Optical properties of sesamum and green gram under sesamum-green gram intercropping system

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ABSTRACT

Spectral properties of vegetation are important to that aspect, that it affects the radiation environment within the crop canopy. Spectral behaviour of leaf becomes complicated in an intercropping system.A two year study was conducted to analyze the effect of radiation environment in sesamum-green gram intercropping system. Altogether there were nine treatment combinations, where three treatments were related to sole crops of sesamum (cv. Rama) and green gram (cv. B-105 and cv. WBM-4-34-1-1) and remaining treatments represented the intercropping system, where sesamum and green gram were intercropped in 1:1, 2:1 and 4:1 row ratio and the whole experiment was conducted in a RBD layout with four replications at Instructional Farm, B.C.K.V., Jaguli.Absorptance (α), transmittance (ζ) and reflectance (ρ) of sesamum and green gram leaves, were measured at 9.30, 11.30 and 13.30 hrs on 30, 45 and 60th days after emergence, with the help of Tube Solarimeter and Line Quantum Sensor. The results showed that the absorptances for TSR and PAR increased from 9.30hr to 11.30 hr, following a decline at 13.30h under sole crop condition of sesamum and green gram, however the reflectances and transmittances for TSR and PAR recorded a dip at 11-30h with higher flanks at 9-30 and 13.30 h. Under intercropping, all the optical properties of the sesamum and green gram leaves were altered in comparison to sole crop. The productivity of sole green gram was higher than any intercrop row ratios, suggesting unsuitability of growing green gram with sesamum. If sesamum is chosen for main crop, then one may go for 4:1 row ratio, in which absorptance of sesamum will be increased resulting higher productivity of sesamum

Key words: Absorptance, PAR, reflectance, transmittance, and TSR

The solar radiation is generally intercepted by natural entities, such as water, soil or leaf and the energy is absorbed, reflected and sometimes transmitted. At the short wavelength, high frequency end of solar spectrum, radiative property of biological entities is determined by the presence of pigments, absorbing radiation at wavelengths, associated with specific electron transitions (Monteith and Unsworth, 2001). The interaction of radiation with plant leaves is extremely complicated. The spectral properties of leaves viz. absorptance, transmittance and reflectance, are not the inherent intrinsic properties of leaves in the context of interaction with radiation. These properties differ due to age, orientation of leaves and due to the apparent position of sun (*i.e.,* solar elevation angle)in the sky on a particular day (Gates, 1981). Spectral properties distinctly determine the productive potential of a particular crop in relation to solar radiation. Monteith and Unsworth (2001), Gates (1981), had made a detailed study on the spectral properties of different plant species, particularly of forest and plantation crops; very few inclusions of field crops are in their investigation. More over, their investigation remains confined to high latitude climate.

Spectral properties of leaf under mixed stand may not be similar to that of a single crop stand (Sole crop). Diurnal pattern of variation has not also been investigated. The present study addresses this paucity of information. In the present context, a two year experiment has been carried out to find out the spectral properties of two different crops (sesamum and green gram) growing in a same plot in different row ratios in comparison to a sole crop stand; the pattern of diurnal variation has also been looked into. The crop scientists may ask about the utilities of this kind of study; but the importance lies on this count that their intercrop row ratios may get a scientific basis when the interaction of solar radiation with crop will be considered.

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MATERIALS AND METHODS

The field experiment was carried out at the Instructional Farm, Jaguli, Bidhan Chandra Krishi Viswavidyalaya, West Bengal, India during Pre-kharif seasons of 2006 and 2007. The Farm is located at $22^0$56' N latitude and $88^0$32' E latitude at an elevation of 9.75m above mean sea level. The soil is typical alluvial (Entisol) and sandy loam in texture, with pH 6.8.

The total organic 'C', total 'N' , available 'P' and 'K' status were 0.63%, 6.06% 18.47 kg/ha and 127.22 kg/ha respectively. The zone is classified as having a tropical humid climate with three distinct seasons divided into winter (November to February), pre-kharif (March–May) and kharif (June - October). The mean monthly minimum temperature is about 16.2^0C in January. The annual rainfall generally varies from 1400- 1500 mm. most of which is received from June- September. The maximum temperatures were recorded in May both in 2007 (35.2^0C) and in 2008 (36^0C) while the lowest temperatures were 16.2^0C (2007) and 21.5^0C (2008) in March. The month of July recorded the highest relative humidity and the month of March, the lowest value in both the years.

One cultivar of sesamum (cv. Rama) and two cultivars of greengram (cv. B-105 and cv. WBM-4-34-1-1), were sown as sole and intercrop in different row combinations with total nine different treatments 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: green gram (cv. WBM-4-34-1-1-) (1:1) sesamum : green gram (cv. B-105) 2:1, sesamum: greengram (WBM-4-34-1-1) 2:1, sesamum: greengram (cv. B-105) 4:1 and sesamum: greengram (cv. WBM-4-34-1-1) 4:1. All these treatments were allotted to the experimental plot, in a Randomised Block Design, in four replications. The size of each plot was 5 × 3m. Absorptance (α), transmittance (ζ) and reflectance (ρ) of both sesamum and green gram leaves were measured at 9.30, 11.30 and 13.30 hrs on 30, 45 and 60^{th} days after emergence with the help of Tube Solarimeter and Line quantum sensor. The results of the investigation have been presented.

