7.1, 19.54 and 23.62 in 2007 and 15.12, 26.69 and 30.91 in 2008 for 1:1, 2:1 and 4:1 row ratios, respectively. The absorption of PAR by the variety WBM-4-34-1-1 was higher than B-105; the extents of increase in absorption by WBM-4-34-1-1 were 18.12, 6.14 and 4.76 in 2007 and 5.40, 2.97 and 2.42 in 2008 for 1:1, 2:1 and 4:1 row ratios, respectively.

Forty five days after sowing: The diurnal pattern of absorption of PAR by greengram was similar to that of 30 DAS. The lowest absorption was observed incase of 4:1 row ratio. The mean reductions of absorption of PAR in 4:1 row ratio in comparison to sole crop were, 22.75 and 22.76%, respectively for 2007 and 2008.

Sixty days after sowing: The diurnal pattern was similar to that of 30 and 45 DAS. The mean absorption of PAR was highest in sole crop and the lowest in 4:1 intercrop. The absorption by greengram decreased with the increased number of sesamum rows growing with the green gram crop. The result clearly showed that greengram absorbed less PAR when combined with the sesamum crop in any of the three row ratios investigated. Sesamum as a tall crop had a shading effect which reduced the absorption by the green gram crop. When the numbers of sesamum rows were increased, sesamum plant offered more shade which actually reduced the incident PAR, over the green gram canopy.

Interception of PAR by sesamum: Pattern of diurnal variation in interception of PAR by sesamum has been shown in Table 3. Interception increased from 9.30-11.30 h, followed by a decline at 13.30 h. The mean interception of PAR was highest in 4:1 row ratio. The interception decreased in 1:1 and 2:1 row ratios where one or two rows of sesamum was grown with one row of greengram in comparison to the sole sesamum stand. The similar pattern of observation was observed on 45 and 60 DAS. The interception increased from 30-60 DAS because of increasing leaf area index during this period. When one or two rows of sesamum was alternated with one row of green gram, the greengram leaves, created a shadow at the middle and lower portion of the sesamum canopy, reducing interception in 1:1 or 2:1 row ratio.

Interception of PAR by greengram: The pattern of diurnal variation in interception of PAR, by greengram cultivars has been shown in Table 4. The results revealed that the sole crop intercepted maximum amount of PAR in comparison to the intercropped combination. As the

Table 3: Pattern of diurnal variation in interception of photosynthetically active radiation in sesamum under sesamum-greengram intercropping

	30 DAE (Interception %)					
	2007			2008		
Treatments	9.30	11.30	13.30	9.30	11.30	13.30
S (Sole)	41.5	51.10	40.8	40.0	50.5	42.0
S:G1(1:1)	21.5	31.74	23.0	25.6	33.5	26.0
S:G2(1:1)	22.7	31.60	24.5	28.0	38.5	28.0
S:G1(2:1)	30.5	39.20	28.6	32.5	40.5	34.0
S:G2(2:1)	33.6	43.80	30.2	33.8	42.6	36.0
S:G1(4:1)	50.1	60.50	48.5	52.5	56.8	50.0
S:G2(4:1)	51.0	65.70	50.2	60.0	70.2	54.0
45 DAE						
S (Sole)	50.0	68.50	540	52.0	80.2	55.0
S:G1(1:1)	40.0	50.20	42.0	45.0	65.2	44.2
S:G2(1:1)	42.5	50.00	44.0	46.8	62.5	46.0
S:G1(2:1)	46.0	52.50	45.0	40.0	75.0	48.0
S:G2(2:1)	47.5	56.00	46.0	42.8	78.0	52.0
S:G1(4:1)	52.0	60.00	50.5	60.5	85.0	54.0
S:G2(4:1)	58.5	75.00	60.2	62.0	88.5	58.6
60 DAE						
S (Sole)	58.0	82.50	60.0	56.5	88.0	65.2
S:G1(1:1)	45.0	72.50	50.5	45.2	78.5	50.0
S:G2(1:1)	46.0	72.00	52.0	46.0	76.5	54.0
S:G1(2:1)	50.2	75.00	54.0	42.0	70.2	56.0
S:G2(2:1)	52.0	76.50	56.2	44.0	72.2	58.0
S:G1(4:1)	62.0	85.00	60.5	58.0	89.5	60.0
S:G2(4:1)	64.0	86.00	66.0	60.5	90.5	68.5

