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Gourav Jain
Department of Climate Change & Agricultural Meteorology
Punjab Agricultural University, Ludhiana, Punjab, India

Sarabjot Kaur Sandhu
Department of Climate Change & Agricultural Meteorology
Punjab Agricultural University, Ludhiana, Punjab, India

Correspondence
Gourav Jain
Department of Climate Change & Agricultural Meteorology
Punjab Agricultural University, Ludhiana, Punjab, India

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Radiation interception and growth dynamics in mustard under different dates of sowing

Gourav Jain and Sarabjot Kaur Sandhu

Abstract
The field experiment was conducted to study the radiation interception and growth dynamics of mustard under different dates of sowing at Punjab Agricultural University, Ludhiana. Mustard was cultivated with three dates of sowing (10th October, 5th November, 1st December) and two mustard cultivars (RLC-3 and PBR-357) replicated thrice under split plot design during *rabi* 2017-18. Photosynthetically active radiation (PAR), dry matter accumulation (DMA) and leaf area index (LAI) was recorded in different treatments at periodic intervals. The PAR interception was higher in 10th October sowing as compared to 5th November and 1st December sowing in both the cultivars RLC-3 and PBR-357 at the flowering as well as siliqua formation stage. Among the cultivars, PBR-357 intercepted more PAR than RLC-3 under all the dates of sowing at flowering and siliqua formation stage. Among dates of sowing, early sown crop (10th October) recorded highest LAI and DMA than second and third date of sowing. PBR-357 produced higher LAI and DMA as compared to RLC-3. The relationship between PAR interception, LAI and DMA gave significant values of coefficient of determination (R^2). The relationships developed explained significant percent variability in PAR interception due to leaf area index (R^2=0.85) and dry matter accumulation (R^2=0.63) in mustard.

Keywords: Cultivars, date of sowing, dry matter accumulation (DMA), leaf area index (LAI), mustard and photosynthetically active radiation (PAR)

Introduction

Indian mustard (*Brassica juncea* (L.) Czern. & Cosson) is an important oilseed crop which occupies about 80 per cent of the total cropped area under oilseed crops in India. In Punjab, rapeseed - mustard was grown on an area of 31.7 thousand hectares with production of 44.8 thousand tonnes and yield of 1413 q/ha during 2016-17 (Anonymous, 2017) [1]. Temperature, radiation and moisture are basic meteorological parameters of significance to agriculture. Under potential conditions, with adequate moisture and fertility, radiation plays the role as a decisive factor for crop growth and development. Growth and final total yields of crops largely depends on the interception and the efficiency of use of growth resources namely water, nutrient and radiation.

The interception of light by a canopy is a fundamental requirement for crop growth. Light interception and relationship to crop growth have been important concepts applicable to virtually all crops. Although canopy light interception is important for yield prediction and crop growth. All determinants of crop growth, namely radiation utilization, dry matter loss due to respiration, partitioning of assimilates to economically harvestable parts and duration of crop growth are influenced by the prevailing environmental conditions of radiation and temperature. Efficiency of conversion of radiation into dry matter depends upon plant traits and environmental conditions (Hundal *et al.* 2003) [5].

Photosynthetically active radiation (PAR) interception and its distribution within the crop canopy is important determinant of photosynthetic activity of the crop. The PAR interception by the canopy influences the leaf photosynthesis efficiency, which in turn effects the dry matter production and seed yield. Under normal conditions, interception of PAR and its utilization are low during early stages of crop growth.

The radiation plays a vital role in photosynthesis (Monteith 1972). Solar radiation, its proper interception and transmission within the crop canopy ensures the higher production. Pandey *et al.* (2010) [11] reported that the leaf area index (LAI) and dry matter production were useful biometric parameters of crop productivity and were closely related to PAR interception.

Leaf area is one of the most important growth characteristics which play important role in radiation interception and yield of crop. It is an inventory of the population of leaves that are absorbing light and momentum and exchanging heat, moisture, CO_2 and trace gases with the atmosphere. The leaf area index (LAI) controls the amount of intercepted PAR and hence photosynthesis (Smith *et al.* 1991) [14]. Kumar *et al.* (2010) [7, 11] reported that lower temperature during vegetative phase caused lowered LAI due to poor growth in late sown conditions (27th October). Kaur and Sidhu (2004) [6] also reported that with the delay in sowing date from October to December the LAI was significantly reduced in *Brassica carinata*.