RESULTS AND DISCUSSION

Sesamum

Absorptance

Pattern of diurnal variation in absorptance of sesamum under sesamum-green gram intercropping system has been presented in Table 1. Absorptance of sesamum leaf recorded a peak at 11.30 h when the solar elevation angle was maximum at this latitude. This was true for TSR and PAR, irrespective of years and dates of observations. However, the difference in magnitude was evident in all cases.

Absorptance of leaf depends on the solar elevation angle (Gates, 1981, Grace, 1983 and Monteith and Unsworth 2001). Absorptance increased with the progress of growth. Average absorptance of sesamum leaf increased by 6.97 and 6.52 percent respectively at 45 and 60 DAE, when compared with the absorptances of 30 or 45 DAE. Gates (1981), observed that the mean absorptance for broad deciduous leaves increased with the leaf age by 5-9%. The author also observed that for a high sun, mean absorptance ranged from 0.48 to 0.56. In the present study, for high sun the mean absorptance ranged from 0.51 to 0.61 for TSR in 2007; from 0.56 to 0.81 for TSR in 2008; from 0.52 to 0.81 for PAR in 2007; and 0.67 to 0.86 for PAR in 2008. Although, Gates (1981), suggested an approximate value of absorptance as 0.56, but his investigation was confined in temperate climate.

In this tropical climate (Lat $22^{0}56'$ N and $88^{0}32'$ E) values of absorptance would be much higher which might be detrimental to higher productivity of crops. Due to this reason, mid day closure of stomata is observed in tropical climate, where water is limiting, not the light. Under intercropping, absorptance of sesamum leaf was altered in comparison to sole crop; absorptance was higher in sole crop in comparison to 1:1 or 2:1 sesamum greengram row ratios, however for 4:1 ratio, the reverse was observed. This suggested that, absorptances of sesamum leaf under low intercropped row ratios, were reduced indicating the probability of lower productivity of sesamum; however for 4:1 sesamum green gram ratio, absorptances for TSR were increased by 7.95, 9.78 and 11% on 30^{th}, 45^{th} and 60^{th} DAE over sole crop in 2007. This high absorptance might be helpful for increasing the productivity of sesamum under this row ratio.

Reflectance

The reflectance of sesamum leaf decreased with the increase in solar elevation angle, the highest reflectance was observed in sesamum, when it was intercropped with green gram in 1:1 ratio; if two cultivars of greengram were brought to the system, reflectance of sesamum leaf was reduced when it was grown with the G_2 cultivar irrespective of row ratios.

This suggested that the cultivar G_2 had a capability to alter the reflectance pattern of sesame, more effectively. On 30^{th} DAE (2007) average reflectance of TSR for sesamum leaf increased by 34.72% over sole crop in 1:1 intercropped ratio. In case of 2:1 ratio, average reflectance increased by 21.7% and in 4:1 ratio the increase was only 2.16% over sole crop. Reflectance decreased with the progress of growth; the mean reflectance of sesamum reduced gradually from 30 to 60 DAE. In 2008, there was a repeatation of trend but not of values. The reflectance of PAR by sesamum was lower when the solar elevation angle was higher.

The mean reflectance for PAR was 0.25 for sole crop. However reflectance increased under 1:1 or 2:1 intercropped ratios and the reverse was observed in 4:1 intercropped ratio. During early phase of growth, reflectance increased due to presence of leaf hair as well as high amount of cell sap in leaf tissues. The young leaf also dumps the atmospheric heat in this particular fashion to protect the photosynthetic apparatus (Grace, 1983). In the present study, it was observed that, the reflectance from sesamum canopy was higher during early or later part of the day. Reflectance of almost every surface increases, when the angle between the surface and the incident beam becomes small. Leaves, which receive the sunlight at a small angle, scatter the light in many directions (Grace, 1983). Foliage in the present case behaved as a compound surface, reflecting more radiation when the angle between the surface and beam was small, which was observed in early morning or in afternoon hours.

Under intercropping, reflectance of sesamum leaf in 1:1 or in 2:1 row ratios was higher in comparison to sole crop with a few exception. This might be due to the interference of green gram at the interface, because one or two rows of sesamum was closely sandwitching one row of green gram. However, when distance between two crops increased i.e. in 4:1 row ratio, where four rows of sesamum made a uniform surface character for about 120 cm., reflectivity was lower than the sole crop, indicating the probability of higher absorption of PAR leading to the increased productivity of the crop.