Table 4: Pattern of diurnal variation in interception of photosynthetically active radiation in greengram cultivars under sesamum-greengram intercropping

	30 DAE (Interception %)					
	2007			2008		
Treatments	9.30	11.30	13.30	9.30	11.30	13.30
G1 (Sole)	36.2	45.9	36.0	38.0	40.5	40.2
G2 (Sole)	38.5	47.6	36.5	40.5	42.6	42.0
S:G1 (1:1)	32.0	38.5	34.0	30.0	40.2	34.8
S:G2 (1:1)	34.2	40.2	35.0	31.5	42.5	36.0
S:G1 (2:1)	30.2	34.5	32.0	28.0	38.5	32.0
S:G2 (2:1)	32.5	36.8	33.5	30.0	40.0	34.0
S:G1 (4:1)	28.6	30.2	30.2	26.8	35.6	32.0
S:G2 (4:1)	32.0	32.5	32.0	28.5	38.0	34.0
45 DAE						
G1(Sole)	50.2	70.5	50.2	55.0	85.0	54.6
G2 (Sole)	56.5	75.0	54.0	58.6	88.3	56.0
S:G1 (1:1)	35.0	42.0	42.0	40.2	60.5	44.0
S:G2 (1:1)	36.0	48.0	44.2	42.0	65.0	45.8
S:G1 (2:1)	34.0	40.2	40.5	38.0	52.0	42.0
S:G2 (2:1)	34.0	42.5	42.6	40.5	55.0	44.0
S:G1 (4:1)	30.5	40.0	38.0	36.0	50.2	40.0
S:G2 (4:1)	32.0	42.0	42.0	38.0	52.0	42.0
60 DAE						
G1 (Sole)	58.0	86.0	60.6	60.5	86.0	60.0
G2 (Sole)	60.0	89.0	64.0	62.0	90.0	61.5
S:G1 (1:1)	44.2	66.5	50.0	46.0	73.0	52.6
S:G2 (1:1)	46.0	68.0	54.2	48.0	74.5	54.0
S:G1 (2:1)	42.0	60.5	48.2	44.0	70.2	52.0
S:G2 (2:1)	44.8	62.5	50.0	45.0	72.0	53.0
S:G1 (4:1)	40.5	58.0	46.0	40.8	68.0	50.0
S:G2 (4:1)	42.6	60.0	49.0	42.6	66.5	50.6

number of row ratios of sesamum increased interception of PAR by the greengram was reduced gradually from 1:1 to 4:1 row ratios. This trend was maintained irrespective of dates and years of observation. For increasing interception of radiation by a crop canopy, a non aberrative situation is essential. When tall and short crops are grown in 1:1 row ratio; interference to the short crop is less. However, increasing the number of rows of tall crop, interference to the penetration of radiation within the crop canopy is increased enormously. This probably reduced interception of PAR by the greengram crop under intercropping system.

