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Quantification of growth and yield of oilseed *Brassica* using thermal indices under semi-arid environment

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ABSTARCT

Field experiments were carried out at IARI research farm, New Delhi representing semi-arid climatic condition, to evaluate the growth and yield of oilseed *Brassica* using thermal indices. Two cultivars of *Brassica juncea* viz., Pusa Jaikisan and Varuna, widely grown in north and north-western parts of the country, were sown on ten different dates from 1st October to 3rd December at weekly interval. Three widely used thermal indices viz, growing degree days (GDD), heliothermal units (HTU) and photothermal units (PTU) were computed up to maximum biomass production in both the seasons. It was observed that GDD was able to explain variation in biomass, seed yield and oil content to the tune of 75, 66 and 78 per cent while PTU could explain 73, 66 and 77 per cent variations respectively. The yields and oil content of these two cultivars were highly influenced by the differential thermal environment and delay of sowing; decreased seed yield and oil content significantly.

Key words: Thermal indices, GDD, HTU, PTU, HUE seed yield, oil content and *Brassica*.

In India, *Brassica spp* is grown mostly in *rainfed* condition during winter season in residual moisture after rainy season (June-September). The crop is grown as monoculture, intercrop and short duration crop to fit into intensive cropping pattern under both *rainfed* as well as assured irrigation conditions. Though, India occupies first position in the acreage (4.83 million hectares) and production (5.34 million tones) of *Brassica spp* in the world, the average yield per hectare is low (1100 kg ha^{-1}) as compared to the other countries (Chakravarty and Gautam, 2002). Among various weather parameters, temperature is considered to be the prime determinant of crop growth and development. However, different crops experience different ranges of temperatures during different phenological stages, which affect its performance (Mendham *et al*., 1990; Nanda *et al.,* 1995; Merle *et al*., 1997 and Hocking and Stapper, 2001). Change in sowing dates leads to change in thermal environment of the crop with respect to different growth and developmental stages.

Thermal indices i.e. growing degree days/accumulated heat unit, heliothermal, phenothermal and photothermal units are widely used to predict phenology, crop growth rate and yield of several crops (Whisler *et al*., 1986; Patel and Mehta, 1987; Perry *et al*., 1993 and Hundal *et al*., 1997). Keeping in view, the present study was conducted to quantify biomass, yield and oil content of *Brassica* spp by using thermal indices under semi-arid conditions of Delhi region.

MATERIAL AND METHODS

Two cultivars of *Brassica* viz., Pusa Jaikisan and Varuna differing in their growth habits, were sown on two successive *rabi* seasons of 2003-04 and 2004-2005 following recommended package of practices on a sandy clay loam textured and weak to medium angular blocky structured soils at IARI research farm, New Delhi (longitude of 77°0' E, latitude of 28°10' N and at an altitude of 229 m above mean sea level). Both cultivars were sown at ten different dates at weekly intervals starting from 1st October to 3rd December in two seasons. The experiment was laid on a Randomized Block Design (RBD) with three replications. The size of the each plot was 5m x 5m with a row to row spacing of 30 cm and plant to plant spacing of 10 cm. Thinning was done manually at 25 days after sowing to maintain plant population of 30 m^{-2}. Weeds were managed manually as and when necessary. For leaf area measurement, above ground plants were cut from 30 cm row length of each plot at weekly interval. The samples collected for estimating leaf area index were utilized for assessing biomass production and these samples were oven dried at 70°C for more than 48 hours to get the constant weight. Oil content of dry seed was estimated by Nuclear Magnetic Resonance (NMR) using the sampling technique at IARI, New Delhi. Daily weather data collected from the Agrometeorological Observatory located adjacent to the experimental site were used for calculating thermal indices for present analysis. The thermal time was expressed in terms of