Transmittance

Pattern of diurnal variation in transmittance (TSR and PAR) of sesamum has been reported in Table 3. The results showed that the transmittance recorded a dip at 11.30 h with a higher flank at 9.30 and 13.30 h. This was a general trend, observed on all days of observation and in all years. In general, transmittance decreased with the progress of growth, with a few aberrations, observed in case of PAR on 60^{th} DAE in 2008. Reduction in transmittance might be due to the increased LAI with the progress of growth. The trend was similar for TSR and PAR, the 2007 trend was repeated in 2008, although magnitude of values of transmittance was different in all cases, which indicated that the transmittance was not a character of inheritance rather it depends on solar elevation angle as well as LAI of crop.

On 30^{th} DAE, for TSR (2007), mean transmittance of seasamum was maximum under sole crop and did not vary remarkably in case of inter cropped situation, irrespective to the dates of observation. In 2008, transmittance increased in case of 1:1 or 2:1 ratio, but declined incase of 4:1 ratio, the extents of increases were 31.6, 23.7 and 21.4 percent on 30, 45 and 60^{th} DAE for 1:1 ratio 23.7 and 15.8 percent on 30 and 45 DAE for 2:1 ratio however reductions in transmittance were 13.1 and 26.3 percent for 4:1 ratio on 30 and 45 DAE. On 60^{th} DAE, the transmittance in sole crop was similar to 4:1 row ratios. The results showed, the increase of transmittance in case of intercropping was maximum in 1:1 ratio, where there was a high probability of interference by the greengram crop. With the progress of growth, height of seasmum increased, it surpassed the green gram, reducing the probability of scattering from the intercropped surface.

Incase of PAR in 2007 mean transmittances were almost similar in all treatments except in 4:1 intercropped ratio, where a reduction in transmittance was observed, the trend was repeated in 2008.

Increase in transmittance in 1:1 or 2:1 row ratios might be the resultant transmittance of both crops under intercropping system. Increase in transmittance of TSR and PAR within the canopy might increase the internal temperature of the canopy leading to higher respiration of lower leaves, water stress and low yield of the crops. Higher transmittance, indicated the low LAI under intercropped (1:1 and 2:1) situation. In case of 4:1 row ratio the transmittance was either low or similar to the sole crop indicating high LAI as well as reduced competition from the companion greengram crop. In sesamum the transmittance was higher than reflectance with a few aberrations. Gates (1981) argued that transmittance might be higher or lower than the reflectance depending on the crop. Aberrations observed in this case, might be attributed to the presence of companion crop in intercropping.

Green gram

Absorptance

The pattern of diurnal variation in absorptance of TSR and PAR in greengram cultivars has been recorded in Table 4. The absorptance of green gram recorded a unimodal increase having a peak at 11.30h. The observation is independent of TSR, PAR, days of observation and the year. The absorptance of green gram cultivars increased with age. The cultivar G_2 recorded a higher absorptance in comparison to G_1. Reduction of absorptance was observed due to intercropping. The maximum reduction was recorded in 4:1 row ratio, such as 41.18, 35.85, and 45.61 percent reduction were noted for TSR on 30, 45 and 60^{th} days after emergence in 2007. High reduction was observed due to shading effect of sesamum under intercropping system. The trend was repeated in 2008 with the variation in magnitude of values. This scenario in 4:1 row ratio, might invite the reduction in total biomass production, LAI and yield of green gram cultivars. With the advancement of growth, both the absorptances for TSR and PAR were reduced gradually indicating the limitations of light to greengram crop when grown with a tall crop like sesamum. Results suggested, that the green gram was not a suitable crop which could be grown as an inter crop with sesamum if the above row ratios are maintained.

Table 1 : Pattern of diurnal variation in absorptance of radiation in sesamum under sesamum-greengram intercropping.