Dry matter accumulation in sesamum: The dry matter accumulation (g m^{-2}) in sesamum and greengram has been shown in Table 5. Results suggest that dry matter accumulation was highest in 4:1 row ratio irrespective of the dates and years of observation. Although, the sole crop recorded no significant difference with 4:1 row ratio in 2007, a significantly higher dry matter was produced than the sole crop in 2008 on 30 DAS, in case of the variety WBM-4-34-1-1. The dry matter production in sesamum did not differ significantly when sesamum was grown with any variety of greengram. However when sesamum was grown in 4:1 row ratio with greengram, the dry matter production was significantly >2:1 and 1:1 row ratio; the sesamum under 2:1 row ratio also recorded higher dry matter than 1:1 row ratio. This trend was maintained up to 45 DAS. On 60th DAE, the dry matter accumulation in sesamum under 4:1 row ratio was significantly higher than the sole crop. The associations of sesamum with the variety B-105, recorded similar dry matter production in sesamum to that of sole sesamum stand. The dry matter accumulation in sesamum was significantly affected by absorption and interception of PAR. Principal component regression analysis showed that both the interception and absorption of PAR at 30 DAS significantly affected the dry matter accumulation. Absorption of PAR during later phase (45 and 60 DAS) seemed to be significant regulator of dry matter production in sesamum (Table 6). About 89, 94 and 94% variations in dry matter production by sesamum could be explained through the variations in absorption and interceptions of PAR on 30, 45 and 60 DAS under intercropping systems. Hundal *et al.* (2003) and Dhaliwal *et al.* (2007) also observed a significant relationship between PAR and dry matter production in Brassica under sole condition.

In the present investigation, absorption and interception were highest in 4:1 row ratio. This higher absorption and interception were due to repeated scattering of radiation from greengram canopy. Any radiation transmitting through the tall crop (sesamum) was reflected by the large sized leaves of greengram and again reabsorbed by sesamum leaves. This led to increased photosynthetic activity of sesamum leading to higher dry matter accumulation.

Dry matter accumulation in greengram: Dry matter accumulation in greengram was highest under sole stand and the lowest under 4:1 row ratio; no significant variation was observed in between the varieties B-105 and WBM-4-34-1-1 in the majority of treatments in any particular combination (Table 5). On 30 DAS, the dry matter production in two greengram varieties did not vary statistically when grown with 1, 2 or 4 rows of sesamum. However in 2008, the variety WBM-4-34-1-1, recorded significantly higher dry matter than B-105 when grown in 4:1 row ratio.

On 45 days after sowing, the variety WBM-4-34-1-1 recorded significantly higher dry matter in sole stand, however no significant differences were observed in intercropped combination. On 60 days after sowing, cultivar WBM-4-34-1-1 recorded higher dry matter production than B-105 in different combinations in 2008. Phasic depression in absorption and interception of PAR in case of short statured canopy is a peculiarity of intercropping system where growth characteristics of a

Table 5: Effect of different treatments on dry matter accumulation of sesamum and greengram in sesamum-greengram intercropping system

	30 DAE				45 DAE				60 DAE			
	2007		2008		2007		2008		2007		2008	
Treatments	S	G	S	G	S	G	S	G	S	G	S	G
S (Sole)	28.9^{a}	-	28.9^{bc}	-	213.0^{a}	-	103.4^{a}	-	420^{b}	-	670.0^{b}	-
G1(Sole)	-	64.1^{a}	-	63.0^{a}	-	113.0^{b}	-	127.0^{b}	-	487^{b}	-	465.6^{b}
G2 (Sole)	-	65.8^{a}	-	64.2^{a}	-	136.0^{a}	-	176.0^{a}	-	504^{a}	-	554.3^{a}
S:G1 (1:1)	16.8^{c}	38.4^{b}	26.5^{c}	49.6^{b}	185.0^{b}	71.0^{c}	67.7^{c}	166.0^{ab}	280^{d}	337^{c}	562.3^{e}	374.0^{d}
S:G2 (1:1)	16.7^{c}	38.5^{b}	26.0^{c}	50.2^{b}	131.0^{c}	71.4^{c}	66.5^{c}	167.0^{ab}	266^{e}	339^{c}	543.0^{e}	388.0^{c}
S:G1 (2:1)	22.0^{b}	31.9^{c}	27.6^{bc}	42.3^{c}	188.0^{b}	60.6^{d}	76.5^{b}	157.0^{ab}	323^{c}	168^{d}	612.5^{d}	280.0^{f}
S:G2 (2:1)	22.8^{b}	33.0^{c}	29.3^{bc}	43.3^{c}	190.0^{b}	63.5^{d}	78.5^{b}	162.0^{ab}	325^{c}	169^{d}	645.0^{c}	300.0^{e}
S:G1 (4:1)	30.5^{a}	15.8^{d}	32.2^{b}	43.0^{c}	215.0^{a}	51.2^{e}	105.2^{a}	139.0^{ab}	426^{ab}	98^{e}	673.0^{b}	238.0^{g}
S:G2 (4:1)	33.6^{a}	16.6^{d}	38.2^{a}	48.0^{b}	217.5^{a}	59.3^{d}	108.0^{a}	148.5^{ab}	437^{a}	101^{e}	716.0^{a}	298.0^{e}