Dry matter accumulation increases progressively with increase in plant age. Total dry matter accumulation of any crop is related to the net photosynthesis. Patel *et al.* (2013) [12] also reported that the increased temperatures during late reproductive phase under delayed sowing hastened the maturity and therefore, the crop growth period was shortened resulting in reduced dry matter production as well as lesser partitioning into different plant parts. The dry matter accumulation (DMA) increased progressively with the advancement of age of the crop. Total dry matter production is related to the net photosynthesis. At initial stages, dry matter production was less but increased after some time as the crop grows over time and reaches maturity. Because of higher PAR interception dry matter production also increased.

Due to changing weather conditions, there is a need to study the role of radiation interception under different dates of sowing in production of biomass of mustard so this experiment was planned to analyse the diurnal pattern of PAR interception in mustard sown under different dates of sowing with an objective to compare the extent of variation in PAR interception by changing dates of sowing and effect of this PAR interception on biometric parameters viz. dry matter accumulation and leaf area index of crop under different treatments.

Materials and Methods

The experiment was carried out during *rabi* season of 2017-18 at the Research Farm, Department of Climate Change and Agricultural Meteorology, Punjab Agricultural University, Ludhiana (30˚54'N latitude and 75˚48'E longitude and at an altitude of 247 meter above mean sea level. The experiment was conducted with three dates of sowing (10th October, 5th November, 1st December) and two mustard cultivars (RLC-3 and PBR-357) having 3 replications under split plot design.

Photosynthetically active radiation interception

The Photosynthetically active radiation (PAR) interception was measured diurnally on clear sunny day at different phenological stages with help of a Line Quantum Sensor (Model LI-190 SB) and output of Quantum Sensor was recorded with a digital multi-voltmeter. The incoming and outgoing PAR on the top of the canopy and radiation penetration at the ground surface below the crop canopy was measured. The observations were recorded at random from two places in each plot. The percent interception was calculated by using following formula given by Flenet *et al.* (1996) [3].

$$\text{PAR Interception (\%)} = \frac{\text{PAR (Incoming)} - \text{PAR (Transmitted + Reflected)}}{\text{PAR (Incoming)}} \times 100$$

Leaf area index (LAI)

Leaf area index was measured with Plant Canopy Analyzer Sun Scan Delta-1. The observations on leaf area index were periodically recorded. For better accuracy in observation the data was recorded by placing the sensor once above the crop canopy followed by placing it below the crop canopy diagonally across the rows.

Dry matter accumulation (DMA)

The periodic dry matter was recorded by taking two representative plants from each plot. The uprooted plant was first sun dried for 1-2 days and then dried in the oven at 60°C for about 72 hours till a constant weight was achieved. The data was expressed as g/plant.

Data analysis

PAR interception was calculated by using the above discussed formulae and relationships were developed between PAR interception and dry matter accumulation as well as PAR interception and leaf area index of crop recorded at 15 days interval using Microsoft EXCEL. Test of significance was applied to know the significance of R^2-values using F-table.

Results and Discussion

Photosynthetically Active Radiation (PAR) interception (%) at different phenological stages

Photosynthetically active radiation (PAR) interception and its distribution within the crop canopy is important determinant of photosynthetic activity of the crop. The PAR interception by the canopy influences the leaf photosynthesis efficiency, which in turn effects the dry matter production and seed yield. Under normal conditions, interception of PAR and its utilization are low during early stages of crop growth. Solar radiation plays a vital role in photosynthesis. The leaf area index (LAI) controls the amount of intercepted PAR and hence photosynthesis (Smith *et al.* 1991) [14]. The data on PAR interception (%) was recorded at flowering and siliqua formation stages under all treatments and presented in Table 1.

The PAR interception was higher in 10th October sowing as compared to 5th November and 1st December sowing in both the cultivars RLC-3 and PBR-357 at the flowering and siliqua formation stage. This may be due to higher leaf area index (LAI) under 10th October sowing. Kumar *et al.* (2010) [7, 11] reported that PAR interception attained its peak value near maximum leaf area index and then started decreasing owing towards leaf senescence. Among the cultivars, PBR-357 intercepted more photosynthetically active radiation than RLC-3 under different dates of sowing at flowering and siliqua formation stage as presented in Tables 1. Singh *et al.* (2014) also showed that, with delay in sowing from October to November in *Brassica spp*. the PAR interception decreases. PAR interception was increased at the flowering stage and then showed a decreasing trend up to siliqua filling stage.