Treatment	TSR(2007)			TSR(2008)			PAR(2007)			PAR(2008)		
	9.30h	11.30h	13.30h	9.30h	11.30h	13.30h	9.30h	11.30h	13.30h	9.30h	11.30h	13.30h
30 DAE												
S (Sole)	0.40	0.51	0.41	0.56	0.66	0.55	0.49	0.56	0.46	0.62	0.77	0.59
S:G1(1:1)	0.32	0.50	0.33	0.46	0.57	0.45	0.47	0.53	0.45	0.59	0.70	0.54
S:G2(1:1)	0.36	0.50	0.35	0.45	0.56	0.44	0.47	0.52	0.45	0.58	0.67	0.50
S:G1(2:1)	0.38	0.50	0.37	0.48	0.58	0.47	0.48	0.54	0.45	0.60	0.74	0.56
S:G2(2:1)	0.40	0.53	0.40	0.50	0.60	0.48	0.50	0.57	0.46	0.60	0.76	0.58
S:G1(4:1)	0.43	0.54	0.42	0.58	0.68	0.57	0.50	0.60	0.48	0.64	0.80	0.62
S:G2(4:1)	0.45	0.55	0.46	0.62	0.70	0.60	0.56	0.70	0.50	0.65	0.83	0.63
45 DAE												
S (Sole)	0.41	0.56	0.42	0.60	0.69	0.56	0.53	0.70	0.48	0.65	0.80	0.62
S:G1(1:1)	0.35	0.51	0.36	0.48	0.60	0.50	0.50	0.65	0.46	0.60	0.72	0.58
S:G2(1:1)	0.37	0.52	0.38	0.46	0.58	0.45	0.48	0.63	0.45	0.60	0.70	0.52
S:G1(2:1)	0.40	0.54	0.39	0.50	0.62	0.48	0.50	0.64	0.48	0.62	0.76	0.57
S:G2(2:1)	0.41	0.56	0.42	0.54	0.65	0.50	0.52	0.67	0.50	0.62	0.79	0.60
S:G1(4:1)	0.45	0.58	0.44	0.60	0.70	0.58	0.54	0.72	0.52	0.65	0.83	0.63
S:G2(4:1)	0.48	0.60	0.47	0.65	0.75	0.63	0.62	0.75	0.56	0.66	0.86	0.67
60 DAE												
S (Sole)	0.45	0.60	0.44	0.67	0.79	0.58	0.55	0.73	0.52	0.66	0.81	0.64
S:G1(1:1)	0.38	0.54	0.40	0.60	0.70	0.50	0.52	0.68	0.49	0.62	0.75	0.60
S:G2(1:1)	0.40	0.52	0.42	0.60	0.66	0.48	0.50	0.65	0.48	0.61	0.71	0.55
S:G1(2:1)	0.42	0.53	0.43	0.65	0.72	0.52	0.51	0.65	0.50	0.65	0.78	0.58
S:G2(2:1)	0.45	0.58	0.46	0.66	0.75	0.59	0.56	0.72	0.52	0.66	0.80	0.62
S:G1(4:1)	0.50	0.61	0.48	0.66	0.81	0.61	0.60	0.78	0.55	0.68	0.85	0.64
S:G2(4:1)	0.56	0.65	0.53	0.67	0.83	0.63	0.66	0.81	0.62	0.68	0.87	0.68

Table2 : Pattern of diurnal variation in reflectance of radiation in sesamum under sesamum-greengram intercropping.

Treatment	TSR(2007)			TSR(2008)			PAR(2007)			PAR(2008)		
	9.30h	11.30h	13.30h	9.30h	11.30h	13.30h	9.30h	11.30h	13.30h	9.30h	11.30h	13.30h
30 DAE												
S (Sole)	0.23	0.21	0.26	0.23	0.20	0.24	0.26	0.23	0.27	0.25	0.20	0.26
S:G1(1:1)	0.32	0.29	0.35	0.27	0.24	0.28	0.32	0.27	0.33	0.30	0.26	0.32
S:G2(1:1)	0.30	0.28	0.32	0.28	0.24	0.30	0.30	0.26	0.32	0.28	0.25	0.30
S:G1(2:1)	0.28	0.27	0.30	0.25	0.22	0.27	0.27	0.23	0.28	0.26	0.24	0.29
S:G2(2:1)	0.28	0.26	0.29	0.24	0021	0.26	0.26	0.23	0.26	0.25	0.21	0.28
S:G1(4:1)	0.25	0.21	0.27	0.22	0.20	0.24	0.26	0.22	0.26	0.25	0.20	0.26
S:G2(4:1)	0.23	0.20	0.26	0.20	0.18	0.21	0.25	0.20	0.25	0.24	0.16	0.25
45 DAE												
S (Sole)	0.20	0.18	0.24	0.20	0.16	0.21	0.22	0.20	0.23	0.20	0.16	0.23
S:G1(1:1)	0.30	0.26	0.32	0.26	0.23	0.26	0.29	0.25	0.30	0.28	0.24	0.28
S:G2(1:1)	0.30	0.28	0.30	0.26	0.25	0.25	0.28	0.25	0.30	0.26	0.24	0.28
S:G1(2:1)	0.28	0.25	0.26	0.24	0.22	0.25	0.26	0.22	0.28	0.25	0.22	0.28
S:G2(2:1)	0.28	0.24	0.28	0.23	0.22	0.24	0.25	0.22	0.26	0.24	0.20	0.26
S:G1(4:1)	0.20	0.16	0.21	0.19	0.15	0.20	0.24	0.19	0.24	0.22	0.18	0.24
S:G2(4:1)	0.18	0.15	0.21	0.18	0.12	0.20	0.22	0.18	0.22	0.20	0.16	0.22
60 DAE												
S (Sole)	0.19	0.16	0.22	0.18	0.15	0.20	0.21	0.16	0.22	0.20	0.14	0.22
S:G1(1:1)	0.28	0.24	0.29	0.25	0.21	0.26	0.27	0.20	0.28	0.25	0.19	0.26
S:G2(1:1)	0.28	0.26	0.28	0.25	0.22	0.24	0.26	0.20	0.26	0.24	0.20	0.24
S:G1(2:1)	0.25	0.22	0.24	0.24	0.20	0.24	0.25	0.19	0.26	0.23	0.17	0.24
S:G2(2:1)	0.26	0.22	0.26	0.22	0.20	0.20	0.24	0.18	0.25	0.22	0.16	0.22
S:G1(4:1)	0.18	0.15	0.20	0.18	0.15	0.19	0.22	0.16	0.22	0.18	0.12	0.20
S:G2(4:1)	0.18	0.14	0.18	0.17	0.10	0.18	0.20	0.15	0.21	0.16	0.09	0.18