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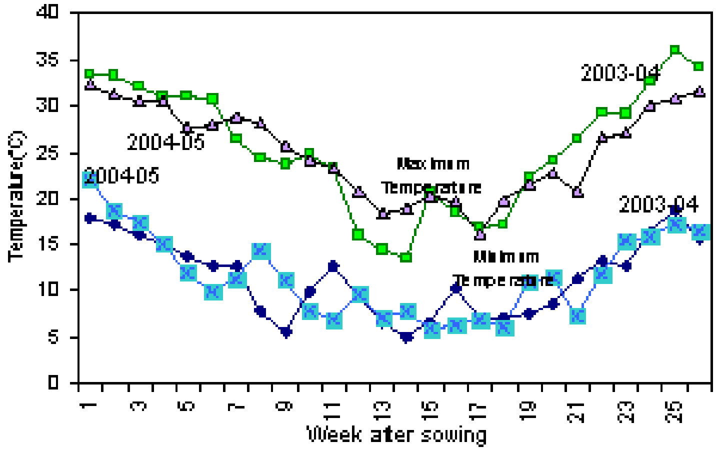

Fig. 1A: Weekly temperatures during crop period of 2003-04 and 2004-05 at IARI farm.

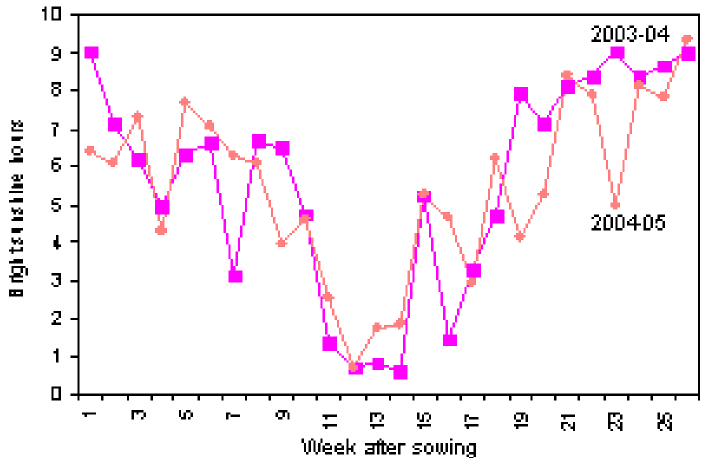

Fig. 1B: Weekly bright sunshine hours during crop period of 2003-04 and 2004-05 at IARI farm.

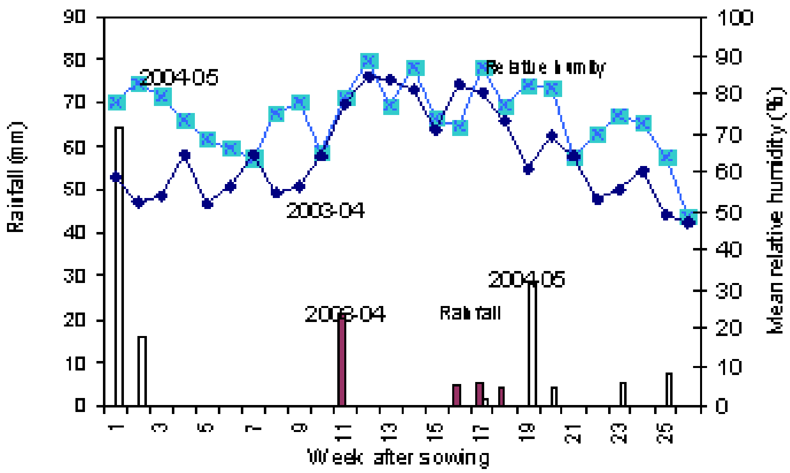

Fig. 1C: Weekly rainfall and mean relative humidity during crop period of 2003-04 and 2004-05 at IARI Farm