Leaf Area Index and dry matter accumulation

Leaf area is one of the important growth characteristics which play important role in radiation interception and yield of crop.

It is an inventory of the population of leaves that are absorbing light and momentum and exchanging heat, moisture, CO_2 and trace gases with the atmosphere. The leaf area index (LAI) controls the amount of intercepted PAR and hence photosynthesis (Smith *et al.* 1991) [14]. From a micrometeorological perspective an increase in leaf area index increases light interception and the source/sink strength for heat, water and CO_2 exchange. Leaf area index was recorded periodically at 45, 60, 75, 90 and 105 days after sowing. There was a linear increase in leaf area index at 90 days after sowing and thereafter there was decline in leaf area index due to leaf senescence in all the treatments. Among the date of sowing early sown crop (10th October) recorded highest leaf area index which was statistically at par with second date of sowing (5th November). The lowest leaf area index was observed in late sown crop (1st December) and the trends remain same till 105 DAS (Table 2). Kumar *et al.* (2010) [7, 11] reported that lower temperature during vegetative phase caused lowered LAI due to poor growth in late sown conditions. Kaur and Sidhu (2004) [6] also reported that with the delay in sowing date from October to December the LAI was significantly reduced in *Brassica carinata*. Among the cultivars PBR-357 produced higher leaf area index as compared to RLC-3. Maximum LAI was recorded at 90 DAS and leaf area indexes between the two cultivars showed significant difference.

Dry matter accumulation increases progressively with increase in plant age. Total dry matter accumulation of any crop is related to the net photosynthesis. Among the date of sowing, early sown (10th October) crop accumulated maximum total dry matter followed by normal sown (5th November) and late sown (1st December) crop as presented in Table 3. Patel *et al.* (2013) [12] also reported that the increased temperatures during late reproductive phase under delayed sowing hastened the maturity and therefore, the crop growth period was shortened resulting in reduced dry matter production as well as lesser partitioning into different plant parts. Among cultivars, in PBR-357 dry matter accumulation was significantly higher than the RLC-3 at different stages of crop growth.

Relationship between PAR interception and leaf area index

The amount of photosynthetically active radiation (PAR) interception by a crop depends on the distribution of leaf area in time and space. The per cent PAR interception varied with the leaf area index (LAI). The maximum PAR interception was recorded when LAI was highest. The leaf area index was found to be higher in 10th October sown crop followed by 5th November and 1st December sown crop. The relationships between leaf area index and PAR interception under three different dates of sowing were developed and the R^2 value was obtained which explained the percent variability in PAR interception due to change in leaf area index (Fig.1). Leaf area index (LAI) plays an important role for crop growth based on its interception and utilization of PAR (Photosynthetically Active Radiation) for producing dry matter (Kumar *et al.* 2007). The 10th October sown crop recorded R^2 value of 0.73 followed by 5th November (0.85) and 1st December (0.79) indicating that the PAR interception depends upon leaf area index. More the leaf area index more will be the PAR interception for a given crop canopy. The each value of R^2 depicts the percent contribution of leaf area index for the interception of photosynthetically active radiation (PAR). Dhaliwal and Hundal (2004) also revealed that with an increase in the LAI, PAR interception also increased to a level of optimum LAI beyond which increase in PAR interception was not significant. A linear and positive relation between leaf area development and photosynthetically active radiation (PAR) interception was observed, which lead to higher dry matter production (Gill and Bains, 2008) [4].

The relationships between LAI and PAR interception for both the cultivars i.e. RLC-3 and PBR-357 were computed. It was found that both the LAI and PAR interception for cultivar PBR-357 were higher than the RLC-3. The R^2 values indicated that LAI is significantly influenced by PAR interception and vice versa (Fig 2). It was concluded that cultivar PBR-357 had higher interception of PAR as compared with RLC-3. Significant differences among varieties for LAI were also reported by Kumar *et al.* (2001) [8].

