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Research Article

Effect of Direction of Sowing and Crop Phenotype on Radiation Interception, Use Efficiency, Growth and Productivity of Mustard (*Brassica juncea* L.)

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ABSTRACT

The mustard crop is commercially grown in the North Western drier tract of India. Different directions of sowing and crop phenotypes grown in the field create various planting geometry in combination which differ in yield and oil productivity. The planting geometry affects the radiation use efficiency (RUE), intercepted photosynthetic active radiation (IPAR) and thereby the biomass and yield. Two different mustard varieties (erect and spreading types) were grown in two sowing directions (North-South and East-West) along with one replication as broadcast during the *rabi* 2004-05. The seasonal cumulated IPAR was significantly higher in East-West oriented plots than North-South in both the varieties, whereas, RUE depended on the crop phenotype. The differences in yield between the two varieties were highly significant at 5 % level with the spreading type yielding more. Direction wise, orientation in the East-West yielded more than in North-South. The difference in oil productivity was non-significant for different directions for spreading type variety. The East-West sown plots showed higher oil productivity than North-South sown plots for erect type variety.

Key words: Radiation use efficiency, PAR, Sowing direction, Crop geometry, Oil productivity

Introduction

The yield of mustard crop is affected by the planting geometry (which is the function of both sowing direction and crop phenotype in combination), the direction of sowing and crop phenotype, affecting directly the radiation use efficiency (RUE), intercepted photosynthetically active radiation (IPAR), biomass production and leaf area expansion. There are contradictory findings among various workers on the effect of crop geometry on RUE. Dhingra *et al.* (1986) reported that wheat cultivars (PBW-12, HD-2009 and WL-1562) have higher average yield in N-S direction than in E-W at Ludhiana. The intercepted PAR and yield attributes were also higher in N-S sown crop than the E-W sown crop. Grewal *et al.* (1989) reported higher grain yield for pearl millet in N-S sowing direction over E-W and these yields were found to be associated with greater LAI and light interception. Kler *et al.* (1989) experimented with wheat cultivar DWL-5023 and reported that grain yield was maximum for crop grown in N-S direction (45.6, 48.7 q/ha) followed by E-W sown crop (42.6, 43.2 q/ha) and broadcast crop (36.2, 39.5 q/ha) during two seasons in 1982-83 and 1983-84, respectively. Suraj Bhan *et al.* (1995) experimented with Indian mustard cultivar Vaibhav in

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Kanpur and reported that the yield was higher for E-W sown crop (9.63 q/ha) and lower for N-S sown crop (8.89 q/ha). Mahto (2001) experimented with 45 genotypes of *Brassica juncea* at Ranchi and observed that the genotypic coefficient of variation of plants sown with E-W row orientation were greater than those of plants sown with N-S orientation for number of seeds/ siliqua, number of siliqua, number of secondary branches/plant, 1000 seed weight and seed yield per plant.

In this study, North-South (NS) and East-West (EW) direction of sowing for two phenotypically different mustard varieties (erect type and spreading type) were investigated for their effect on IPAR and RUE. Broadcasting (BC) was also taken as another treatment in the study as this way of sowing is also practiced by farmers in some parts of India. RUE is assumed to be constant (Sinclair, 1986) in many studies on crop models, but other authors reported that it varied widely during the plant growth cycle and studies by Rinaldi and Vonella (2006) have confirmed the latter. In this study, the correlation between leaf area index (LAI) and IPAR was studied for different crop phenotypes. The yield and oil productivity in different sowing directions for two phenotypically different varieties of *Brassica* were also studied.