S – Sesamum (cv. Rama), G_1 – Greengram (cv. B-105), G_2 – Greengram (cv. WBM-4-34-1-1),
DAE- Days after emergence, TSR- Total solar radiation, PAR- Photosynthetically active radiation

Table 3 : Pattern of diurnal variation in trasmittance of radiation in sesamum under sesamum-greengram intercropping.

Treatment	TSR(2007)			TSR(2008)			PAR(2007)			PAR(2008)		
	9.30h	**11.30h**	**13.30h**	**9.30h**	**11.30h**	**13.30h**	**9.30h**	**11.30h**	**13.30h**	**9.30h**	**11.30h**	**13.30h**
30 DAE												
S (Sole)	0.37	0.28	0.33	0.21	0.14	0.21	0.25	0.21	0.27	0.13	0.03	0.15
S:G1(1:1)	0.36	0.21	0.32	0.27	0.19	0.27	0.21	0.20	0.22	0.11	0.04	0.14
S:G2(1:1)	0.34	0.22	0.33	0.27	0.20	0.27	0.23	0.22	0.23	0.14	0.08	0.20
S:G1(2:1)	0.34	0.23	0.33	0.27	0.20	0.27	0.25	0.23	0.27	0.14	0.02	0.15
S:G2(2:1)	0.32	0.21	0.31	0.26	0.19	0.26	0.24	0.20	0.28	0.15	0.03	0.14
S:G1(4:1)	0.32	0.35	0.31	0.20	0.12	0.20	0.24	0.18	0.26	0.11	0.02	0.12
S:G2(4:1)	0.32	0.25	0.28	0.18	0.18	0.18	0.24	0.10	0.25	0.11	0.01	0.12
45 DAE												
S (Sole)	0.39	0.26	0.34	0.20	0.15	0.22	0.25	0.10	0.29	0.15	0.14	0.15
S:G1(1:1)	0.35	0.23	0.32	0.26	0.17	0.24	0.21	0.10	0.24	0.12	0.04	0.14
S:G2(1:1)	0.33	0.20	0.32	0.28	0.17	0.30	0.24	0.12	0.25	0.14	0.06	0.20
S:G1(2:1)	0.32	0.21	0.35	0.26	0.14	0.27	0.24	0.14	0.24	0.13	0.02	0.15
S:G2(2:1)	0.31	0.20	0.30	0.23	0.23	0.26	0.23	0.11	0.24	0.14	0.01	0.14
S:G1(4:1)	0.35	0.26	0.35	0.21	0.15	0.32	0.22	0.09	0.24	0.13	0.	0.13
S:G2(4:1)	0.34	0.25	0.32	0.17	0.13	0.17	0.16	0.07	0.22	0.14		0.11
60 DAE												
S (Sole)	0.36	0.24	0.34	0.15	0.06	0.22	0.24	0.11	0.26	0.14	0.05	0.14
S:G1(1:1)	0.34	0.22	0.31	0.15	0.09	0.24	0.21	0.12	0.25	0.13	0.06	0.14
S:G2(1:1)	0.32	0.22	0.30	0.15	0.12	0.28	0.24	0.15	0.26	0.15	0.09	0.21
S:G1(2:1)	0.33	0.25	0.33	0.11	0.08	0.24	0.24	0.16	0.24	0.12	0.05	0.18
S:G2(2:1)	0.29	0.20	0.28	0.12	0.05	0.21	0.20	0.10	0.23	0.12	0.04	0.16
S:G1(4:1)	0.32	0.24	0.32	0.16	0.04	0.20	0.18	0.06	0.23	0.14	0.03	0.16
S:G2(4:1)	0.34	0.21	0.29	0.16	0.07	0.19	0.14	0.04	0.17	0.16	0.04	0.14

Table 4 : Pattern of diurnal variation in absorptance of radiation in greengram cultivars under sesamum-greengram intercropping.