Table 1: PAR interception at flowering and siliqua formation stage under different treatments

PAR interception (%) at flowering stage		
10th October	5th November	1st December
RLC-3		
70.5	67.6	65.3
PBR-357		
72.1	69.4	67.4
PAR interception (%) at siliqua formation stage		
10th October	5th November	1st December
RLC-3		
76.1	69.9	67.1
PBR-357		
78.6	72.4	69.8

Table 2: Leaf area index in mustard cultivars under different treatments during *rabi* season2017-18

Treatments	Days after sowing				
	45	60	75	90	105
Date of sowing					
10th Oct	1.97	3.26	4.29	5.37	4.61
5th Nov	1.85	2.96	3.98	4.97	4.11
1st Dec	1.56	2.59	3.62	4.62	3.79
CD (p=0.05)	0.09	0.09	0.01	0.08	0.05
Cultivars					
RLC-3	1.72	2.69	3.66	4.58	3.78
PBR 357	1.87	3.18	4.27	5.39	4.57
CD (p=0.05)	0.03	0.05	0.05	0.04	0.04

Table 3: Total dry matter (g/plant) accumulated by mustard cultivars in different dates of sowing during *rabi* season 2017-18

Treatments	Days after sowing				
	45	60	75	90	105
Date of sowing					
10th Oct	47.75	83.50	108.50	145.75	180.67
5th Nov	34.25	56.08	82.92	112.83	142.75
1st Dec	30.58	46.08	68.75	95.50	116.25
CD (p=0.05)	1.61	1.74	1.64	1.93	2.06
Varieties					
RLC-3	33.83	55.67	78.89	110.00	137.61
PBR-357	41.22	68.11	94.56	126.06	155.50
CD (p=0.05)	1.09	1.02	1.26	0.27	2.80

Relationship between PAR interception and dry matter accumulation

The mustard crop sown on different dates (10th October, 5th November and 1st December) showed differences in PAR interception and dry matter accumulation. The leaf area index was higher in case of early sowing than late sowing which caused higher production of dry matter in early sown crop (10th October). In case of late sown crop (1st December), the decrease in dry matter accumulation was due to rise in temperature and decrease in relative humidity that caused the crop to mature earlier with less amount of dry matter accumulation. So the relationships between dry matter accumulation and PAR interception were developed for different dates and presented in Fig 3 and 4. The R^2 value of 0.61, 0.63 and 0.62 for 10th October, 5th November and 1st December respectively depicted the variability of 61.0 per cent, 63.0 per cent and 62.0 per cent respectively in the PAR interception due to dry matter accumulation for each of the sowing dates. Kaur and Sidhu (2004) [6] also exhibit the effect of three sowing dates (15th October, 15th November and 15th December) on the growth parameters and yield of *Brassica carinata*. The higher plant height, dry matter accumulation, leaf area index and no. of branches per plant were obtained in early sown crop *i.e.* 15th October than late sown crop *i.e.* 15th November and 15th December.

The two cultivars of mustard i.e. RLC-3 and PBR-357 showed significant difference in the dry matter accumulation and PAR interception. The cultivar RLC-3 showed greater dry matter accumulation than the cultivar PBR-357. The relationships between dry matter accumulation and PAR interception for both cultivars were developed and presented in Fig 9 and 10. The R^2 values for cultivar RLC-3 and PBR-357 were 0.53 and 0.51 respectively. From the results it was revealed that dry matter contributed 53 per cent and 51 per cent for the PAR interception in both the cultivars respectively. Hundal *et al.* (2003) [5] also observed a direct and significant relationship between dry matter and PAR interception in different mustard cultivars.