Materials and Methods

The present study was conducted in the experimental farm (MB-4C) of Indian Agricultural Research Institute located at $28^0$35' N latitude, $77^0$12'E longitude and at an altitude of 228.16 m above mean sea level. Two cultivars of *Brassica juncea*, *viz*, Pusa Agrani (erect type, medium height and early maturing variety) and Pusa Jagannath (bushy type, broad-leaved and late maturing variety) were grown during the *rabi* season of 2004-05, following the recommended agronomic practices with one irrigation (6 cm) at the pre-flowering stage. These cultivars differed in their maturity periods, growth habits and phenotypic characters. The experiment was laid out in a randomised block design with three replications, size of each plot being 5m × 5m. Sowing was done with hand drill, maintaining a row to row distance of 45 cm and plant to plant distance of 15 cm. A seed rate of 5 kg/ha was used for Pusa Agrani and Pusa Jagannath. The seeds were sown in the rows directed towards North-South for N – S sown plots and in the rows directed towards East-West for E – W sown plots. Seeds were simply broadcast for the broadcast treatment in the design. Urea at the rate of 60 kg N/ha, single super phosphate at the rate of 40 kg P_2O_5/ha, muriate of potash at the rate 40 kg K_2O/ha and sulphur at the rate 20 kg/ha were applied as per recommended practices at the time of preparation of seedbeds. Besides, the plots were sprayed twice with phosphamidon at the rate of 750 active ingredients per ha using manually operated knapsack sprayer. For determining the leaf area index, three plants were randomly selected in each plot and cut at ground level. Each sampling was done at 7-10 days interval. The green leaf portions were separated and the area of the leaves was measured using leaf area meter (LICOR-100). The samples collected for determination of leaf area index were also used for recording above ground biomass production. For this purpose these samples were oven dried at 70°C for more than 48 hours as recommended.

A line quantum sensor (LI-COR: LI-191SA) with an integrator was used to measure the photosynthetically active radiation (PAR 400-700 nm) at canopy level. The reflected radiation was obtained by keeping the sensor downward inverted and it was also kept on the ground across the rows diagonally to get transmitted radiation at the ground. To get the reflected PAR from the ground the sensor was held in the inverse position at 0.05 m above the ground. The IPAR was determined using the following relationship:

IPAR of the whole canopy = (Incident radiation on canopy – Transmitted radiation at bottom) …(1)

The above measurements were taken at regular intervals on clear days between 11.00 and 12.00 hours IST when disturbances due to leaf shading and leaf curling and solar zenith angle were minimum. Data were recorded at three points in each plot and averaged.

The extra terrestrial radiation for daily periods (Ra) was calculated following Allen *et al*., 1998.The mean daily values of incoming solar radiation were estimated using Angstrom's formula where 0.32 and 0.46 have been used for the values of constant a and b, respectively for Delhi, following Gangopadhyaya *et al.* (1970). The photosynthetically active radiation (PAR) was calculated by multiplying it with 0.48 following Monteith (1972) and Kailasnathan and Sinha (1984). The biomass produced per unit amount of intercepted photosynthetically active radiation (IPAR) expressed as gram of dry matter produced per 1 MJ of PAR is termed as Radiation use efficiency (RUE). The values of RUE for the total crop duration were computed as following:

RUE for the whole crop duration = [{Total above ground dry matter (g/m^2)} / {Cumulated intercepted PAR for the whole crop duration (MJ/m^2)}] …(2)

Fraction intercepted photosynthetically active radiation (fIPAR) (%) is the ratio between intercepted PAR and the total incident PAR. This ratio was derived for different stages of growth of mustard crop. Oil content (percent) of the seeds for each plot was measured using low resolution pulsed H1 NMR (model no.- PC20 Bruker (made) frequency – 20MHz). For this purpose, 15 g of dry, clean seeds from each plot were kept for drying at 105°C and desiccation till measurements for oil content were taken.