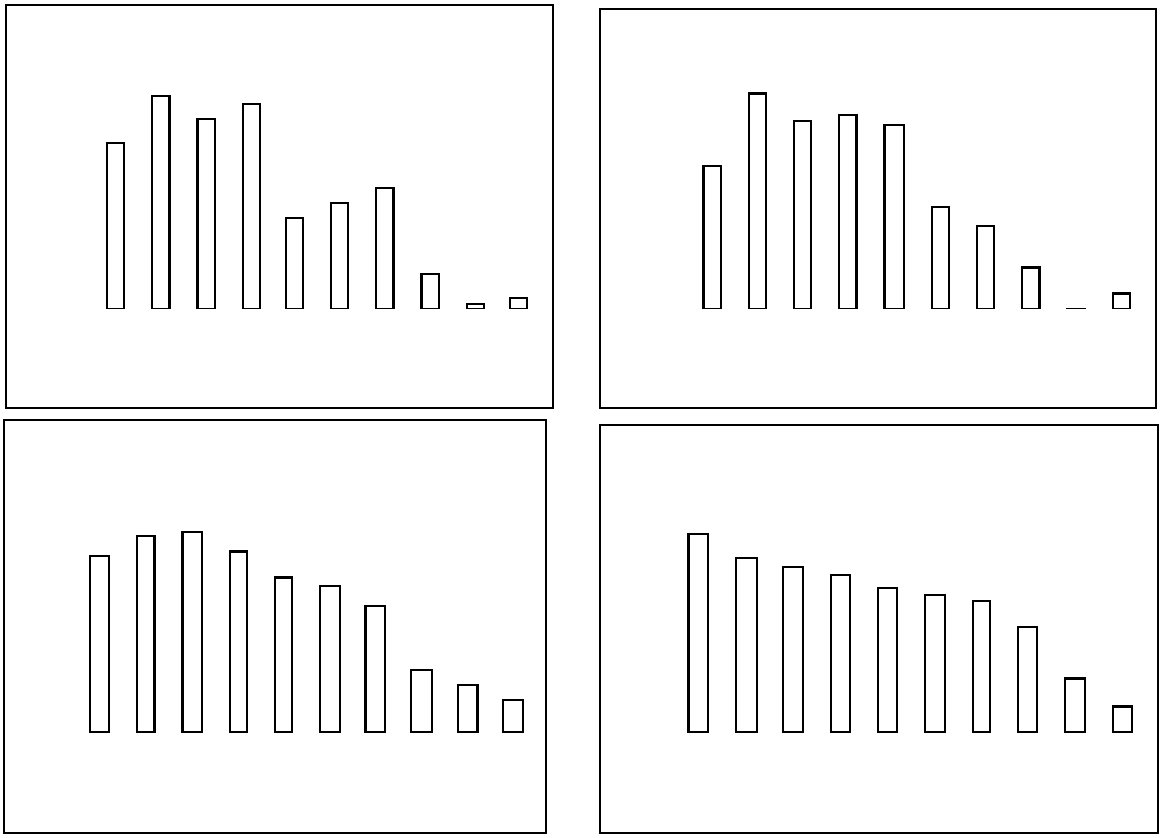

Fig. 2: Mean seed yield and oil content of Pusa Jaikisan and Varuna

GDD with a base temperature of 5^0C (Morrison *et al*., 1990). The GDD were calculated on daily basis and cumulated values were taken up to maximum biomass. Experimental data were analyzed in SPSS package. Standard deviations (SD), Standard error of mean (SEm), Coefficient of variation (CV) and Pearson's correlation coefficient were derived. The best fit regression equations were developed between biomass, seed yield and oil content as a dependable variable with GDD, HTU and PTU as an independent variable. Pooled data were used to avoid varietals response and to predict more authentic information of crop-weather interactions.

The heat use efficiency (HUE) was determined as

HUE (g m^{-2} $degree^{-1}$ C days) = (seed yield or total dry biomass) / GDD

RESULTS AND DISCUSSION

Weather and seed yield

The early rainfall during the first week of October (64.4mm) in the second crop season recharged the soil moisture and provided suitable macro environmental conditions for good growth (fig. 1a-c). The daily maximum temperature varied from 14 to 32 and minimum temperature from 10.4 to 23.3 °C during the first season (2003-04) while during the second crop season (2004-05) the maximum temperature varied from 17.4 to 26.2 and minimum temperature varied between 3.4 and 14 °C. The daily maximum temperature varied from 27 to 38.2°C and minimum temperature from 9.8 to 20.2 °C during the first season while during the second crop season the maximum temperature varied from 22.3 to 34.6°C and minimum temperature varied between 10.8 and 20 °C during March month. The total rainfall during February was 4.2 mm in 2003-04 and 32.2 in 2004-05. The total rainfall during March was 0.0 mm in 2003-04 and 13.0 in 2004-05, respectively. Fig. 2 shows that mustard sown on Oct. 1, produced seed yield less than that sown during Oct. 8-22. Thereafter it decreesed with further delayed sowings. Yield reduction of about 23 per cent was recorded after 29th October sowing for Varuna cultivar for Pusa Jaikisan cultivar after 22nd October sowing (Fig. 2). Kar and Chakravarty (2000) and Sikder (2009) have reported that mustard and wheat yield significantly decreased with delayed sowing.