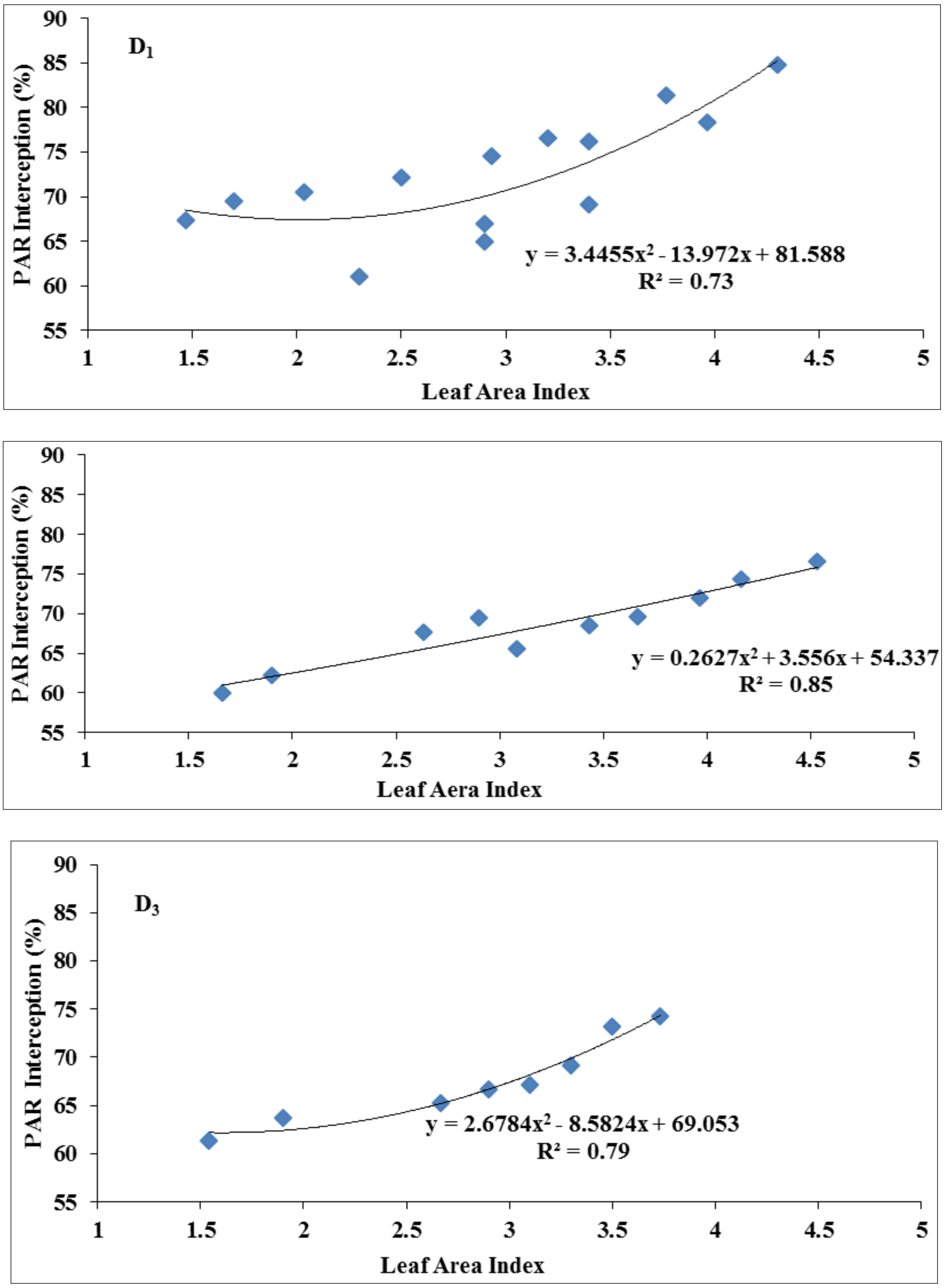

Fig 1: Relationship between LAI and PAR interception under different dates of sowing