Results and Discussion

There was an exponential increase in LAI from emergence to maximum LAI stage in both the varieties. The maximum LAI was found to reach on 80 DAS, which coincided with the pod formation stage in Pusa Agrani. There was no marked difference among the LAI observed for North-South sown, East-West sown or for broadcasted plots, though broadcast had a little higher LAI values than others for this variety (Fig 1.). The maximum LAI reached on 86 DAS, which coincided with the pod formation stage of the Pusa Jagannath. The LAI of this variety in North-South sown plots and East-West sown plots did not differ much except between 80-94 DAS when the LAI of East-West sown plots was found to be higher than that of the North-South sown plots (Fig 2.). fIPAR (%) variation followed the LAI variation pattern in both the varieties. The fIPAR (%) in East-West direction was higher than that in North-South direction till peak LAI stage in Pusa Agrani (Fig 3). At later stage before harvesting, fIPAR (%) in East-West directional plots were lower than that of the North-South directional plots. The fIPAR (%) was observed to attain its maximum value at 82 DAS. In the East-West sowing, the maximum fIPAR (%) was 94.8% whereas the same in North-South sowing was 87.7%. The maximum fIPAR (%) was observed on 87 DAS in Pusa Jagannath (spreading type variety). There was no appreciable increase in fIPAR (%) in one direction over the other in this variety unlike that of Pusa Agrani (Fig 4). In the North-South sowing maximum fIPAR (%) was observed to be 97.5% on 87 DAS, whereas the same in the East-West sowing was 94.1%. But fIPAR (%) was observed to be highest in the