Treatment	TSR(2007)			TSR(2008)			PAR(2007)			PAR(2008)		
	9.30h	**11.30h**	**13.30h**	**9.30h**	**11.30h**	**13.30h**	**9.30h**	**11.30h**	**13.30h**	**9.30h**	**11.30h**	**13.30h**
30 DAE												
G1(Sole)	0.48	0.60	0.44	0.44	0.60	0.42	0.52	0.60	0.48	0.50	0.76	0.56
G2(Sole)	0.50	0.64	0.48	0.46	0.68	0.48	0.56	0.62	0.60	0.52	0.78	0.51
S:G1(1:1)	0.30	0.48	0.36	0.38	0.50	0.40	0.40	0.56	0.48	0.48	0.58	0.44
S:G2(1:1)	0.40	0.58	0.46	0.42	0.55	0.41	0.48	0.62	0.60	0.48	0.65	0.45
S:G1(2:1)	0.30	0.45	0.32	0.32	0.48	0.36	0.40	0.50	0.42	0.40	0.48	0.43
S:G2(2:1)	0.32	0.48	0.42	0.36	0.51	0.40	0.42	0.52	0.46	0.41	0.50	0.44
S:G1(4:1)	0.28	0.30	0.26	0.30	0.46	0.32	0.38	0.48	0.40	0.40	0.46	0.38
S:G2(4:1)	0.30	0.40	0.36	0.35	0.46	0.33	0.40	0.50	0.42	0.41	0.48	0.38
45 DAE												
G1(Sole)	0.50	0.62	0.45	0.40	0.48	0.44	0.53	0.60	0.50	0.52	0.56	0.53
G2(Sole)	0.52	0.65	0.50	0.50	0.78	0.52	0.57	0.65	0.62	0.53	0.78	0.52
S:G1(1:1)	0.36	0.49	0.38	0.40	0.56	0.42	0.42	0.57	0.50	0.58	0.65	0.48
S:G2(1:1)	0.42	0.50	0.46	0.43	0.60	0.45	0.50	0.58	0.54	0.59	0.66	0.50
S:G1(2:1)	0.35	0.46	0.33	0.33	0.52	0.38	0.41	0.52	0.43	0.44	0.52	0.45
S:G2(2:1)	0.40	0.49	0.43	0.38	0.54	0.40	0.43	0.53	0.48	0.45	0.54	0.46
S:G1(4:1)	0.30	0.35	0.28	0.32	0.48	0.34	0.40	0.50	0.42	0.42	0.48	0.40
S:G2(4:1)	0.36	0.42	0.35	0.36	0.50	0.36	0.42	0.51	0.43	0.44	0.50	0.42
60 DAE												
G1(Sole)	0.52	0.66	0.47	0.42	0.65	0.45	0.56	0.62	0.51	0.57	0.60	0.54
G2(Sole)	0.53	0.70	0.52	0.52	0.78	0.53	0.58	0.68	0.63	0.60	0.78	0.56
S:G1(1:1)	0.37	0.58	0.38	0.43	0.58	0.44	0.43	0.60	0.51	0.60	0.66	0.50
S:G2(1:1)	0.45	0.60	0.47	0.46	0.61	0.47	0.52	0.62	0.55	0.62	0.67	0.52
S:G1(2:1)	0.36	0.48	0.34	0.34	0.53	0.38	0.42	0.53	0.44	0.45	0.55	0.46
S:G2(2:1)	0.43	0.50	0.44	0.40	0.55	0.42	0.44	0.54	0.48	0.46	0.56	0.48
S:G1(4:1)	0.32	0.42	0.30	0.33	0.50	0.35	0.41	0.52	0.43	0.43	0.52	0.42
S:G2(4:1)	0.37	0.43	0.36	0.38	0.51	0.37	0.43	0.52	0.43	0.44	0.53	0.45

S – Sesamum (cv. Rama), G_1 – Greengram (cv. B-105), G_2 – Greengram (cv. WBM-4-34-1-1

DAE- Days after emergence, TSR- Total solar radiation, PAR- Photosynthetically active radiation

Table 5 : Pattern of diurnal variation in reflectance of radiation in greengram cultivars under sesamum-greengram intercropping.