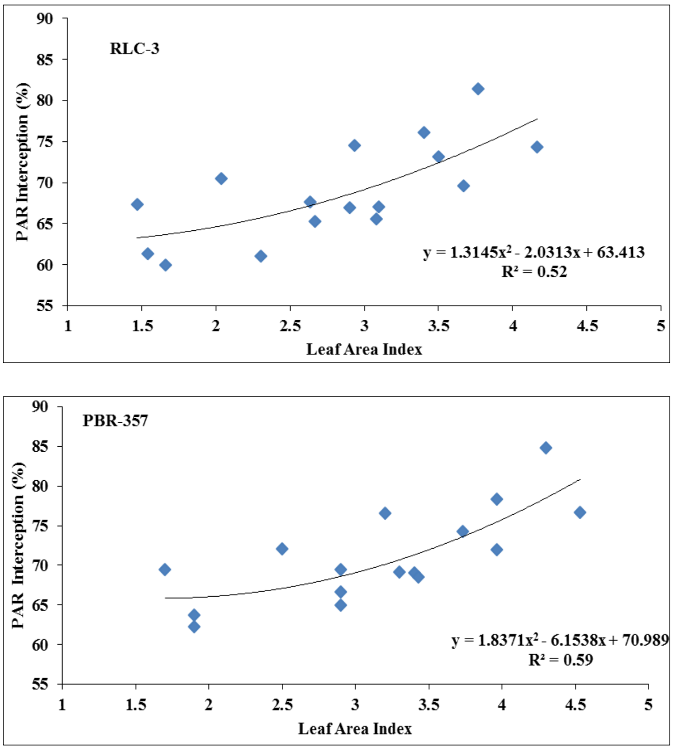

Fig 2: Relationship between LAI and PAR interception in mustard cultivars

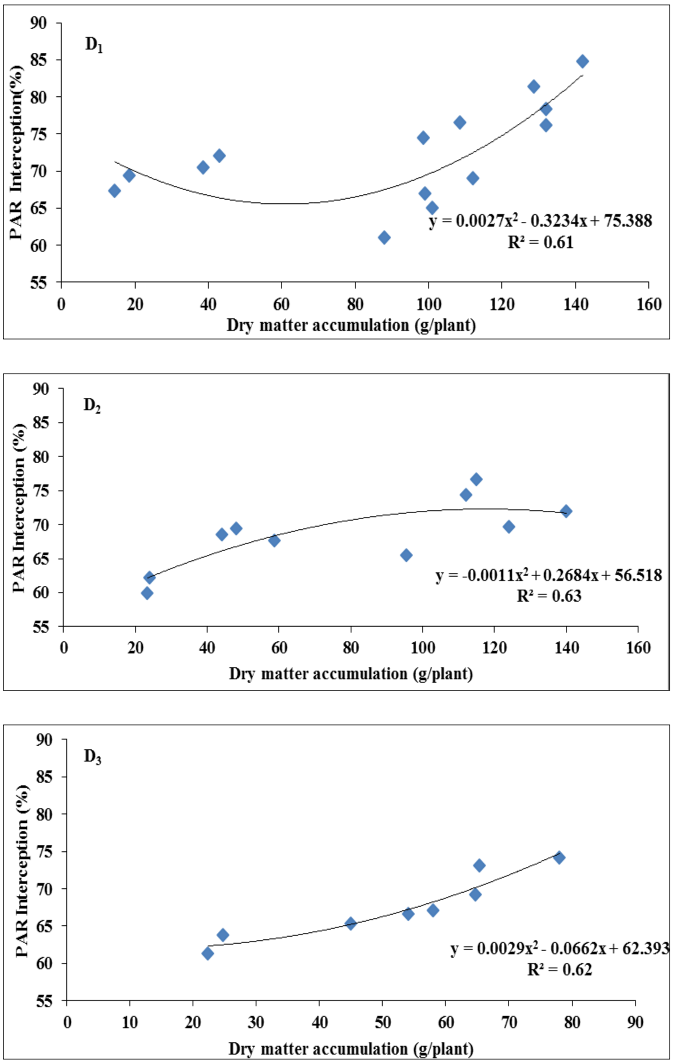

Fig 3: Relationship between dry matter accumulation and PAR interception under different date of sowing

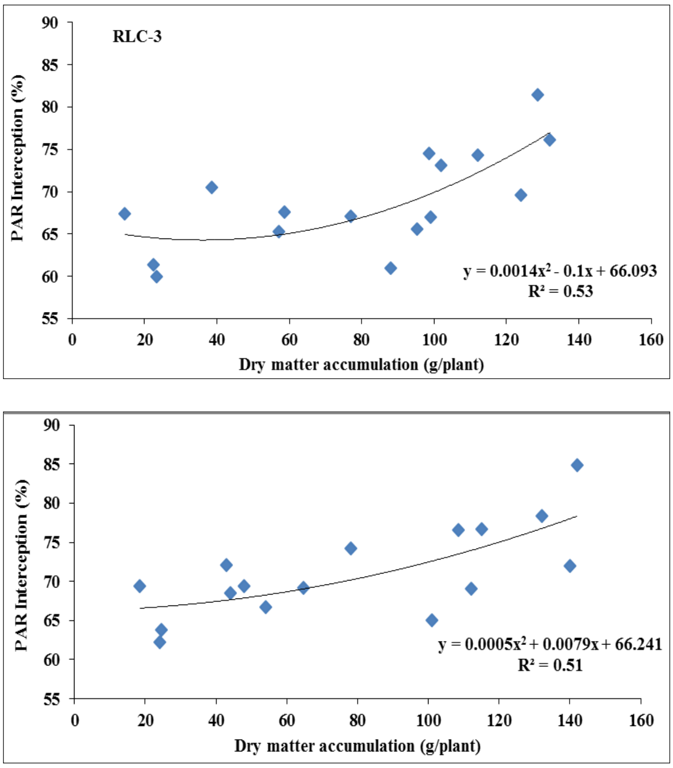

Fig 4: Relationship between dry matter accumulation and PAR interception in mustard cultivars

Conclusion

Radiation interception is significantly influenced by leaf area index and dry matter accumulation. The relationship between PAR interception, leaf are index and dry matter accumulation gave significant values of coefficient of determination (R^2) which explained direct and significant relationship between radiation interception and leaf area index and dry matter accumulation.

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