Table 6: Relationship among radiation components, dry matter production and yield of sesamum under sesamum-greengram intercropping system

Variables	Unstandardized coeff. B	Unstandardized coeff. Std. error	Standardized coeff. (Beta)	t	Sig.	Statistical analysis
Dependent variable: Yield						
Constant	815.58	11.73		69.52	0.00	
pc_interception at 30 DAE	145.34	12.17	0.96	11.94	0.00	
R^2						0.92
Adj. R^2						0.92
SE (est.)						43.89
Dependent variable: Dry matter at 30 DAE						
Constant	27.14	0.53		51.15	0.00	
pc_interception at 30 DAE	4.18	0.65	0.69	6.46	0.00	
pc_absorption30	2.35	0.65	0.39	3.63	0.00	
R^2						0.91
Adj. R^2						0.89
SE (est.)						1.99
Dependent variable: Dry matter at 45 DAE						
Constant	138.95	4.06		34.23	0.00	
pc_absorption at 30 DAE	57.58	4.21	0.97	13.67	0.00	
R^2						0.94
Adj. R^2						0.94
SE (est.)						15.19
Dependent Variable: Dry matter at 60 DAE						
Constant	492.77	10.45		47.14	0.00	
pc_absorption at 30 DAE	153.61	10.85	0.97	14.16	0.00	
R^2						0.94
Adj. R^2						0.94
SE (est.)						39.11

Table 7: Relationship among radiation components, dry matter production and yield of greengram under sesamum-greengram intercropping system

Variables	Unstandardized coeff. B	Unstandardized coeff. Std. error	Standardized coeff. (Beta)	t	Sig.	Statistical analysis
Dependent variable: Yield						
Constant	620.360	8.980		69.09	0.000	
pc_interception at 30 DAE	142.210	9.270	0.970	15.33	0.000	
R^2						0.94
Adj. R^2						0.94
SE (est.)						35.92
Dependent variable: Dry matter at 30 DAE						
Constant	43.810	2.110		20.78	0.000	
pc_interception at 30 DAE	13.110	2.180	0.850	6.02	0.000	
R^2						0.72
Adj. R^2						0.70
SE (est.)						8.43
Dependent variable: Dry matter at 45 DAE						
Constant	116.780	6.000		19.47	0.000	
pc_interception at 45 DAE	40.140	10.910	0.870	3.68	0.000	
pc_transmission at 30 DAE	61.980	12.250	1.350	5.06	0.000	
pc_absorption at 45 DAE	41.820	13.210	0.910	3.17	0.010	
R^2						0.78
Adj. R^2						0.73
SE (est.)						23.99
Dependent variable: Dry matter at 60 DAE						
Constant	318.810	13.790		23.13	0.000	
pc_interception60	130.590	14.240	0.930	9.17	0.000	
Constant	318.810	9.970		31.98	0.000	
pc_interception60	101.850	12.890	0.720	7.90	0.000	
pc_transmission60	-47.806	12.885	-0.339	-3.71	0.003	
R^2						0.93
Adj. R^2						0.92
SE (est.)						39.88

companion crop are different. The tall crop grows faster than the short one and a veil of shadows which hampers the interception and absorption is created over the short crop. Principal component regression analysis showed that dry matter accumulation in greengram was principally controlled by the interception of PAR on all the dates of observations (Table 7). During the later phase of growth (45 and 60 DAE), besides interception, absorption and