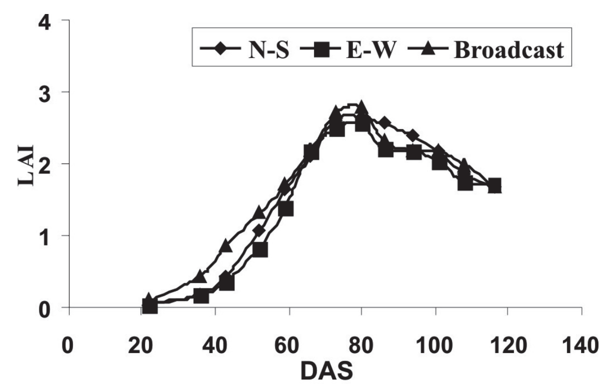

Fig. 1. Variation of LAI in Pusa Agrani

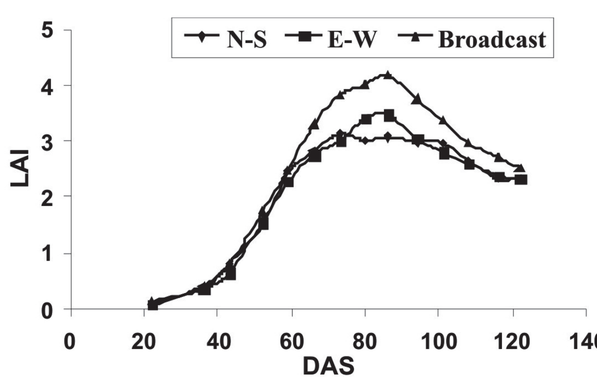

Fig. 2. Variation of LAI in Pusa Jagannath

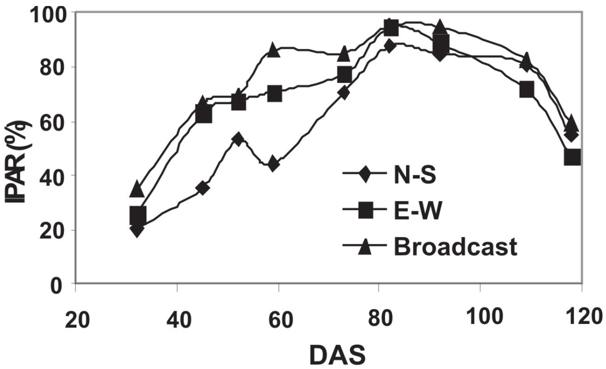

Fig. 3. IPAR Variation in Pusa Agrani over crop season

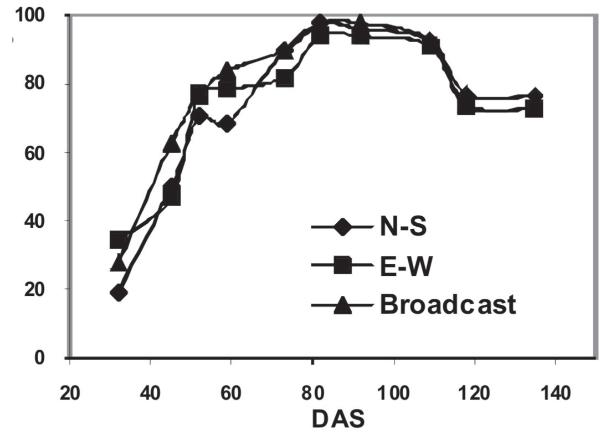

Fig. 4. IPAR Variation in Pusa Jagannath over crop season

broadcast plots in case of both the varieties. Variation of fIPAR (%) with DAS in the North-South direction was observed to be higher in Pusa Jagannath than that in Pusa Agrani. Pusa Jagannath being a spreading plant type, intercepted more fIPAR during the entire crop growth period than the erect plant type Pusa Agrani. When comparing the variation of fIPAR (%) in the North-South and East-West direction by the Pusa Agrani and Pusa Jagannath, it was observed that though in both the cases the spreading type Pusa Jagannath intercepted more fIPAR, the trend was steadier in the North-South direction. An exponential relationship was found between the fIPAR and LAI, but up to peak LAI stage it could be represented by linear relationship. The regression equations between fIPAR and LAI are shown in Table 1. The R^2 values for the equations in the North-South and East-West direction in Pusa Agrani variety were 0.86 and 0.68, respectively. The same for Pusa Jagannath was 0.91 in both the sowing directions.

It was clear from the equations and R^2 values that the spreading type variety had better correlation of LAI with fIPAR in both the directions up to peak LAI and fIPAR was less sensitive to LAI in East-West direction compared to North–South in Pusa Agrani.

RUE in Pusa Agrani in North-South and the East-West sown plots was 1.32 and 1.30 g/MJ, respectively. The same for Pusa Jagannath was 1.25 and 1.36 g/MJ, respectively. The RUEs in the North-South and the East-West directions for erect type Pusa Agrani were not markedly different, whereas in spreading type Pusa Jagannath, RUE in the East-West direction was higher than that in the North-South sowing. But the cumulated IPAR for the whole crop duration and accumulated biomass for the whole crop duration were higher in the East-West direction for both the varieties than that in the North-South direction (Table 2 and 3).

Table 1. Regression equation between fIPAR vs LAI for Pusa Agrani and Pusa Jagannath

Variety	Treatment	Regression equation	R^2
PUSA AGRANI	N-S	Y= 0.2169 X + 0.2088	0.86
	E-W	Y= 0.1829 X+0.4261	0.68
PUSA JAGANNATH	N-S	Y= 0.2386 X+0.2117	0.91
	E-W	Y= 0.1747 X+0.3592	0.91

Where X= LAI AND Y= fIPAR %

Peak LAI occurrence at 80 DAS in PUSA AGRAN

Peak LAI occurrence at 86 DAS in PUSA JAGANNATH

Table 2. Cummulated IPAR, biomass and RUE in Pusa Agrani

Variety	IPAR MJ/m^2	Biomass g/ m^2	RUE g/MJ
NS	316.21	450	1.32
EW	353.26	490	1.30
Broadcast	420.56	600	1.43

Table 3. Cummulated IPAR, biomass and RUE in Pusa Jagannath

Variety	IPAR MJ/m^2	Biomass g/ m^2	RUE g/MJ
NS	484.17	647	1.25
EW	489.09	707	1.36
Broadcast	535.89	780	1.45

This high interception of PAR in the East-West direction may be due to the planting geometry of the plots and the solar elevation angle during the period on this location. But cumulated IPAR and biomass in broadcast plots for both the varieties were found to be maximum resulting in the maximum RUE in broadcast plots for both the varieties. Higher number of plant stands per unit area in broadcast than in the directionally sown plots apparently caused these maximum values in the broadcast plots.