Linear regression equations were developed among the thermal indices with maximum biomass. It was revealed that the variability of biomass to the tune 75 per cent could

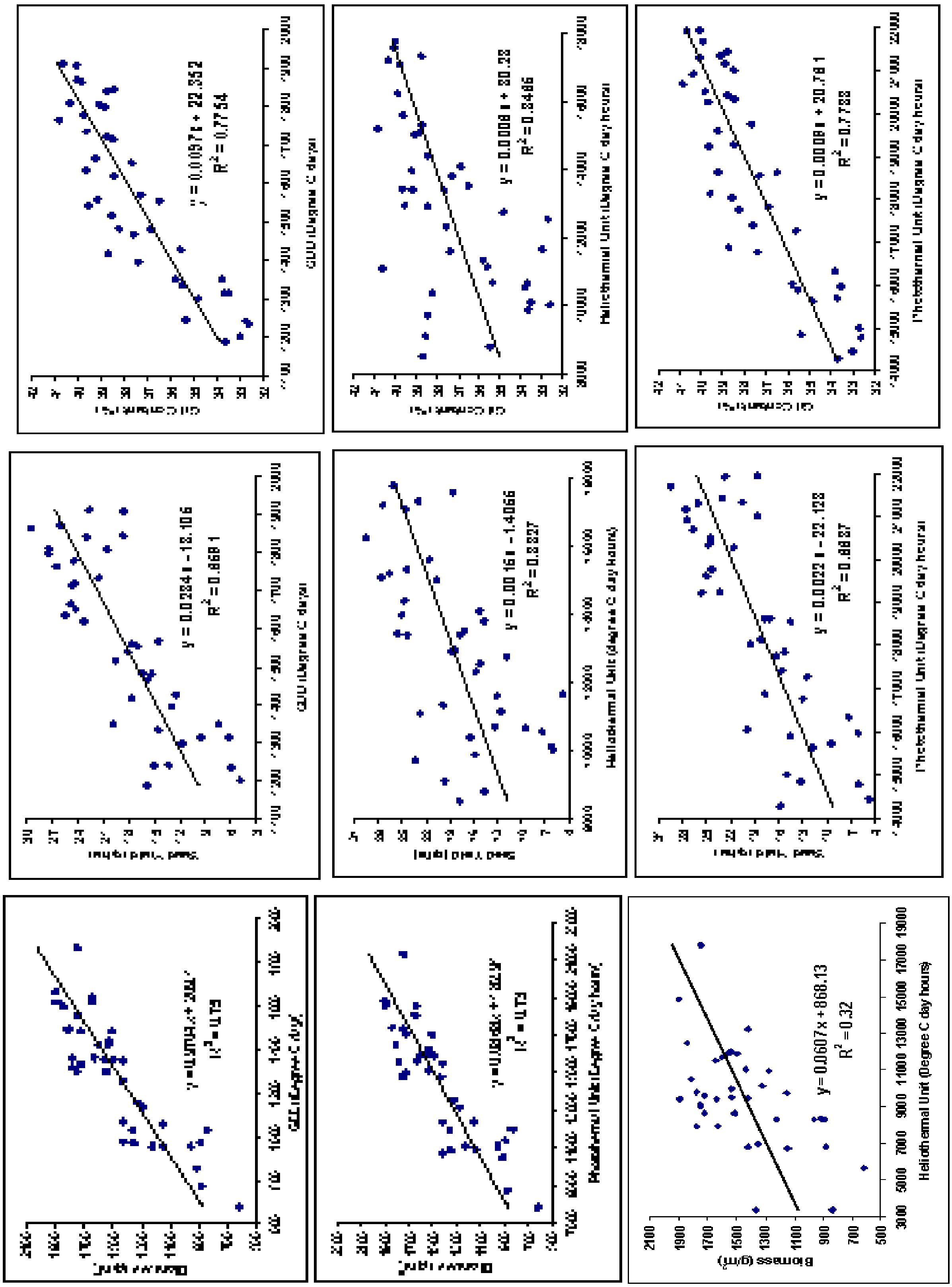

Fig. 3: Thermal response curves for biomass in *Brassica* spp, Seed yield and Oil content

Table 1: Biomass and seed yield heat use efficiency (g m^{-2} ^{0}Cd^{-1}) in *Brassica* spp.