Table 8: Effect of different treatments on yield (kg ha^{-1}) of sesamum and greengram in sesamum-greengram intercropping system

	Yield					
	2007		2008		Land equivalent ratio	
Treatments	Sesamum	Greengram	Sesamum	Greengram	2007	2008
S (Sole)	825.0^{b}	-	950^{c}	-	-	-
G1 (Sole)	-	825.2^{a}	-	803^{b}	-	-
G2 (Sole)	-	841.6^{a}	-	845^{a}	-	-
S:G1 (1:1)	650.0^{e}	644.0^{b}	667^{e}	625^{d}	1.56	1.47
S:G2 (1:1)	648.0^{e}	650.0^{b}	665^{e}	675^{c}	1.55	1.49
S:G1 (2:1)	713.6^{d}	540.0^{c}	750^{d}	527^{f}	1.51	1.40
S:G2 (2:1)	780.0^{c}	550.0^{c}	765^{d}	600^{e}	1.54	1.51
S:G1 (4:1)	930.0^{a}	410.0^{e}	1020^{b}	450^{h}	1.61	1.63
S:G2 (4:1)	932.0^{a}	430.0^{d}	1120^{a}	510^{g}	1.63	1.77

transmission also played a major role in dry matter production in greengram crop. About 70, 73 and 92% variation in dry matter production by greengram could be explained through the variation in interception and absorption of PAR on 30, 45 and 60 DAS, respectively.

It was also interesting to note that the R^2 value did not show much change in case of sesamum canopy whereas it gradually increased in case of greengram with the advancement of crop age indicating a strong association between absorption and interception of PAR with dry matter accumulation. This might be due to reduiced interference of tall crop during the later phase.

Moreover, during the later phase fall of the senile sesamum leaves from the lower layers created a space through which radiation was transmitted to the short statured greengram canopy. Lott *et al.* (2009) also observed a reduction in biomass and grain yield in maize when incident radiation was reduced under combined canopy of forest and maize.

In the present investigation, absorption and interception by the greengram crop were reduced by the interference of sesamum, although the scattering from the sesamum canopy seemed to be beneficial for the greengram.

Seed yield: The seed yields (kg ha^{-1}) of sesamum and greengram have been shown in Table 8. Seed yields of sesamum recorded a significant increase when sesamum was grown with greengram in 4:1 row ratio which was followed by sole stand.

When sesamum was intercropped with greengram in other row ratios, yield was rather depressed and maximum depression was observed when sesamum was intercropped with greengram in 1:1 row ratio (Table 8). About 92% variation in seed yield could be explained through interception of PAR during the early phase of sesamum growth (Table 6). The seed yield in greengram was maximum under sole stand. The seed yield was drastically reduced when greengram was grown in association with sesamum. The response of varieties was different and WBM-4-34-1-1 recorded significantly higher seed yield than that of B-105 in both the years of experimentation.

Principal component regression analysis showed that the seed yield in greengram solely depended on interception of PAR during earlier phase of growth (Table 7).

About 94% variation in seed yield in greengram could be explained through the variation in interception of PAR during 30 DAS indicating importance of interception at the early phase in case of short statured component crop.

CONCLUSION

Absorption and interception of radiation regulate the productive potentiality by a crop. In the present study, both absorption and interception were greatly influenced by the crop as well as their row arrangement in the field. When 4 rows of sesamum were grown in companion of 1 row of greengram, sesamum recorded the highest absorption and interception whereas the sole stand of greengram was proved to be effective in absorption and interception of PAR.

Dry matter accumulation was significantly related to absorption and interception of PAR for both the crops indicating increased productivity of crop with increased absorption. The seed yield in sesamum was better in 4:1 intercropping whereas the sole grrengram recorded the maximum yield. The interception of PAR within sesamum and greengram during the early phase played a determining role in the seed yields of both the crops. In eastern Indian Plain Zone, greengram should not be grown as a companion crop of sesamum when greengram would be considered as the principal crop.

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