Among the directional sowings, the RUE for the whole crop duration was found to be higher in East-West than North-South sown plots in case of the spreading type of variety (Pusa Jagannath), whereas the corresponding values differed non-significantly in the erect type of variety Pusa Agrani (Table 2 and 3). But the cumulated IPAR and accumulated biomass values were higher in East-West than North-South sown plots irrespective of the two varieties. The difference in crop geometry of the two varieties might resulted in more RUE in the spreading type of variety in the East-West direction where interception was high. Yield of Pusa Agrani in North-South, East-West and broadcast plots were 1200, 1283 and 1209 kg/ha, respectively. And the same in Pusa Jagannath were 1333, 1367 and 1372, kg/ha respectively (Table 4 and 5). From the analysis it is evident that differences in yields of two varieties were highly significant at 5% level, with Pusa Jagannath (mean 1357 kg/ha) yielding better than Pusa Agrani (mean 1231 kg/ ha)(Table 6). The differences in yields in North-South, East-West and broadcast plots were also significant at 5% level (Table 7), with the East-West direction (mean 1325 kg/ha) yielding best followed by the broadcast (mean 1291 kg/ha) and North-South sowing (mean 1267 kg/ha). Oil per cent in Pusa Agrani in North-South, East-West and broadcast plots were 38.2, 37.6 and 37.7%, respectively, whereas the same for Pusa Jagannath were 38, 37.56 and 37%, respectively (Table 4 and 5). The analysis showed that the differences in oil (%) among North-South, East-West and

Table 4. Yield, oil content and oil productivity in Pusa Agrani

Variety	Yield (kg/ha)	Oil (%)	Oil productivity (kg/ha)
NS	1200	38.2	458
EW	1283	37.6	482
BC	1209	37.7	456

Table 5. Yield, oil content and oil productivity in Pusa Jagannath

Variety	Yield (kg/ha)	Oil (%)	Oil productivity (kg/ha)
NS	1333	38.0	507
EW	1367	37.5	513
BC	1372	37.0	508

Table 6. Mean RUE, mean yield and mean oil content of Pusa Agrani and Pusa Jagannath

Variety	Mean RUE (g/MJ)	Mean yield (kg/ha)	Mean oil content (%)
Pusa Agrani	1.350	1231	37.84
Pusa Jagannath	1.355	1357	37.50
CD (at 5%)	0.018	14.85	1.367

Table 7. Mean RUE, mean yield and mean oil content of the two varieties in north-south, east-west direction of sowings and broadcast plots

Treatments	Mean RUE (g/MJ)	Mean yield (kg/ha)	Mean oil content (%)
N-S sown	1.288	1267	38.12
E-W sown	1.328	1325	37.53
Broadcast	1.441	1291	37.73
CD (at 5%)	0.022	18.19	1.67

broadcast as well as between the two varieties were non-significant (Table 6 and 7).

Conclusions

The above results indicated that though the RUE and oil content of the Pusa Agrani and Pusa Jagannath differed non-significantly, yield was significantly higher in Pusa Jagannath (the spreading type of variety and longer duration), higher cumulated IPAR and genetic character may be the reason behind it. Among the direction of sowings (N-S, E-W and Broadcast), the RUE and yields differed significantly, whereas the differences were non-significant for oil content. The cumulated IPAR, RUE, biomass were found to be maximum in the broadcast plots followed by the E-W sown plots and N-S sown plots. But so far as yield was concerned, it was highest in the E-W sown plots and the oil productivity also was observed to be highest. Inconveniences related to the intercultural activity and proper management of the crop limited advantages of the broadcast plots. And the directional effect on oil productivity was more prominent in the Pusa Agrani (erect variety) than that in Pusa Jagannath (spreading type). Farmers should therefore opt for the E-W directional sowing when they are going to select the erect plant type and short duration mustard varieties in respect of more oil productivity, RUE and yield. Otherwise, they may safely go for the longer duration spreading types of variety, which is less affected by the sowing direction in respect of oil productivity.

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