Treatment	TSR(2007)			TSR(2008)			PAR(2007)			PAR(2008)		
	9.30h	**11.30h**	**13.30h**	**9.30h**	**11.30h**	**13.30h**	**9.30h**	**11.30h**	**13.30h**	**9.30h**	**11.30h**	**13.30h**
30 DAE												
G1(Sole)	0.20	0.12	0.20	0.22	0.13	0.21	0.23	0.17	0.22	0.22	0.16	0.20
G2(Sole)	0.18	0.10	0.16	0.20	0.11	0.18	0.22	0.16	0.21	0.21	0.15	0.20
S:G2(1:1)	0.20	0.18	0.20	0.23	0.17	0.24	0.24	0.20	0.22	0.23	0.19	0.22
S:G1(2:1)	0.24	0.22	0.26	0.26	0.22	0.27	0.28	0.23	0.27	0.27	0.21	0.26
S:G2(2:1)	0.23	0.21	0.24	0.25	0.21	0.26	0.26	0.22	0.25	0.24	0.21	0.24
S:G1(4:1)	0.26	0.23	0.27	0.27	0.23	0.28	0.29	0.24	0.28	0.27	0.22	0.27
S:G2(4:1)	0.24	0.22	0.25	0.26	0.23	0.27	0.27	0.23	0.28	0.26	0.21	0.27
45 DAE												
G1(Sole)	0.19	0.12	0.20	0.18	0.10	0.20	0.20	0.15	0.21	0.18	0.14	0.19
G2(Sole)	0.17	0.11	0.19	0.16	0.09	0.18	0.19	0.14	0.18	0.17	0.12	0.17
S:G1(1:1)	0.21	0.17	0.22	0.20	0.16	0.22	0.24	0.16	0.23	0.23	0.14	0.22
S:G2(1:1)	0.19	0.15	0.18	0.18	0.16	0.21	0.22	0.15	0.21	0.21	0.13	0.21
S:G1(2:1)	0.23	0.18	0.25	0.22	0.17	0.23	0.26	0.18	0.27	0.25	0.16	0.26
S:G2(2:1)	0.21	0.16	0.22	0.20	0.17	0.22	0.25	0.16	0.26	0.24	0.15	0.25
S:G1(4:1)	0.25	0.22	0.26	0.24	0.20	0.25	0.28	0.21	0.27	0.27	0.20	0.26
S:G2(4:1)	0.23	0.21	0.25	0.24	0.18	0.24	0.26	0.20	0.27	0.26	0.19	0.26
60 DAE												
G1(Sole)	0.18	0.10	0.17	0.17	0.09	0.18	0.18	0.09	0.20	0.16	0.08	0.15
G2(Sole)	0.16	0.10	0.18	0.15	0.09	0.16	0.16	0.07	0.17	0.14	0.06	0.13
S:G1(1:1)	0.20	0.16	0.21	0.20	0.15	0.20	0.23	0.14	0.21	0.20	0.11	0.20
S:G2(1:1)	0.18	0.14	0.17	0.17	0.12	0.16	0.21	0.12	0.20	0.20	0.10	0.19
S:G2(2:1)	0.20	0.13	0.21	0.18	0.15	0.18	0.23	0.11	0.24	0.22	0.10	0.21
S:G1(4:1)	0.24	0.18	0.25	0.23	0.17	0.24	0.27	0.14	0.26	0.26	0.14	0.24
S:G2(4:1)	0.22	0.17	0.24	0.22	0.16	0.22	0.25	0.12	0.26	0.25	0.11	0.23

Table 6 : Pattern of diurnal variation in trasmittance of radiation in greengram cultivars under sesamum-greengram intercropping.

Treatment	TSR(2007)			TSR(2008)			PAR(2007)			PAR(2008)		
	9.30h	**11.30h**	**13.30h**	**9.30h**	**11.30h**	**13.30h**	**9.30h**	**11.30h**	**13.30h**	**9.30h**	**11.30h**	**13.30h**
30 DAE												
G1(Sole)	0.32	0.28	0.36	0.34	0.27	0.37	0.25	0.23	0.30	0.28	0.08	0.24
G2(Sole)	0.32	0.26	0.36	0.34	0.21	0.34	0.22	0.22	0.19	0.27	0.07	0.29
S:G1(1:1)	0.48	0.32	0.40	0.38	0.32	0.35	0.35	0.22	0.28	0.28	0.22	0.33
S:G2(1:1)	0.40	0.24	0.34	0.35	0.28	0.35	0.28	0.18	0.18	0.29	0.16	0.33
S:G1(2:1)	0.46	0.33	0.42	0.42	0.30	0.37	0.32	0.27	0.31	0.33	0.31	0.31
S:G2(2:1)	0.45	0.31	0.34	0.39	0.28	0.34	0.32	0.26	0.29	0.35	0.29	0.32
S:G1(4:1)	0.46	0.47	0.47	0.43	0.31	0.40	0.33	0.28	0.32	0.33	0.32	0.35
S:G2(4:1)	0.46	0.38	0.39	0.39	0.31	0.50	0.33	0.27	0.30	0.33	0.31	0.35
45 DAE												
G1(Sole)	0.31	0.26	0.35	0.42	0.42	0.36	0.27	0.25	0.29	0.30	0.30	0.28
G2(Sole)	0.31	0.24	0.31	0.34	0.15	0.30	0.24	0.21	0.20	0.30	0.10	0.31
S:G1(1:1)	0.43	0.34	0.40	0.40	0.28	0.36	0.34	0.27	0.27	0.19	0.21	0.30
S:G2(1:1)	0.39	0.35	0.36	0.39	0.24	0.34	0.28	0.27	0.25	0.20	0.21	0.29
S:G1(2:1)	0.42	0.34	0.42	0.45	0.31	0.31	0.24	0.30	0.30	0.31	0.32	0.29
S:G2(2:1)	0.39	0.35	0.35	0.42	0.29	0.38	0.32	0.31	0.26	0.31	0.31	0.29
S:G1(4:1)	0.45	0.43	0.46	0.46	0.32	0.41	0.32	0.29	0.31	0.31	0.32	0.34
S:G2(4:1)	0.41	0.37	0.40	0.40	0.32	0.40	0.32	0.29	0.30	0.30	0.31	0.32
60 DAE												
G1(Sole)	0.30	0.24	0.36	0.41	0.26	0.37	0.26	0.21	0.29	0.27	0.32	0.31
G2(Sole)	0.31	0.20	0.30	0.33	0.15	0.31	0.26	0.25	0.20	0.26	0.16	0.31
S:G1(1:1)	0.43	0.26	0.41	0.37	0.27	0.36	0.24	0.26	0.28	0.20	0.23	0.30
S:G2(1:1)	0.37	0.26	0.36	0.37	0.27	0.37	0.27	0.26	0.25	0.18	0.23	0.29
S:G1(2:1)	0.42	0.36	0.43	0.45	0.31	0.40	0.33	0.33	0.30	0.31	0.32	0.31
S:G2(2:1)	0.37	0.37	0.35	0.42	0.30	0.40	0.33	0.35	0.28	0.32	0.34	0.31
S:G1(4:1)	0.46	0.40	0.45	0.44	0.33	0.41	0.32	0.34	0.21	0.31	0.34	0.34
S:G2(4:1)	0.41	0.40	0.40	0.40	0.33	0.41	0.32	0.36	0.21	0.31	0.36	0.32