Date of sowing	Biomass heat use efficiency (g m^{-2} ^{0}Cd^{-1})						Seed yield heat use efficiency(kg ha^{-1} ^{0}Cd^{-1})					
	Pusa Jaikisan			Varuna			Pusa Jaikisan			Varuna		
	2003-04	2004-05	mean	2003-04	2004-05	mean	2003-04	2004-05	mean	2003-04	2004-05	mean
1-Oct	1.15	0.94	1.04	1.00	0.93	0.97	1.01	1.39	1.20	0.97	1.19	1.08
8-Oct	1.21	1.14	1.17	1.12	1.14	1.13	1.38	1.51	1.44	1.25	1.58	1.42
15-Oct	1.12	1.17	1.15	1.06	1.01	1.04	1.25	1.51	1.38	1.14	1.53	1.33
22-Oct	1.29	1.16	1.22	1.08	1.02	1.05	1.56	1.50	1.53	1.44	1.42	1.43
29-Oct	1.35	1.20	1.27	1.05	1.31	1.18	0.93	1.18	1.06	1.47	1.44	1.45
5-Nov	1.45	1.10	1.27	1.19	1.15	1.17	1.07	1.29	1.18	1.10	1.13	1.12
12-Nov	1.38	1.35	1.37	1.13	1.13	1.13	1.47	1.25	1.36	1.03	1.11	1.07
19-Nov	1.20	1.14	1.17	1.08	1.33	1.21	0.72	1.09	0.91	0.88	0.93	0.90
26-Nov	1.07	1.32	1.19	0.91	0.82	0.86	0.49	1.07	0.78	0.55	0.91	0.73
3-Dec	0.91	1.27	1.09	1.13	1.00	1.07	0.40	1.33	0.86	0.47	1.22	0.84
Mean	12.13	11.77	11.95	10.75	10.83	10.79	10.28	13.12	11.70	10.30	12.45	11.38
SD	0.16	0.12	0.09	0.08	0.16	0.11	0.40	0.17	0.26	0.33	0.24	0.26
CV (%)	1.32	1.01	0.79	0.73	1.48	0.99	3.90	1.26	2.24	3.23	1.91	2.30
SEm	0.003	0.001	0.001	0.001	0.003	0.001	0.016	0.003	0.007	0.011	0.006	0.007

be explained through GDD; 73 per cent through PTU and 32 per cent by HTU respectively (Fig. 3). These response curves explain the linear relationship of the thermal accumulation with biomass in mustard cultivars. Linear regression equations were also developed between the thermal indices and seed yield to find out the extent of variability in seed yield under differential micro environment during crop growth periods. It was found that the thermal indices (GDD and PTU) were able to explain the variability of seed yield by about 66% (Fig. 3).

Assessment of oil content (%) through thermal indices

Oil content drastically reduced after the optimum sowing window (15th October to 22nd October) in both the cultivars(Fig.2). The differential temperatures at different phenophases may lead to influence the oil formation in the pods. It was found that variation in oil content could be explained by 78 and 77 per cent through GDD and PTU and 35 per cent through HTU, respectively. Neog *et.al*.(2005) also quantified the oil content of *Brassica* through thermal indices and found that GDD and PTU significantly explained the variability of oil content of different cultivars of Mustard.

Heat use efficiency

Heat use efficiency (HUF) is the efficiency of utilization of heat in terms of dry matter accumulation by the crops. Higher heat use efficiency was observed in Pusa Jaikisan as compared to Varuna (Table 1), which indicates that the cultivars vary greatly in their response to heat utilization and heat use efficiency. Kar and Chakravarty (1999) observed that biomass and yield of mustard crop can be explained through HUE.

CONCLUSIONS

The study confirmed that 75 per cent variation in biomass of mustard could be explained through GDD. GDD and PTU may be used for quantification of *Brassica* biomass and oil content, respectively in simulation model. The thermal indices based models may be used to quantify the crop growth and yield in different agro-ecological zones.

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