S – Sesamum (cv. Rama), G_1 – Greengram (cv. B-105), G_2 – Greengram (cv. WBM-4-34-1-1)

DAE- Days after emergence, TSR- Total solar radiation, PAR- Photosynthetically active radiation

Reflectance

Pattern of diurnal variation in reflections of radiation in greengram cultivars has been presented in Table 5. Results showed that the reflectance in G_1 was higher than G_2, both in sole and intercropped situation irrespective of dates of observation, TSR, PAR and year of investigation. The reflectance in G_1 was higher in intercropped system than the sole crop (except 30 days after emergence); reflectances increased gradually as the number of sesamum rows were increased from one to four. The results revealed that a part of TSR and PAR transmitted to the sesamum canopy was subjected to scattering by the surface of the green gram which led to the consequent increase in reflectance. As reflectance component increased under intercropping situation, there remained a probability to have a low dry matter production and yield of the short statured crop. When more number of rows of tall crop were grown in association of short crop, there was a probability of receiving the reflected radiation from the upper surface of the short crop, by the lower surface of the tall crop. This situation might help the tall crop to increase their productivity. The sesamum and green gram had a competitive height up to 30 days after emergence, thereafter sesamum won the competition in respect to height and led to a complicated situation in the pattern of reflection by green gram crop.

Transmittance

The pattern of diurnal variation in transmittance of radiation through green gram cultivars under sesamum-greengram intercropping system has been presented in Table 6. The transmittance through the greengram crop was minimum at 11.30 h in comparison to 9.30 or 13.30 hrs. The pattern of transmittance was similar in TSR, PAR and in all years of investigation. When two cultivars were considered, the transmittance was less in G_2 than in G_1, indicating the probability of higher biomass and leaf area index in G_2 in comparison to G_1. The transmittance was higher in intercropped situation than the sole crop of greengram and the maximum transmittance was observed in case of 4:1 row ratio. This might be attributed to the reflected, scattered and transmitted radiation from sesamum canopy. When four rows of sesamum were grown with one row of greengram, there remained a probability of repeated scattering from sesamum canopy. This might have some detrimental effect on growth and productivity of the short statured greengram crops. The mean transmission in general, reduced with the progress of growth, which might be due to increased LAI and height of the crop, preventing the light from penetration. Gates (1981), observed that the transmittance in the visible wavelength (400 – 700 nm), did not exceed 0.2 for *Populus deltoides* and *Nerium oleander* leaves. In the present study, the mean transmittance through the canopy was as high as 0.46 which was observed on 30^{th} DAE in 4:1 row ratio for TSR in 2007. Gate's measurement was done in case of forest plantation, where the plant height was very high, which increase the depletion of radiation; however for sunflower, transmittances for high and low Sun, were 0.23 and 0.30 respectively (Gates, 1981). The high value of transmittance at the early growth stage was also due to low LAI.

Spectral properties of crop indicate the productive potentiality of the crop. Incase of intercropping, spectral properties were altered. The 4:1 row ratio had high absorptance for sesamum, however, the reverse was true for green gram. The productivity of sole green gram was higher than any intercrop ratios, suggesting unsuitability of growing greengram with sesamum. However, if sesamum is chosen for main crop, one may go for 4:1 row ratio in which absorptance of sesamum would be increased resulting high productivity of sesamum crop.

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